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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P36736B US
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Andrew	H.	Martin	

Residence Information (Select One) ● US Residency Non US Residency Active US Military Service

City	State/Province	Country of Residence
West Chester	PA	US

Mailing Address of Inventor:

Address 1	926 Pine View Drive
Address 2	
City	West Chester
State/Province	PA
Postal Code	19380
Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	William	D.	LeFebvre	

Residence Information (Select One) ◉ US Residency Non US Residency Active US Military Service

City	State/Province	Country of Residence
West Chester	PA	US

Mailing Address of Inventor:

Address 1	1145 Saint Finegan Drive
Address 2	
City	West Chester
State/Province	PA
Postal Code	19382
Country	US

Inventor 3 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Brent	M.	Wilson	

Residence Information (Select One) ◉ US Residency Non US Residency Active US Military Service

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P36736B US
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE	

City	Edwardsville	State/Province	IL	Country of Residence	US

Mailing Address of Inventor:

Address 1	667 Notre Dame Avenue		
Address 2			
City	Edwardsville	**State/Province**	IL
Postal Code	62025	**Country**	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	29880		
Email Address	ipdocket@foxrothschild.com	Add Email	Remove Email
Email Address	ghecht@foxrothschild.com	Add Email	Remove Email

Application Information:

Title of the Invention	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE		
Attorney Docket Number	P36736B US	**Small Entity Status Claimed**	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	7	**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P36736B US
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE	

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	29880		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	13842427	2013-03-15
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
13842427	Claims benefit of provisional	61661661	2012-06-19
Prior Application Status	Patented		Remove

Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
13842427	Continuation in part of	12861713	2010-08-23	9026281	2015-05-05

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P36736B US
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE	

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P36736B US
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Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P36736B US
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 — Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

● Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name	Amsted Rail Company, Inc.		
Mailing Address Information For Applicant:			
Address 1	311 South Wacker Drive, Suite 5300		
Address 2			
City	Chicago	**State/Province**	IL
Country	US	Postal Code	60606
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P36736B US
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add

Signature:

Remove

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/gah/			Date (YYYY-MM-DD)	2016-05-18
First Name	Gary	Last Name	Hecht	Registration Number	36826

Additional Signature may be generated within this form by selecting the Add button. Add

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P36736B US
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE	

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1 The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent CooperationTreaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

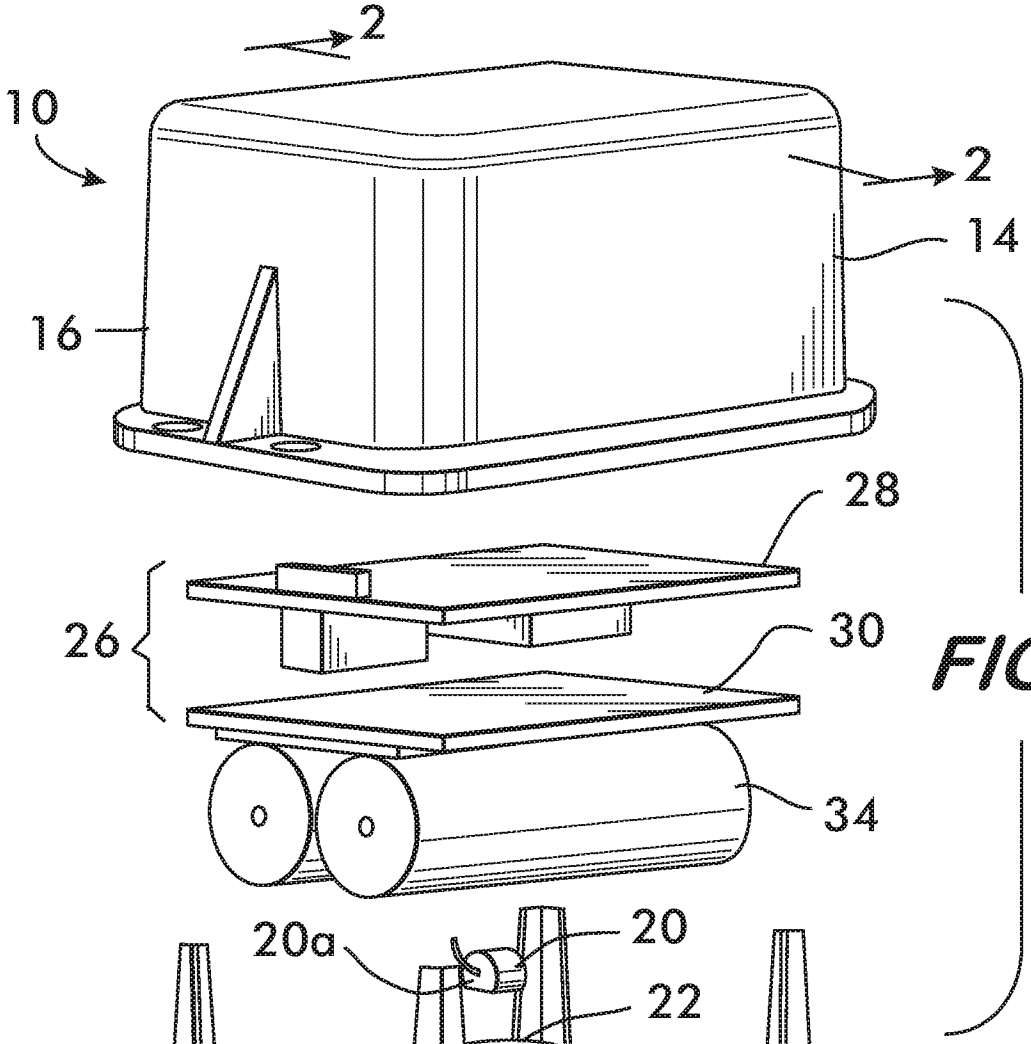


FIG.1

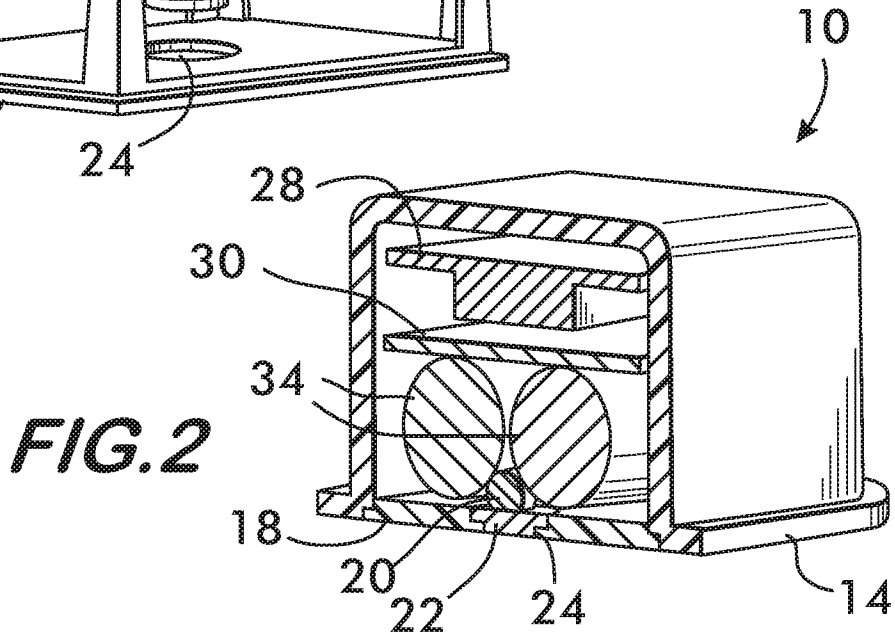
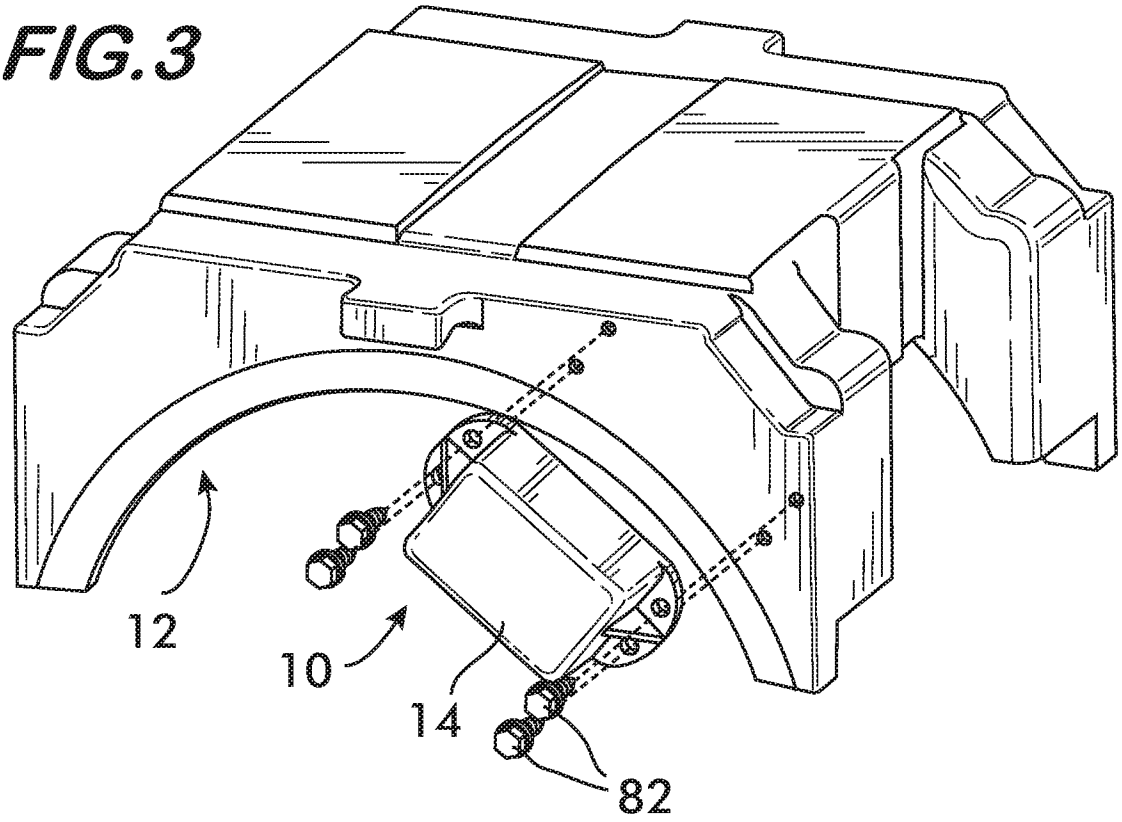


FIG.2

FIG.3



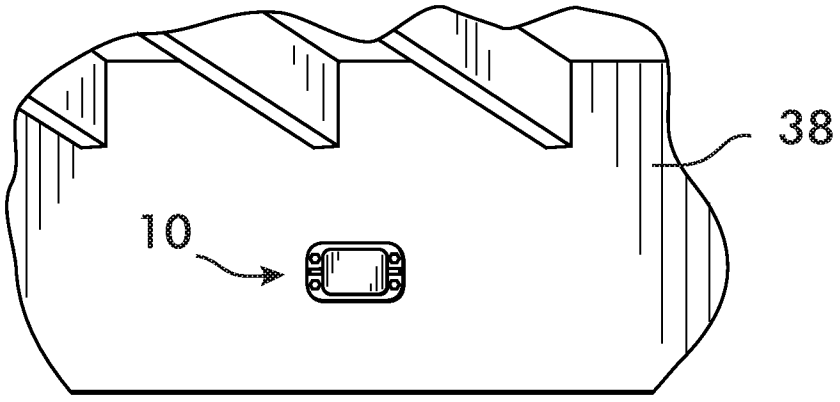


FIG.4

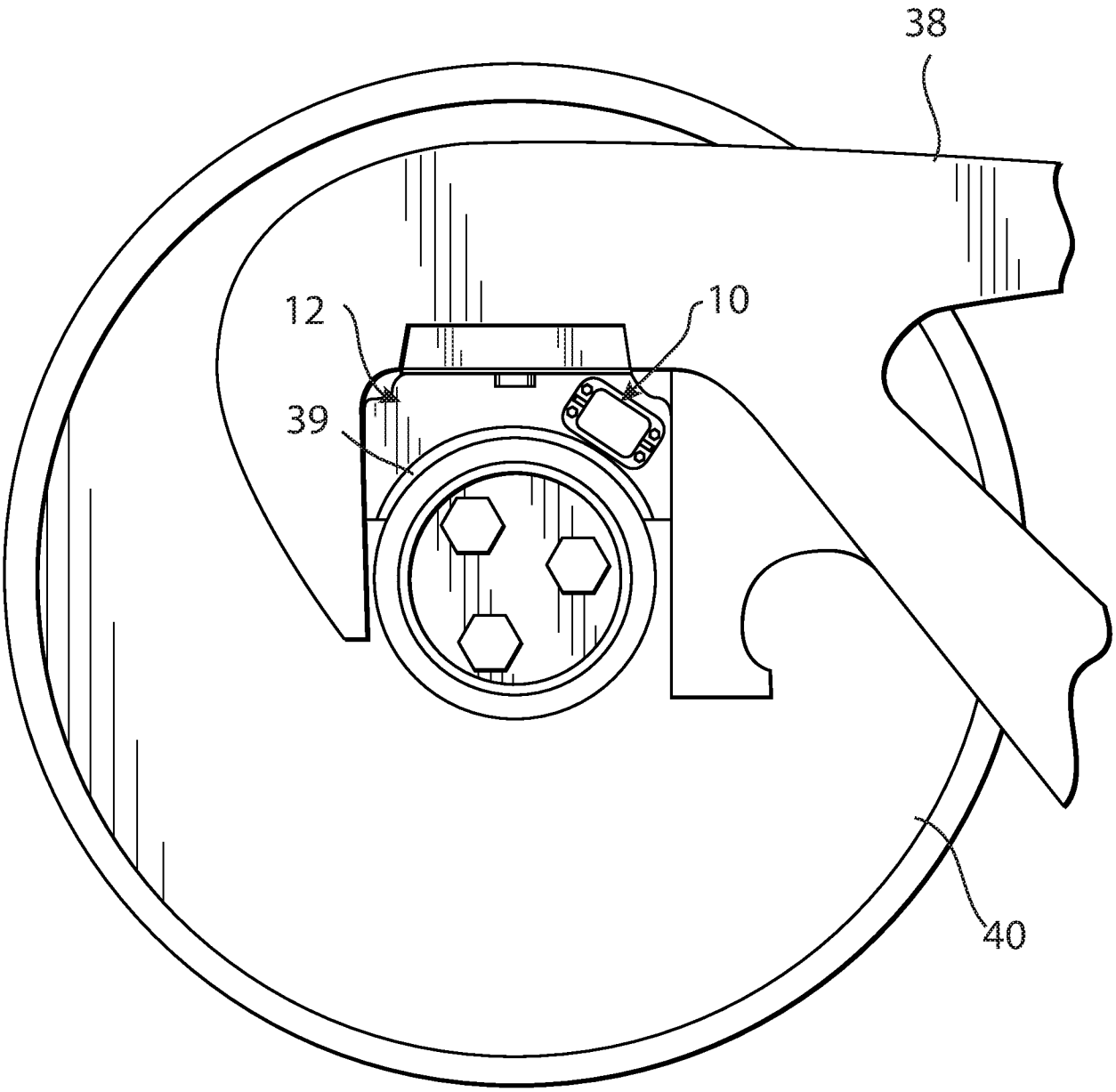


FIG. 3A

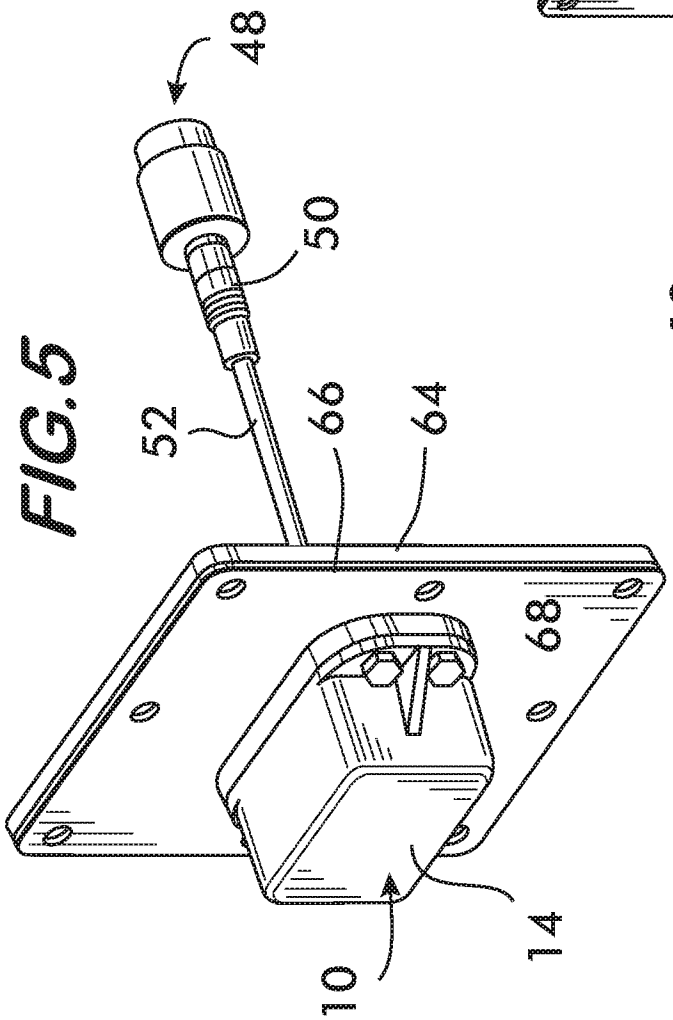

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FIG.5

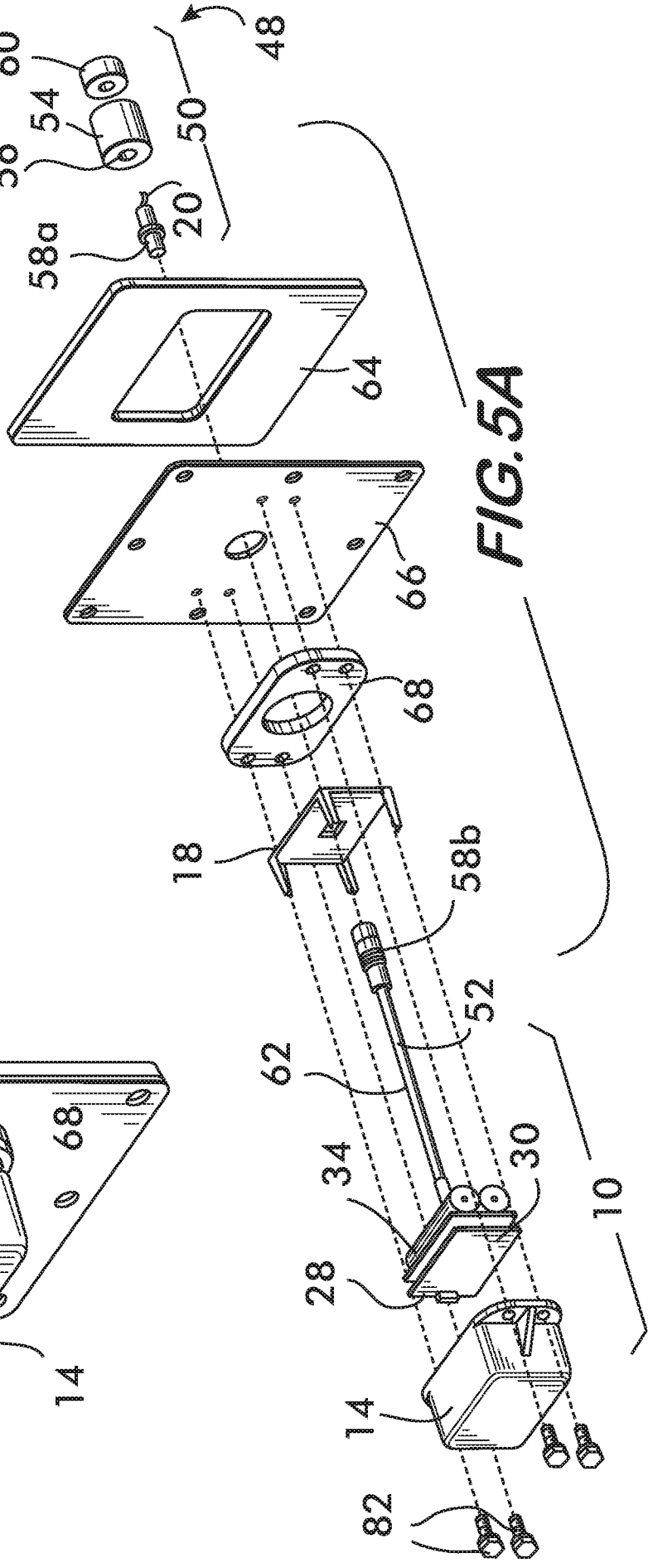
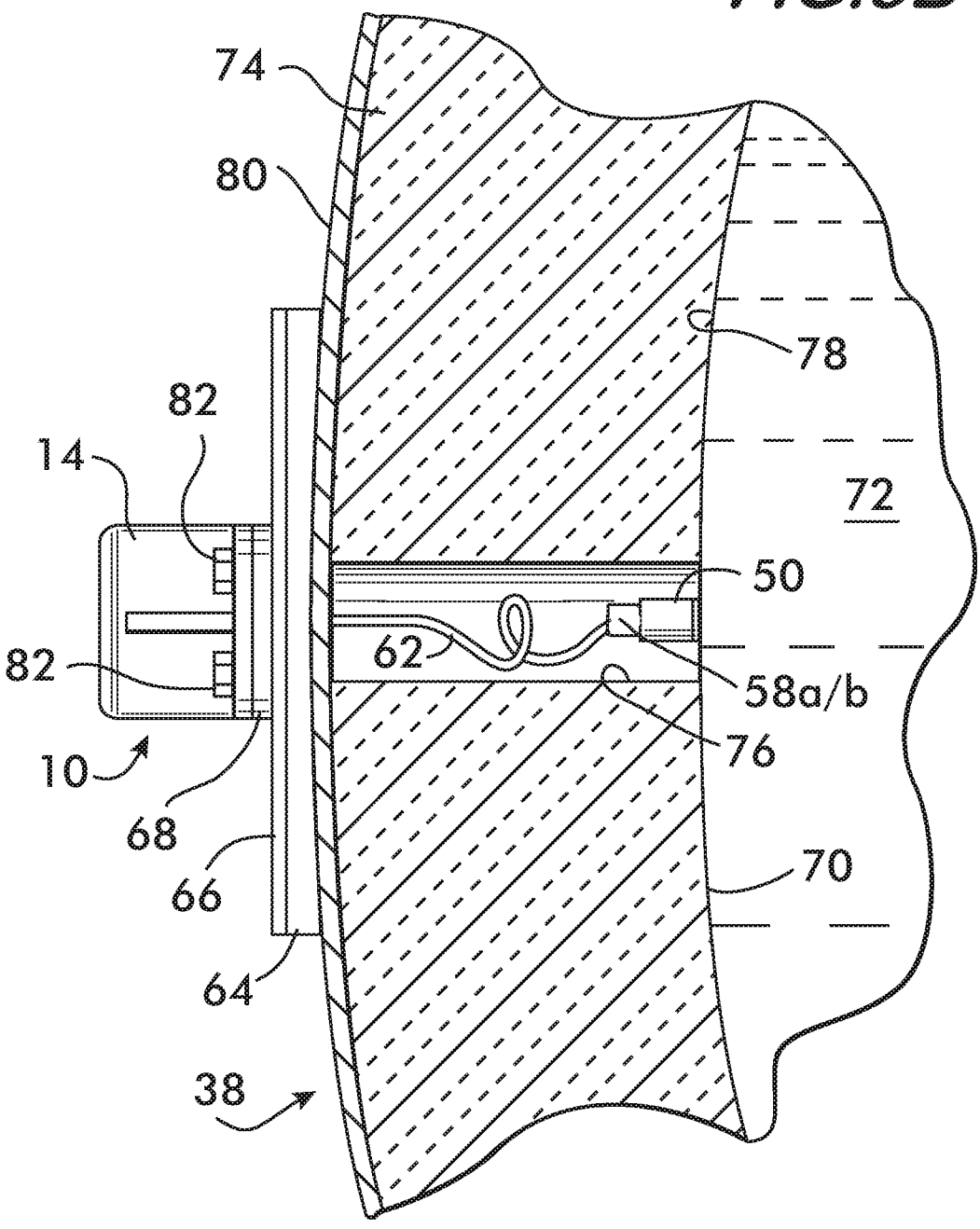

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FIG.5A

FIG.5B



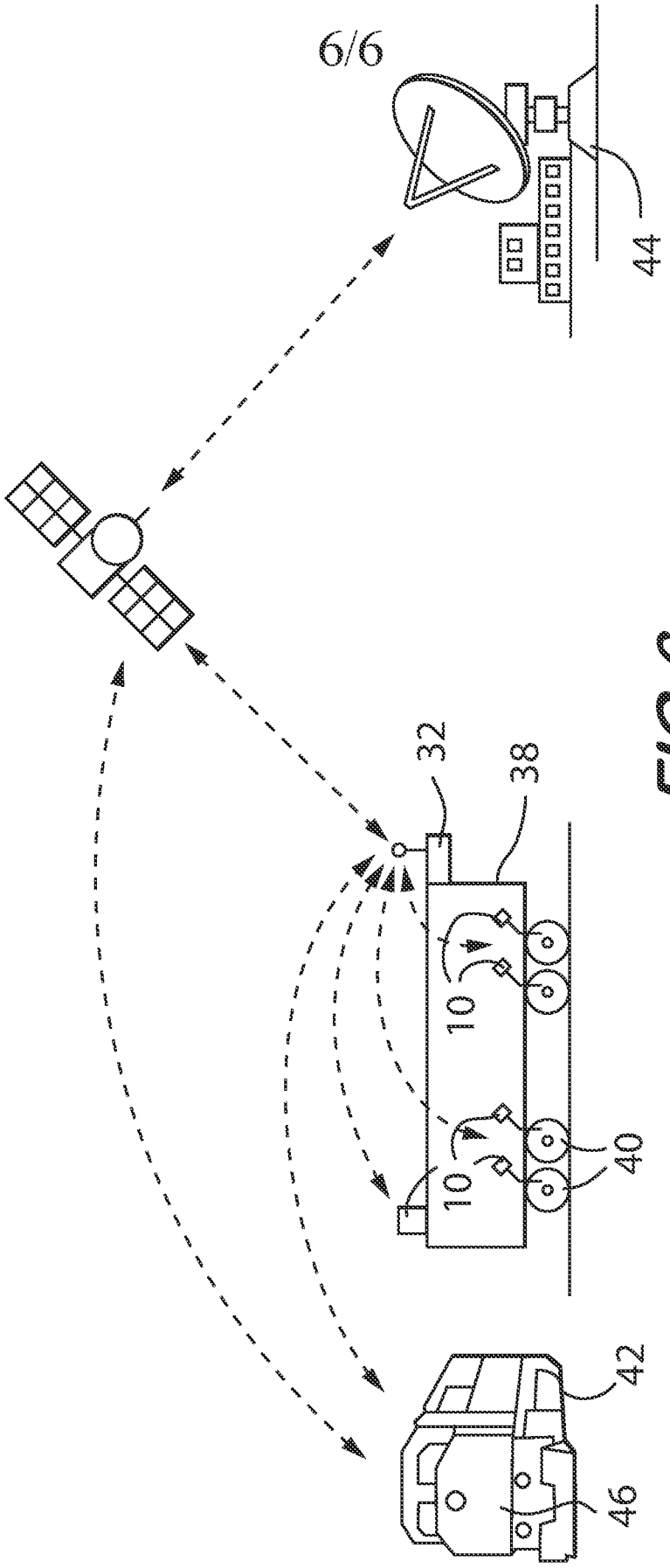


FIG. 6

PTO/AIA/01 (06-12)
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Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	System and Method for Monitoring Railcar Performance

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 13/842427

filed on March 15, 2013.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Andrew Martin Date (Optional): 5/24/13

Signature: Andrew Martin

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/01 (06-12)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	System and Method for Monitoring Railcar Performance

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 13/842427

filed on March 15, 2013.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Brent M. Wilson Date (Optional): 1/9/2015

Signature: [signature]

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of invention	System and Method for Monitoring Railcar Performance

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 13/842427 filed on March 15, 2013

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

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LEGAL NAME OF INVENTOR

Inventor: William D. LeFebvre Date (Optional): _____

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System and Method for Monitoring Railcar Performance

Related Applications

[0001] The application is a continuation of U.S. patent application serial number 13/842,427, filed March 15, 2013, which claims the benefit of U.S. provisional filing serial number 61/661661, filed June 19, 2012, and is a continuation-in-part of U.S. patent application serial number 12/861713, filed August 23, 2010, (now U.S. Patent No. 9,026,281, issued May 5, 2015), the disclosures of which are incorporated herein by reference.

Field of the Invention

[0002] This invention relates to a real-time monitoring and analysis system for railcars, and, more particularly, to a system that gathers data regarding various operating parameters and conditions from remote sensors and applies heuristics to analyze the data to detect and/or predict operational failures. Specific uses for monitoring temperatures on a railcar are also disclosed.

Background of the Invention

[0003] To prevent incidents and improve efficiency, railcar owners and operators need an understanding of how their assets are performing. With heavier cars in service, there is a greater need to identify "bad actors" (cars which can damage track infrastructure and lead to derailments) as soon as their performance becomes unacceptable. There is also a need to increase average train speed by improving high speed performance and reducing unplanned service interruptions through mechanical failures. Car owners increasingly seek to implement preventative maintenance programs to predict and avoid mechanical failures in the field and to efficiently schedule repairs at a facility and time of their choice. Finally, with more automation of rail operations and increasing regulation to improve safety,

the railroad industry needs new ways to monitor the performance of trains, cars and railcar trucks.

[0004] Even minor mechanical failures could lead very quickly to a catastrophic failure, not only of a single railcar, but of the entire train. Thus it is desirable to detect and report deviations from operational norms or predictions of impending failure to the locomotive or to a central data handling facility as quickly as possible, allowing for timely human intervention.

[0005] One approach in use in North America is the use of wayside defect detectors at fixed locations throughout the railroad network. Detectors measuring bearing temperature (hotbox detectors) are common, while other wayside detectors to measure wheel impacts, bearing condition (from acoustical signatures) and lateral forces are gradually being introduced. However, while one detector can monitor many freight cars as they pass, they can only provide a spot check on performance. It is quite possible that defects will only become apparent and escalate to a critical level between detectors.

[0006] Another approach to railcar performance monitoring has been to use on-board instrumentation. One such prominent system has been developed for the Federal Railroad Administration. In this and other similar systems, a number of instruments on different areas of a freight car are used to make discrete measurements before being communicated to a central hub on the freight car. While providing a superior solution to that provided by wayside monitors, wiring, complexity and costs increase the investment required to monitor the cars and decrease efficiency and reliability.

[0007] The current systems, however, lack the ability to apply heuristics to act on data gathered from more than one sensor or to detect operational deviations or trends which show deviations from nominal operating parameters. Furthermore, current systems are limited in that they lack the ability to apply such heuristics at multiple levels, for example, at the individual sensor level, at the railcar level, and at the train level. Lastly, current systems lack the ability for sensors to efficiently and reliably communicate their data to a central data gathering facility using a wireless communications infrastructure that has multiple redundancies and which allows communication of data between

individual sensors.

[0008] Therefore, it would be desirable to have a system which addresses these current deficiencies and which improves (1) the ability to reliably collect and utilize data from multiple sensors on each railcar; (2) the ability to analyze collected data by the application of heuristics to detect and predict operational deficiencies; and (3) the ability to determine the severity of detected conditions to determine if immediate alarms should be raised to facilitate human intervention.

Summary of the Invention

[0009] The present invention has the objective of providing means for monitoring the output from a variety of sensors attached to a railcar and determining the behavior and condition of the railcar and its various components based on an analysis of this data. This provides regular assurance of proper performance and condition as well as necessary warnings of impending or actual failure in a timely and useful manner to the operators and owners of the train.

[0010] Some of the performance criteria that is useful to monitor, for example, include roller bearing temperature, temperature of the commodity being carried, position of the hand brake, roller bearing adapter displacement, wheel condition, truck hunting/warp/binding, brake status and performance, load status and load amount, whether a partial derailment has occurred and potentially problematic track conditions.

[0011] Given the demanding environment in which railroad trains operate, any monitoring system must be rugged, reliable and able to operate for long periods with little or no maintenance. In addition, to be cost effective, it should not add significant cost to install, maintain or operate the system. Because there are more than 1.5 million freight cars in North America alone, a system of monitoring all cars in use is highly desirable and, as such, the system needs to be able to deal with a very large number of potential devices.

[0012] In one embodiment of the invention, sensing units or devices, herein referred to as "motes", are deployed at various locations around the railcar. The motes can include a sensor, a power source, circuitry to read the sensor and convert the readings to a digital form, and communication circuitry which allows the mote to wirelessly transmit the sensor readings to an external receiver. In some instances, a mote may also have the capability to perform low-level analysis of the data to determine if an alarm needs to be raised, and the ability to communicate the alarm to an external receiver.

[0013] Each railcar also can be equipped with a communication management unit (CMU) which communicates with each of the motes deployed on the railcar. The CMU is capable of wirelessly collecting data from each of the motes and performing higher-level analysis of the data to detect imminent or actual failures. During such data analysis, heuristics may be applied to determine potential failures based on statistical models and empirical data. The CMU is also capable of communicating both the data and the results of any analysis to a receiver remote from the railcar.

[0014] The remote receiver may be located on the locomotive or other central location on the train, or may be off-train. The remote receiver may also be able to perform higher-level analysis of the condition of the train by applying heuristics and statistical models to data collected from a plurality of CMUs, located on different railcars in the train. The analysis of the data collected can be carried out at any of the different event engines distributed among the various components in the present invention, including the sensor units, CMU, and mobile or land base stations.

[0015] It is therefore an objective of this invention to provide a comprehensive system which allows the wireless collections of data and the analysis of that data to predict operational failures and to provide adequate warning of those failures to allow for human intervention before a catastrophic failure occurs.

[0016] It is another object to provide specific sensor applications, such as temperature sensors that can monitor the temperature of various components and items on the railcar.

[0017] The discussion which follows describes the system as in the context of a freight car, however, it will be understood by one of skill in the art that the same methods are applicable to any railroad vehicle. Furthermore, while the description which follows features a freight car with two trucks (or bogies), it is applicable to any configuration with more or less trucks or axles.

Brief Description of the Drawings

[0018] Figure 1 is an exploded perspective view of a mote in accordance with the present invention;

[0019] Figure 2 is a cross sectional view of the mote shown in Figure 1;

[0020] Figures 3 and 3A are views of the mote of Figure 1 shown mounted on a railcar bearing adapter;

[0021] Figure 4 is view of a mote, configured as a temperature sensor, mounted on a railcar to obtain ambient air temperature readings;

[0022] Figure 5 is a view of an alternative temperature sensor mote;

[0023] Figure 5A is an exploded view of the sensor mote of Figure 5 shown with components for mounting to the railcar;

[0024] Figure 5B is a schematic view of the sensor mote of Figure 5 shown in use with a tank railcar; and

[0025] Figure 6 is a schematic diagram showing the communications pathways in accordance with the primary embodiment of the invention.

Detailed Description of the Embodiments

[0026] In broad terms, a novel means for monitoring the performance and operation of a railcar is provided. This includes a system for monitoring the railcar and sensors mounted on the railcars for use

with the system. These sensors communicate with a communication management unit preferably mounted on the railcar. The sensors monitor and/or collect data on particular parameters and conditions of the railcar. If a problem is detected, alarms can be forwarded for further action. The sensors are describe below with an exemplary sensor directed to monitoring temperature. This is followed by a detailed description of the monitoring system using the sensors.

[0027] In a preferred embodiment of the invention, the sensors are contained and deployed in a self-contained housing which generally includes the sensor, long-life batteries, a processor board and communications unit. As previously mentioned, these remote units are referred to herein as "motes". The motes can be configured for the parameter or condition to be monitored, and can be placed on the train in the location chosen for such monitoring.

[0028] With reference to Figures 1, 2, 3 and 3A, an exemplary mote 10 is now described. In this particular embodiment, the mote 10 is configured to be mountable to the surface of bearing adapter 12 of a railcar for monitoring the temperature of the wheel bearing. The mote 10 has a housing 14 having a first or lid section 16 and a second or base section 18. Preferably, the housing sections 16 and 18 are composed of a hard plastic resistant to environmental damage, such as a UV rated polymer, e.g., a polycarbonate/ABS blend, and when fully assembled is weatherproof. After the various components are installed within the housing 14 as described below, a potting material (not shown) is provided through openings in the housing 14 to maintain, encapsulate and environmentally seal the components within. Any suitable electrical potting material capable of protecting the electric circuitry and components from the harsh railroad environment can be used, where harsh weather, UV exposure, humidity, vibration, mechanical impact, thermal shocks and abrasion might occur while the device is in operation. Such materials include epoxies, polyurethanes and silicone compounds. A flexible urethane suitable for electrical use and through which wireless signals of the frequencies to be used can be transmitted is preferred.

[0029] A sensor 20 configured for monitoring the desired parameter or condition may be mounted within the housing 14 or may be external to the mote and be electrically connected thereto. Figures 1 and 2 show a temperature sensor 20a, which is thermally coupled to heat transfer element 22 which extends through an opening 24 in the housing 14, a preferred heat transfer element 22 being a brass plug as shown. The thermal transfer element 22 is thermally coupled to the sensor 20 via a thermal epoxy. This configuration is preferred for monitoring the surface temperature of the item to which the mote is attached since the heat transfer element 22 will contact the surface on which the mote is attached. A preferred temperature sensor is a silicon temperature sensor which is ideal for electronic circuits. In this embodiment, the mote 10 will be mounted to place the brass plug 22 in thermal communication with the portion of the railcar for which a temperature reading is desired. As one of ordinary skill would recognize, the configuration of the motes 10 with respect to the sensor 20 is dependent upon the type of sensor and the type of data desired. Sensor 20 can be any type of sensor, including for example, a temperature sensor, a pressure sensor, a load cell, a strain gauge, a hall effect sensor, a vibration sensor, an accelerometer, a gyroscope, a displacement sensor, an inductive sensor, a piezio resistive microphone or an ultrasonic sensor. In addition, the sensor may be a type of switch, including, for example, reed switches and limit switches. An example of another type of mote sensor which uses a strain gauge, e.g. a hand brake monitor sensor, is described in U.S. patent publication 2012/0046811 (US Patent Application 12/861,713 filed August 23, 2010), the disclosure of which is hereby incorporated herein by reference.

[0030] Electrical circuitry 26 is provided for the operation of the mote 10. The electrical circuitry 26 includes the components and wiring to operate and/or receive and process the signals from the sensor 10. This can include, but is not limited to, analog and digital circuitry, CPUs, processors, circuit boards, memory, firmware, controllers, and other electrical items, as required to operate the temperature sensor and process the information as further described below. In the illustrated embodiment, the circuitry 26

is in electrical communication with the temperature sensor for receiving signals therefrom. Two circuit boards are provided connected to one another via a header, as further discussed below.

[0031] The circuitry 26 includes a main board 28 which includes the communications circuitry, antennae and microprocessor and a daughter board 30 including the circuitry to read the data from the sensor 10 and may perform analog to digital conversion of the data and also may include power conditioning circuitry. Main board 28 may also include intelligence sufficient to perform low-level analysis of the data, and may accept parameters from outside sources regarding when alarms should be raised. For example, for the mote 10 shown in Figures 1 and 2, with a temperature sensor 20, may be programmed to raise an alarm when the sensed temperature exceeds a certain threshold for several consecutive readings.

[0032] The main board 28 also includes circuitry for wireless communications. Preferably, each mote 10 on a railcar is formed into an ad-hoc mesh network with other motes 10 on the same railcar and with a Communication Management Unit (CMU) 32, also preferably mounted on the same railcar 38 (see Fig. 6). In the preferred embodiment, each mote 10 would transfer its data to the CMU 32 mounted on the same railcar. This transfer of data may occur directly or the data may be relayed by other motes in the mesh network to the CMU 32. The ad-hoc mesh network is preferably formed using the Time Synchronized Mesh Protocol, a communications protocol for self organizing networks of wireless devices.

[0033] Mote 10 also includes a long-term power source 34, preferably a military grade lithium-thionyl chloride battery. Daughter board 30 includes power conditioning and management circuitry and may include a feature to conserve battery life which keeps mote 10 in a standby state and periodically wakes mote 10 to deliver readings from sensor 20.

[0034] The individual motes 10 are mounted on the areas of interest on a railcar 38. As an example, Figures 3 and 3A show a temperature sensing mote 10 of the type described above mounted to a bearing

adapter 12 of a railcar wheel bearing 39 of a railcar. The unit may be attached using a thermally conductive epoxy adhesive between the brass plug 22 and the adapter 36 to ensure good heat transfer to the temperature sensor and mechanical fasteners such as self tapping screws to hold the mote 10 in place. In this particular example, motes 10 may be attached to all 8 wheel bearing adapters 12 of each railcar wheel 40. In addition, an ambient temperature sensor mote 10 may also be mounted on an area of the railcar 38 receiving free airflow. Figure 4 shows a mote 10 mounted on the body of a railcar 38 for monitoring the ambient temperature. The device electrical circuitry 26 obtains information related to the temperature being monitored, e.g., a bearing or ambient. Since the temperature sensor is not in direct contact with the bearing, but the bearing adapter, the device is calibrated so that the temperature reading is indicative of the bearing temperature. This calibration takes into account the temperature of the bearing adapter at the point measured (see Fig 3a), the ambient temperature as measured by the second temperature sensor mote mounted elsewhere on the rail car so as to sense ambient temperature (see Fig 4), and information about the type of bearing adapter (different models have different sizes and configurations). Calibration information for use by the circuitry 26, such as a calibration algorithm, can be developed with suitable testing. Bearing temperature information that constitute various alarm states can also be provided to the circuitry 26, preferably stored thereon, allowing the device 10 to monitor the bearing temperature and, based on the ambient temperature, determine the bearing temperature and take action as desired. On a typical railcar 38, there will be eight sensors 10, one on each bearing adapter 12 (at each wheel 40); and one sensor 10 placed to measure ambient temperature. The ambient temperature sensor 10 will communicate the ambient temperature to the CMU, which provides this information to the sensors at the bearing adapters as they call for the information. This will allow the sensors 10 at the bearing adapter 12 to determine the bearing temperature and then determine if further action is required, such as communicating an alarm of high temperature. Again, time Synchronized Mesh Protocol, a communications protocol for self-organizing networks of wireless devices, is

preferred to communications between the devices 10 and the CMU 32.

[0035] An alternative temperature sensor mote 10 is illustrated with reference to Figures 5, 5A and 5B showing a mote 10 for monitoring the temperature of a part of the railcar spaced from the housing 14 of the mote 10. For example, it may be desirable to monitor the temperature of a commodity stored in a vessel or the temperature inside of a container by monitoring the temperature of the vessel or container wall, but a mote 10 as described above for attaching directly to the surface to be monitored is not suitable. Here the mote 10 is constructed the same as that described above but with the temperature sensor 20 positioned in a probe 48 spaced from the housing 14. The temperature sensor 20 sits within a sensor probe head 50 electrically attached to the housing 14 via wires 52. The head 50 is preferably cylindrical having a ring shaped head body 54 made of a thermally conductive material such as stainless steel. Fitting within a head body opening 56 is the temperature sensor 20 electrically attached to an electrical connector 58a. A ring shaped magnet 60 with an opening in its center fits around the sensor 20 within the head 50. Thermally conductive epoxy or other suitable potting material seals the magnet 60 and temperature sensor 20 within the body 50 and ensures good heat transfer to the sensor 20. A corresponding electrical connector 58b connected to corresponding connector 58a connects temperature sensor 20 via wire 52, preferably a flexible PVC coated cable 62, to the mote housing 14. To aid in the mounting of this housing 14, a silicon gasket 64, metal mounting plate 66, and housing silicon mounting gasket 68 are provided. The mote 10 continuously monitors the commodity temperature and alerts when specific criteria are met such as rapid temperature change, temperature thresholds exceeded, etc.

[0036] As an example of such a device and a method of installing the device, shown in Fig 5B representing a liquid holding tank 70 of a rail tank car 38, the temperature mote 10 with the spaced probe 48 can be used to monitor the temperature of a liquid 72 stored within the tank 72 on a rail tank car 38 that is covered with a fairly thick insulation jacket 74 having an outside cover 80. Here, a small

opening 76, about 2" diameter, can be cut into the jacket 74 allowing the probe head 50 to be attached to the cleaned outside surface 78 of the vessel 70 with thermally conductive epoxy. The magnet 60 within the head 50 helps hold the probe 48 in place while the epoxy cures. The housing 14 of the mote 10 is mounted on the outside of the jacket cover 80, connected to the head 50 vial the cable 62 which can be coiled if necessary to fit within the opening 76. To attach the housing 14 to the jacket cover 80, the silicone gasket 64 is placed against the jacket cover 80 over the opening 76, followed by the metal mounting plate 66, followed by silicone gasket 68, the gaskets 64 and 68 ensuring a good weather seal of the housing 14 to the jacket cover 80. The metal mounting plate 60 is screwed or bolted to the jacket cover 80, and the mote housing 14 is screwed to the mounting plate 66 with screws 82. Calibration of the mote circuitry ensures an accurate temperature reading of the liquid 72 within the vessel 70, and ambient temperature, monitored from another sensor 10, can be used to calculate accurate temperature readings.

[0037] To communicate data collected by the motes 10, each mote is in two-way communication with a CMU 32 mounted on the railcar 38, which collects data from each mote and can also send instructions to the motes, as shown in Fig. 6. As previously stated, CMU 32 and each of the motes 10 connected to the same railcar 38 form a local area ad-hoc mesh network, to facilitate communications therebetween. The term "Communication Management Unit" or "CMU" as used herein means any device capable of receiving data and/or alarms from one or more motes 10 and capable of transmitting data and alarm information to a remote receiver. CMU 32 is preferably a single unit that would serve as a communications link to other locations, such as a mobile base station 42 (e.g., the locomotive 46), a land-based base station 44, etc, and have its own circuitry, CPUs, processors, memory, power source, etc. to process the data received. In a preferred embodiment, it can also communicate with, control and monitor motes 10 on the railcar 38.

[0038] CMU 32 is capable of performing advanced data analysis, using data collected from multiple

motes 10, and may apply heuristics to draw conclusions based on the analysis. The chart below contains examples of the types of mote sensors 10 and high level descriptions of the heuristics applied to analyse the data.

[0039]

Parameter Sensed	**Sensor Type**	**Output**	**Heuristic**
Adapter Temp.	Temperature Sensor	Bearing Temp.	Adapter temperature is correlated to bearing cup temperature using empirical data.
Hatch Position	Reed Switch	Hatch open/close	Determine open/closed state dependent upon state of switch.
Pressure	Pressure Transducer	Brake pressure	The pressure transducer is fitted directly to the trainline for measuring pressure.
Handbrake Link Strain	Strain Gauge	Handbrake On/Off	Handbrake link strain is correlated to the ON/OFF status of the handbrake.
Bolster Displacement	Hall Effect Sensor	Car Load	Bolster/side frame displacement is measured and spring stiffness data is used to convert displacement to load.
Bolster position	Reed Switch	Car Empty/Full	The relative position of bolster/sideframe is measured. The LOADED position is determined using empirical data or spring stiffness.
Inner Jacket Temp.	External Temperature Sensor	Tank Car Commodity	Inner jacket surface temperature on a tank car

		Temp.	is determined and commodity temperature can be estimated using theoretical conduction/convection laws.
Bolster Position	Limit Switch	Car Empty/Full	A limit switch is mounted to the sideframe and activated when the bolster/sideframe position is in the loaded state.
Sill Acc.	Accelerometer	Coupler Force	Impact data is collected. Using empirical data, a modal influence matrix can be computed for different coupler types that relates the impact data to the output. Using an FFT on the sampled data, and multiplying by the inverse of the modal matrix yields the input in the frequency domain. This input can be converted to the time domain to yield the coupler force.
Adapter Acc.	Accelerometer	Bearing Fault Indicator	An adapter mounted accelerometer can be used to sample dynamic bearing data. An FFT can be used on data sets and plotted over time to isolate dominant modes and any shifting or relative amplification. Amplification at rolling frequency indicates a likely fault.
Radial Axle Acc.	Accelerometer	Vehicle Speed	An axle mounted accelerometer can be used to measure radial acceleration. The radial acceleration can be converted to vehicle speed

			using simple dynamics using the wheel and axel diameters.
Adapter Acc.	Accelerometer	Bearing Fault	An adapter mounted accelerometer can be used to sample dynamic bearing data. Kurtosis can be computed as an indicator of bearing damage. Kurtosis is measured in the time domain and requires computation of a probability density function.
Adapter Acoustics	Piezio-electric sensor, microphone, and accelerometer	Bearing Fault	Sampled acoustic data can be used for either an acoustic noise response or Acoustic Emission which is ring-down counts and amplitude. Empirical data from defective bearings is needed.
Temp.	Temperature sensor	Commodity/Fluid Pressure	A temperature sensor can be used to measure surface temperature of a pressure vessel (Tubing, tank, etc.). Heat conduction equations can be used to convert the surface temperature to fluid temperature. Using published data for the working fluid, the temperature can be converted to pressure.
Displ.	Displacement Sensor	Coupler Force	Coupler displacement is measured and correlated to force using force-closure curves.
Axle RPM	Inductive Type Sensor	Vehicle Speed	An inductive proximity sensor facing the axle can generate a signal in response to an exciter ring on the axle, and converted

			to vehicle speed using wheel and axle diameters.
Adapter Acc.	Accelerometer	Track Damage Detection	Sensor is mounted on an adapter or other truck component to sample dynamic data. A Probability Density Function and Kurtosis can be computed from the data. High Kurtosis, or impulsivity, will indicate track defects. A transfer function relating the wheel input to the adapter is needed, and can be determined empirically or by creating a theoretical model.
Adapter Acc.	Accelerometer	Truck Hunting Detection	Sensor can be mounted on an adapter or other truck component to sample dynamic data. A simple algorithm could use an FFT to isolate known hunting frequencies. More sophisticated algorithms could detect flange impacts using time-series data.
Wheel Temp.	IR Temperature Sensor	Wheel Tread Temp	Wheel temperature is correlated to tread temperature using empirical data.
Proximity	Ultrasonic Sensor	Empty/Full status	An ultrasonic sensor could be used to detect the presence of lading in tank-cars, box-cars, covered hoppers, etc.
Strain	Load Cell	Car Load	Load cell on multiple places of the truck.
Displ.	Reed Switch	Handbrake On/Off	Position of a handbrake chain is determined and correlated to On/Off

			Status.
Bolster Acc.	Accelerometer	Truck tilt angles	Using a 3-axis accelerometer fixed to a bolster, the gravitational field can be used to measure the respective roll, pitch, and yaw angles with respect to fixed-earth coordinates.
Hatch Acc.	Accelerometer	Hatch Tilt	Accelerometer measures the relative tilt of hatch with fixed-earth coordinates.

[0040] As shown in Figure 6, CMU 32 also communicates data and alarms to a remote location, either a mobile base station 42 located on the train, usually in the locomotive, or to a stationary, land-based base station 44, or both. Data and/or alarms may be relayed from land-based base station 44 to the mobile base station 42. CMU 32 may be in constant wireless or wired communication with the mobile base station 42, which may communicate with the land-based base station 44 via the cellular network, via satellite, or via any number of other well known means.

[0041] Data collected from motes 10 may be sent to base station 44 for analysis and further action. The heuristics shown in the chart above may be performed by either mobile base station 42 or land-based base station 44. In addition, either station 42, 44 may utilize train–wide heuristics to predict train-wide failures, or to spot train-wide trends, which a single CMU 32 may be unable to do with data from only a single railcar 38.

[0042] When an alert is detected, it is preferably sent to a display unit in the locomotive 46 or at the land-based base station 44. Any typical display unit of a type that would be mounted in a mobile base station 42, such as in a locomotive, may be used. Communications devices as known in the art communicate with base station 44 via satellite, and display units display the alert to the locomotive

engineers. Incoming alerts may appear on the display and are accompanied by an audible alarm which must be acknowledged and cancelled by the driver. Each type of alert is accompanied by a recommended practice that the locomotive driver should take when an alert appears, based on the needs of the particular rail network. The action required to be taken by the locomotive driver varies based on the severity of the alert. Alerts may also be sent via email or posted to a web site.

[0043] Setting locomotive alarm thresholds at values that are sub-critical will likely lead to an excess of stoppages and delays. As such, alert messages are selected such that only actionable messages are sent to the locomotive 46, meaning that only those alarm levels that require the crew to take action are typically transmitted to the locomotive crew. In addition, rather than requiring the train to be stopped on the mainline, some alerts could be addressed by putting operating restrictions in place. For example, speed restrictions can be placed on the operation of the train at tiered alarm levels so that the train would be allowed to proceed to a siding or other appropriate stoppage point, allowing other traffic to continue on the mainline without inordinate delays or costs. Low level (Level 1 / Stage 1) alerts, however, can still be monitored at base station 44 to make determinations about repeat temperature offenders and/or trending events that would signify an impending problem, although not imminent.

[0044] As an example of operation, consider the monitoring of wheel bearings. The goal is to monitor bearings in motion, therefore, data that is collected while the railcars 38 are motionless does not contribute to determining the condition of the bearing. To save power and limit the uninformative temperature information, data may be suppressed when the railcar was not moving. As such, data is only stored in CMU 32 and transmitted to the base station 42, 44 when useful data is found. Three conditions that might define "interesting" or "useful" data include:

1. 'Differential Condition' events;

2. 'Above Ambient Condition' events; and

3. 'Node Temp Anomalies'.

[0045] A *Differential Condition* event exists when the difference across any axle is greater than or equal to a specified variable.

[0046] An *Above Ambient Condition* event occurs when any bearing temperature exceeds the value reported from the Ambient Temperature Node by a specified constant.

[0047] A *Node Temp Anomaly* occurs when any data channel, bearing or ambient, does not report valid temperatures even though other channels are collecting data well past the corresponding time period. The delay allows the system a chance to recover from possible communication errors. CMU 32 will continue to gather and save temperatures from the other bearings, even if a full data set should have been gathered and one or more channels are missing data.

[0048] The data suppression is confirmed by seeing all temperature data converge to ambient (train has stopped) before logging stops. Divergent temperatures show the bearings are generating heat again and the train has started moving.

[0049] **Levelled Alarms and Responses** These are examples of various levels of alarms, based on severity, and the appropriate response:

Stage 1: "Bearing Temp Alarm"
-Alarm to base station only
- Used for trending recommendations and repeat offender identifications

Stage 2: "Axle Differential Alarm": is the condition any bearing that is a predetermined amount hotter than its axle mate
-Action: Stop train, check journal of alarming bearing. Look for any sign that the bearing is "walking off" the axle, grease is being purged, or the bearing has been damaged.
-Proceed at predetermined reduced maximum speed until a stage 2 "alarm clear" message is received at the locomotive terminal
-If stage 2 "alarm clear" message is received at the locomotive terminal, proceed as normal

Stage 3: "Above Ambient Alarm": is when any bearing is at a temperature a predetermined amount above ambient
-Action: Stop train, check journal of alarming bearing. Look for any signs that the bearing is "walking off" the axle, grease is being purged, or the bearing has been damaged.

-Proceed at predetermined reduced maximum speed until stage 3 "alarm clear" message is received at the locomotive terminal, at which point speed can be increased
-If the alarm message does not clear, a choice can be made to remove and change the bearing at an appropriate stoppage point; otherwise, reduced speeds are required to reduce the chance of a screwed journal or catastrophic bearing failure
-If Stage 2 and Stage 3 "alarm clear" messages are both received at the locomotive terminal, proceed as normal

Stage 4: "Critical Alarm": this is the absolute alarm set at a predetermined bearing temperature
-Action: Stop train, remove bearing

[0050] Advanced Algorithms - Improvements to the alarms can be made based on statistical models of bearing temperature behaviour. The following section details examples of advancements to the existing data analysis as it pertains to identifying bearings that are on the "watch list" for degrading/trending condition.

[0051] Level 2 Algorithms The Level 2 algorithms use temperature data that had been collected every minute while the railcar had been moving during a period of days directly preceding this analysis. When at least four of the following five criteria are flagged for the same bearing, an alert may be sent to the customer to schedule maintenance for that bearing.

Criteria 1 - Peak Analysis: Count the percentage of bearing temperature values > a predetermined value

- For each bearing, count the number of temperature readings that occur above a predetermined value
- Flag any bearing with a certain percentage of temperature values > a predetermined value

Criteria 2 – Above Ambient Analysis: Count the percentage of bearing temperature values > a defined value above ambient

- For each bearing, count the number of temperature readings that occur over a defined value above ambient
- Flag any bearing with a certain percentage of temperature values > the defined threshold

Criteria 3 – Deviation from Wagon Average Analysis: Calculate the average bearing temperature and standard deviation of each bearing compared to the average of bearing temperatures for the rest of the wagon

- Calculate the average temperature over the time span for each bearing and the wagon average
- Calculate the standard deviation on each bearing temperature from the wagon average
- Flag any bearing with a certain standard deviation

Criteria 4 – Deviation from Fleet Average Analysis: Calculate the average bearing temperature and standard deviation of each bearing compared to the average of bearing temperatures for the rest of the fleet

- Calculate the average temperature over the time span for each bearing and the fleet average
- Calculate the standard deviation on each bearing temperature from the fleet average
- Flag any bearing with a certain standard deviation

Criteria 5 – Heating Rate of Change Analysis: Calculate the percent of operating time that a bearing is heating quickly

- Calculate a linear fit to a moving window of temperature data
- Count the number of instances where the slope of the linear fit is above a certain threshold
- Flag any bearing with > a certain amount of the operating time having a slope of the linear fit > the threshold

[0052] Level 3 Algorithms The Level 2 algorithms use temperature data that has been collected every minute while the railcar is moving for the previous 30 days directly preceding this analysis. When a bearing is ranked in the top five percent for at least four of the five criteria, an alert is sent to the customer to schedule maintenance for that bearing.

Criteria 1 – Peak Analysis: Count the percentage of bearing temperature values > a predetermined value

- For each bearing, count the number of temperature readings that occur above a predetermined value
- Rank the bearing in a league table with the rest of the fleet
- Flag the top percent of bearings in the fleet

Criteria 2 – Above Ambient Analysis: Count the percentage of bearing temperature values > a defined value above ambient

- For each bearing, count the number of temperature readings that occur over a defined value above ambient
- Rank the bearing in a league table with the rest of the fleet
- Flag the top percent of bearings in the fleet

Criteria 3 – Deviation from Wagon Average Analysis: Calculate the average bearing temperature and standard deviation of each bearing compared to the average of bearing temperatures for the rest of the wagon

- Calculate the average temperature over the time span for each bearing and the wagon average
- Calculate the standard deviation of each bearing temperature from the wagon average
- Rank the bearing in a league table with the rest of the fleet

- Flag the top percent of bearings in the fleet

Criteria 4 – Deviation from Fleet Average Analysis: Calculate the average bearing temperature and standard deviation of each bearing compared to the average of bearing temperatures for the rest of the fleet

- Calculate the average temperature over the time span for each bearing and the fleet average
- Calculate the standard deviation on each bearing temperature from the fleet average
- Rank the bearing in a league table with the rest of the fleet
- Flag the top percent of bearings in the fleet

Criteria 5 – Heating Rate of Change Analysis: Calculate the percentage of operating time that a bearing is heating quickly

- Calculate a linear fit to a moving window of temperature data
- Count the number of instances where the slope of the linear fit is > a certain threshold
- Rank the bearing in a league table with the rest of the fleet
- Flag the top percent of bearings in the fleet

[0053] In another alternate embodiment of the invention, one or more motes may be housed in alternative housings or built in to the railcar itself. In one such embodiment, motes can be built into the form of an adapter pad similar to the type shown in U.S. Patents 7,698,962 and 7,688,218, the disclosures of both of which are incorporated herein by reference, which could be adapted for use with the present invention.

[0054] Various embodiments of the invention have been described in the context of various examples, however, the invention is not meant to be limited in any way. As one of skill in the art recognizes there may be many implementations that are within the scope of the invention, as is described in the following claims.

We Claim:

1. A device for monitoring temperature on a railcar, comprising:

a housing mountable on a railcar;

a temperature sensor;

electrical circuitry in communication with said temperature sensor for obtaining information regarding the temperature being sensed, said electrical circuitry positioned within said housing;

a power source electrically connected to said electrical circuitry for providing power thereto, said power source positioned within said housing; and

a communication device capable broadcasting information regarding the temperature sensed, said communication device positioned within said housing.

2. The monitoring device of claim 1 wherein said temperature sensor is positioned within said housing.

3. The monitoring device of claim 1 wherein said temperature sensor is external of said housing and in electrical communication with said circuitry via a cable.

4. The monitoring device of claim 3 further comprising a probe external to said housing and which probe includes said temperature sensor and a magnet positioned to magnetically attract the part of the railcar against which the probe will be placed.

5. A system for monitoring and reporting the status of temperature on a railcar, comprising:

the railcar;

a sensor device for monitoring the temperature as set forth in claim 1, said device mounted to said railcar and said temperature sensor of said device positioned at a location to monitor a desired temperature on said railcar; and

a communication management unit (CMU), in wireless communication with one or more of said sensing devices for receiving information therefrom, said CMU having a wireless communication device for broadcasting information about the temperature being monitored.

6. The system of claim 5 wherein said system can make a determination of an alarm condition based on data collected by said sensing device.

7. The system of claim 6 wherein said sensor device is attached to a bearing adapter of a railcar to monitor the temperature of a bearing, said temperature sensor of said device being in thermal communication with said adapter to sense the temperature thereof.

8. The system of claim 7 further comprising a second said sensor device mounted on said railcar for monitoring an ambient temperature, wherein said system uses data from said two temperature devices for determining the temperature of said bearing.

9. The system of claim 6 wherein said temperature sensor of said device is in thermal communication with a part of the railcar to sense the temperature thereof, said housing of said device being mounted on said railcar away from said temperature sensor and connected thereto by wires external to said housing.

10. A system for monitoring a railcar, comprising:

the railcar;

a plurality of sensor devices located on the railcar for monitoring parameters or conditions of the railcar;

said plurality of sensor devices including at lest one temperature sensor device having:

a temperature sensor in thermal communication with the item being monitored;

a housing;

electrical circuitry in communication with said temperature sensor for obtaining information regarding the temperature being sensed, said electrical circuitry positioned within said housing;

a power source electrically connected to said electrical circuitry for providing power thereto, said power source positioned within said housing;

a communication device capable broadcasting information regarding the

temperature sensed via wireless communication, said communication device positioned within said housing; and

a communication management unit (CMU), mounted on the railcar, capable of two way wireless communication with each of said plurality of sensor devices for receiving information therefrom, said CMU having a wireless communication device for broadcasting information about the parameter or condition being monitored.

11. The system of claim 10 wherein one of said temperature devices is mounted to a bearing adapter of a wheel bearing to monitor the temperature of the bearing adapter; said system being calibrated to determine the temperature of said wheel bearing.

12. The system of claim 10 wherein said plurality of sensor devices includes a second temperature sensor device.

13. The system of claim 10 wherein said plurality of sensor devices includes a sensor device that monitors a parameter or condition of the railcar other than temperature.

14. The system of claim 10 wherein said system can make a determination of an alarm condition based on data collected by said one or more sensing units.

15. The system of claim 10 wherein said determination of an alarm condition can be made by at least one of said CMU or one of said plurality of sensor devices based on data collected by said one or more sensing devices.

16. The system of claim 10 wherein each of said plurality of sensing devices is capable of exchanging data with other of said plurality of sensing devices and with said CMU.

17. A system for monitoring the operation of a railcar comprising:

a. one or more sensing units, mounted on said railcar, each of said sensing units monitoring an operating parameter of said railcar; and

b. a communication management unit, in wireless communication with said one or more sensing units;

wherein said system can make a determination of an alarm condition based on data collected by said one or more sensing units.

18. The system of claim 17 wherein said determination of an alarm condition can be made by one of said sensing units.

19. The system of claim 17 wherein said determination of an alarm condition can be made by said communication management unit based on data collected by said one or more sensing units.

20. The system of claim 17 wherein said communication management unit makes said determination of an alarm condition by applying a heuristic to data collected from said one or more sensing units.

21. The system of claim 17 wherein each of said sensing units comprises:

a. a sensor;

b. a power source;

c. a processor;

d. memory;

e. communications circuitry; and

f. software, stored in said memory and executed by said processor, said software performing the functions of collecting data from said sensor at periodic intervals.

22. The system of claim 21 wherein said software further performs the function of:

assessing the collected data to determine if an alarm condition exists; and

communicating said alarm condition to said communication management unit via said communications circuitry.

23. The system of claim 21 wherein each of said sensing units exchanges data with other sensing units and with said communication management unit via said communications circuitry.

24. The system of claim 17 wherein said one or more sensing units and said communication management unit are in wireless communication with each other and form a local area network.

25. The system of claim 24 wherein said local area network is a mesh network running the Time Synchronized Mesh Protocol to facilitate communications therebetween.

26. The system of claim 17 wherein said communication management unit is in wireless communications with communication management units on other railcars, forming a wide area network.

27. The system of claim 17 further comprising a base unit, said base unit being in wireless communication with said communication management unit, said based unit performing the functions of:

a. collecting data and alarms from said communication management unit;

b. displaying alarm conditions raised by said communication management unit; and

c. determining high level alarms based on data and alarms collected from said communication management unit.

28. The system of claim 27 wherein said base unit is in wireless communication with multiple communication management units.

29. The system of claim 28 wherein said base unit uses distributed event processing to perform trend analysis based on alarms and data collected from one or more communication management units to determine if a high level alarm should be raised.

30. The system of claim 28 wherein said base unit applies heuristics to data collected from said one or more communication units to determine if a high level alarm should be raised.

31. The system of claim 30 wherein said base unit and said one or more communication management units communicate with each other via a satellite communications capability or a cellular network capability.

32. The system of claim 17 wherein said sensor is selected from a group consisting essentially of temperature sensors, pressure sensors, strain sensors, load cell sensors, hand brake position sensors, magnetic sensors, vibration sensors, gyroscopes, acceleration sensors, hall effect sensors, piezio resistive microphones and switches.

33. The system of claim 17 wherein data and alarms may be relayed from said one or more communication management units to an on-train base unit via an off-train base unit.

34. The system of claim 17 wherein said alarm is determined using distributed event processing based on a comparison between current data and statistical models of behavior.

35. The system of claim 17 wherein said alarms are determined based on a comparison of currently collected data versus data collected over a pre-determined preceding time period.

36. The system of claim 17 wherein an alarm is raised based one or more of the following criteria:

a. a pre-determined percentage of current data readings exceeds allowable peak readings;

b. a pre-determined percentage of current data readings exceeds an determined value;

c. a pre-determined percentage of current data readings exceeds a standard deviation from readings from the same railcar;

d. a pre-determined percentage of current data readings exceeds a standard deviation from all railcars in the fleet; or

e. the rate of change of current data readings exceeds a pre-determined threshold.

37. A method of monitoring operational characteristics of a railcar comprising the steps of:

a. receiving data or processed information regarding said operational characteristic from one or more sensing units on said railcar, said sensing units monitoring an operational characteristic of said railcar;

b. applying a heuristic to said received data to determine deviations from nominal

operating conditions;

c. assigning a severity level to said deviations from nominal operating conditions; and

d. determining an alarm condition based on said assigned severity level.

38. The method of claim 37 further comprising the initial step of establishing wireless communication with said one or more remote sensing units.

39. The method of claim 38 wherein said one or more remote sensing units form a mesh network.

40. The method of claim 38 wherein steps a-d are executed by a processing unit located on said railcar.

41. The method of claim 40 wherein said processing unit located on said railcar is a part of said mesh network.

42. The method of claim 38 further comprising the step of transmitting said alarm condition to a location remote from said railcar.

43. The method of claim 38 further comprising the step of transmitting said data received from said one or more sensing units to a location remote from said railcar.

44. The method of claim 38 further comprising the steps of:

a. receiving data from a plurality of railcars;

b. applying a heuristic to said received data to determine deviations from nominal operating conditions;

c. assigning a severity level to said deviations from nominal operating conditions;

d. determining an alarm condition based on said assigned severity level;

e. transmitting said raised alarm to a display unit on a train of which said plurality of railcars are a part.

45. The method of claim 42 further comprising the steps of

a. determining a recommended course of action based on said alarm condition; and

b. transmitting said recommended course of action to a display unit on a train of which said railcar is a part.

46. The method of claim 1 wherein said one or more remote sensors are temperature sensors.

47. A method of monitoring a temperature of a desired part of a railcar, comprising:

(a) sensing the temperature of a part of the railcar other than the desired part by use of a temperature sensor in thermal communication with said other part;

(b) determining the temperature of the desired part by use of the temperature sensed in step (a);

(c) determining if said temperature of the desired part is outside an acceptable range of temperatures; and

(d) transmitting an alarm if in step (c) it is determined that the temperature of the desired part is outside an acceptable range.

48. A method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, further comprising the step of determining the temperature of the ambient air, which temperature is used in the determination of step (b).

49. A method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, wherein steps (a) through (d) are carried out by a single unit attached to said railcar.

50. The method of claim 37 wherein steps (a) through (d) can be carried out at different event engines distributed among at least two of said sensor unit, a communication management unit, and a mobile or land base station.

ABSTRACT

A system for monitoring operation of a railcar having one or more sensing units, mounted on the railcar, for monitoring operating parameters and or conditions of the railcar, and a communication management unit, in wireless communication with the sensing units, wherein the system can make a determination of an alarm condition based on data collected the sensing units. A temperature sensor device for use in such a system is also provided.

Electronic Acknowledgement Receipt

EFS ID:	25816380
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht/Patricia Frisoli
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	P36736B US
Receipt Date:	18-MAY-2016
Filing Date:	
Time Stamp:	16:01:35
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	CON_ADS.PDF	1858273 bed5fc4aa88eff319f7e8f4e8895c85d37621f70	no	9

Warnings:	
Information:	

2	Drawings-only black and white line drawings	CON_Drawings_Formal.PDF	419429 bf8ea5231b079f963a511779d461510afc141b34	no	6
Warnings:					
The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing					
Information:					
3	Oath or Declaration filed	ExecutedDeclarationAndrewMartin.PDF	315929 0df1e32a20ff231f49fc5307ba19b0ec4d7b5566	no	1
Warnings:					
Information:					
4	Oath or Declaration filed	IX007-DeclarationApplication-Wilson_Brent-2015-01-07.PDF	332086 628bf82fa29465ee6222f86d68e0b2d4714c1594	no	1
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5	Oath or Declaration filed	LeFebvre_Declaration.PDF	1313007 7c6ea8a3efd5c45a7b149a0199ddc40c15f7a6bf	no	2
Warnings:					
Information:					
6		CON_App.PDF	262216 e8415a7cc4eef47d53e9dc26b54d6ec2c3d35122	yes	30

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	21
Claims	22	29
Abstract	30	30

Warnings:	
Information:	
Total Files Size (in bytes):	4500940

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/158,018	05/18/2016	Andrew H. Martin	P36736B US

CONFIRMATION NO. 1036

29880
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FORMALITIES LETTER

OC000000083381630

Date Mailed: 06/06/2016

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
- The application search fee must be submitted.
- The application examination fee must be submitted.
- The inventor's oath or declaration or an application data sheet (ADS) naming each inventor has not been submitted. An inventor's oath or declaration in compliance with 37 CFR 1.63 or 1.64 executed by or with respect to each inventor, or a properly executed ADS in compliance with 37 CFR 1.76 identifying each inventor by his or her legal name, mailing address, and residence (if an inventor lives at a location which is different from where the inventor customarily receives mail) is required. If an ADS as set forth above is provided, the filing of the inventor's oath or declaration may be postponed until the application is otherwise in condition for allowance. See 37 CFR 1.53(f).
- Additional claim fees of $ **3240** as an undiscounted entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- Surcharge as set forth in 37 CFR 1.16(f) must be submitted.
  The surcharge is due for any one of:
  - late submission of the basic filing fee, search fee, or examination fee,
  - late submission of inventor's oath or declaration,
  - filing an application that does not contain at least one claim on filing, or
  - submission of an application filed by reference to a previously filed application.

SUMMARY OF FEES DUE:

The fee(s) required within **TWO MONTHS** from the date of this Notice to avoid abandonment is/are itemized below. No entity status discount is in effect. If applicant is qualified for small entity status, a written assertion of small entity status must be submitted to establish small entity status. (See 37 CFR 1.27). If applicant is qualified

for micro entity status, an acceptable Certification of Micro Entity Status must be submitted to establish micro entity status. (See 37 CFR 1.29 and forms PTO/SB/15A and 15B.)

- $ **280** basic filing fee.
- $ **140** surcharge.
- $ **600** search fee.
- $ **720** examination fee.
- $ **840** for **2** independent claims over 3.
- $ **2400** for **30** total claims over 20.
- $(**0**) previous unapplied payment amount.
- $ **4980** TOTAL FEE BALANCE DUE.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

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For more information about EFS-Web please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/vvan/

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/158,018	05/18/2016	3744	0.00	P36736B US	50	5

CONFIRMATION NO. 1036

29880
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FILING RECEIPT

OC000000083381629

Date Mailed: 06/06/2016

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

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Applicant(s)

Amsted Rail Company, Inc., Chicago, IL;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 13/842,427 03/15/2013 PAT 9365223
which claims benefit of 61/661,661 06/19/2012
and is a CIP of 12/861,713 08/23/2010 PAT 9026281

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 06/02/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/158,018**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No
Title

SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

Preliminary Class

062

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 15/158,018

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	600
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	50 minus 20 =	* 30			OR	x 80 =	2400
INDEPENDENT CLAIMS (37 CFR 1.16(h))	5 minus 3 =	* 2				x 420 =	840
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	4840

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/158,018	05/18/2016	Andrew H. Martin	P36736B US

CONFIRMATION NO. 1036

29880
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

FORMALITIES LETTER

OC00000083405872

Date Mailed: 06/06/2016

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
- The application search fee must be submitted.
- The application examination fee must be submitted.
- Additional claim fees of $ **3240** as an undiscounted entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- Surcharge as set forth in 37 CFR 1.16(f) must be submitted.
  The surcharge is due for any one of:
  - late submission of the basic filing fee, search fee, or examination fee,
  - late submission of inventor's oath or declaration,
  - filing an application that does not contain at least one claim on filing, or
  - submission of an application filed by reference to a previously filed application.

SUMMARY OF FEES DUE:

The fee(s) required within **TWO MONTHS** from the date of this Notice to avoid abandonment is/are itemized below. No entity status discount is in effect. If applicant is qualified for small entity status, a written assertion of small entity status must be submitted to establish small entity status. (See 37 CFR 1.27). If applicant is qualified for micro entity status, an acceptable Certification of Micro Entity Status must be submitted to establish micro entity status. (See 37 CFR 1.29 and forms PTO/SB/15A and 15B.)

- $ **280** basic filing fee.
- $ **140** surcharge.
- $ **600** search fee.
- $ **720** examination fee.
- $ **840** for **2** independent claims over 3.
- $ **2400** for **30** total claims over 20.

- $(**0**) previous unapplied payment amount.
- $ **4980** TOTAL FEE BALANCE DUE.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web, including a copy of this Notice and selecting the document description "Applicant response to Pre-Exam Formalities Notice". https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/vvan/

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 15/158,018

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
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MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	4840

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
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	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
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	Application Size Fee (37 CFR 1.16(s))									
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United States Patent and Trademark Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/158,018	05/18/2016	Andrew H. Martin	P36736B US

CONFIRMATION NO. 1036

29880
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

WITHDRAWAL NOTICE

OC000000083405828

Date Mailed: 06/06/2016

Letter Regarding a New Notice and/or the Status of the Application

If a new notice or Filing Receipt is enclosed, applicant may disregard the previous notice mailed on 06/06/2016. The time period for reply runs from the mail date of the new notice. Within the time period for reply, applicant is required to file a reply in compliance with the requirements set forth in the new notice to avoid abandonment of the application.

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web. https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

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If the reply is not filed electronically via EFS-Web, the reply must be accompanied by a copy of the new notice.

If the Office previously granted a petition to withdraw the holding of abandonment or a petition to revive under 37 CFR 1.137, the status of the application has been returned to pending status.

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/vvan/

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United States Patent and Trademark Office
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www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/158,018	05/18/2016	3744	0.00	P36736B US	50	5

CONFIRMATION NO. 1036

29880
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PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

FILING RECEIPT

OC000000083405871

Date Mailed: 06/06/2016

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Andrew H. Martin, West Chester, PA;
William D. LeFebvre, West Chester, PA;
Brent M. Wilson, Edwardsville, IL;

Applicant(s)

Amsted Rail Company, Inc., Chicago, IL;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 13/842,427 03/15/2013 PAT 9365223
which claims benefit of 61/661,661 06/19/2012
and is a CIP of 12/861,713 08/23/2010 PAT 9026281

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Title 37, Code of Federal Regulations, 5.11 & 5.15

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The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: A. Martin	Group Art Unit: Unknown
Application No: 15/158,018	Examiner: Unknown
Filing Date: 5/18/2016	Attorney Docket: P36736B US
For: System and Method for Monitoring Railcar Performance	Customer No. 29880
	Confirmation No: 1036

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PRELIMINARY AMENDMENT FILED WITH MISSING PARTS

Sir:

This is in response to the missing parts requirement of 6/06/2016. New drawings were previously filed. Filing fees are filed herewith.

Please amend the above-identified application as follows:

Amendments to the claims are reflected in the listings of claims which begin on page 2 of this paper.

Remarks begin on page 5.

11/10/2016 JVONG1 00000003 501943 15158018
05 FC:1252 600.00 DA

11/10/2016 JVONG1 00000003 501943 15158018
01 FC:1011 200.00 DA
02 FC:1111 600.00 DA
03 FC:1311 720.00 DA
04 FC:1051 140.00 DA

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claims 1-36 (canceled)

Claim 37 (original): A method of monitoring operational characteristics of a railcar comprising the steps of:

a. receiving data or processed information regarding said operational characteristic from one or more sensing units on said railcar, said sensing units monitoring an operational characteristic of said railcar;

b. applying a heuristic to said received data to determine deviations from nominal operating conditions;

c. assigning a severity level to said deviations from nominal operating conditions; and

d. determining an alarm condition based on said assigned severity level.

Claim 38 (original): The method of claim 37 further comprising the initial step of establishing wireless communication with said one or more remote sensing units.

Claim 39 (original): The method of claim 38 wherein said one or more remote sensing units form a mesh network.

Claim 40 (original): The method of claim 38 wherein steps a-d are executed by a processing unit located on said railcar.

PAGE 4/7 * RCVD AT 11/7/2016 5:19:25 PM [Eastern Standard Time] * SVR:W-PTOFAX-001/5 * DNIS:2738300 * CSID:Fox Rothschild LLP * DURATION (mm-ss):03-31

Claim 41 (original): The method of claim 40 wherein said processing unit located on said railcar is a part of said mesh network.

Claim 42 (original): The method of claim 38 further comprising the step of transmitting said alarm condition to a location remote from said railcar.

Claim 43 (original): The method of claim 38 further comprising the step of transmitting said data received from said one or more sensing units to a location remote from said railcar.

Claim 44 (original): The method of claim 38 further comprising the steps of:

a. receiving data from a plurality of railcars;

b. applying a heuristic to said received data to determine deviations from nominal operating conditions;

c. assigning a severity level to said deviations from nominal operating conditions;

d. determining an alarm condition based on said assigned severity level;

e. transmitting said raised alarm to a display unit on a train of which said plurality of railcars are a part.

Claim 45 (original): The method of claim 42 further comprising the steps of

a. determining a recommended course of action based on said alarm condition;

and

b. transmitting said recommended course of action to a display unit on a train of which said railcar is a part.

Claim 46 (original): The method of claim 1 wherein said one or more remote sensors are temperature sensors.

Claim 47 (original): A method of monitoring a temperature of a desired part of a railcar, comprising:

PAGE 5/7 * RCVD AT 11/7/2016 5:19:25 PM [Eastern Standard Time] * SVR:W-PTOFAX-001/5 * DNIS:2738300 * CSID:Fox Rothschild LLP * DURATION (mm-ss):03-31

(a) sensing the temperature of a part of the railcar other than the desired part by use of a temperature sensor in thermal communication with said other part;

(b) determining the temperature of the desired part by use of the temperature sensed in step (a);

(c) determining if said temperature of the desired part is outside an acceptable range of temperatures; and

(d) transmitting an alarm if in step (c) it is determined that the temperature of the desired part is outside an acceptable range.

Claim 48 (original): A method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, further comprising the step of determining the temperature of the ambient air, which temperature is used in the determination of step (b).

Claim 49 (original): A method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, wherein steps (a) through (d) are carried out by a single unit attached to said railcar.

Claim 50 (original): The method of claim 37 wherein steps (a) through (d) can be carried out at different event engines distributed among at least two of said sensor unit, a communication management unit, and a mobile or land base station.

PAGE 6/7 * RCVD AT 11/7/2016 5:19:25 PM [Eastern Standard Time] * SVR:W-PTOFAX-001/5 * DNIS:2738300 * CSID:Fox Rothschild LLP * DURATION (mm-ss):03-31

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15/158,018 Attorney Docket: P36736B US
Preliminary Amendment

Remarks

Applicant requests that the required fees – filing, search, examination, extensions of time and surcharge for late filing – be charged to Deposit Account 50-1943.

Applicant reserves all rights to prosecute the canceled claims in this application or a continuation application.

Respectfully submitted,

November 7, 2016 /gah/

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GAH/dsg

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I certified that this correspondence is being facsimile transmitted to the U.S. Patent and Trademark Office on November 7, 2016 at 571-273-8300.

November 7, 2016 Sherry L. Barag

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Serial No. 15/158,018 - Confirmation1036	15712738300	Barag, Sherry

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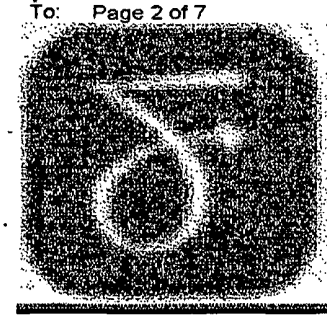
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Sherry
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/158,018	05/18/2016	3744	1740	037659.00062 (P36736B US)	14	2

CONFIRMATION NO. 1036

UPDATED FILING RECEIPT

29880
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

OC000000087255853

Date Mailed: 11/17/2016

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Andrew H. Martin, West Chester, PA;
William D. LeFebvre, West Chester, PA;
Brent M. Wilson, Edwardsville, IL;

Applicant(s)

Amsted Rail Company, Inc., Chicago, IL;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 13/842,427 03/15/2013 PAT 9365223
which claims benefit of 61/661,661 06/19/2012
and is a CIP of 12/861,713 08/23/2010 PAT 9026281

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 06/02/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/158,018**

Projected Publication Date: 02/23/2017

Non-Publication Request: No

Early Publication Request: No
Title

SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

Preliminary Class

062

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 15/158,018

APPLICATION AS FILED - PART I

	(Column 1)	(Column 2)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE($)	FEE($)		RATE($)	FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	600
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	14 minus 20 =	*			OR	x 80 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*				x 420 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1600

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1)		(Column 2)	(Column 3)					
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: **A. Martin**	Group Art Unit: **3744**
Application No: **15/158,018**	Examiner: **Unknown**
Filing Date: **5/18/2016**	Attorney Docket: **P36736B US**
For: **System and Method for Monitoring Railcar Performance**	Customer No. **29880**
	Confirmation No: **1036**

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

SECOND PRELIMINARY AMENDMENT

Sir:

This is supplemental to the Preliminary Amendment Filed with Missing Parts filed 11/07/2016 in the above-referenced case.

Please amend the above-identified application as follows:

Amendments to the claims begin on page 2.

Remarks begin on page 7.

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claims 1-36 (canceled)

Claim 37 (original): A method of monitoring operational characteristics of a railcar comprising the steps of:

a. receiving data or processed information regarding said operational characteristic from one or more sensing units on said railcar, said sensing units monitoring an operational characteristic of said railcar;

b. applying a heuristic to said received data to determine deviations from nominal operating conditions;

c. assigning a severity level to said deviations from nominal operating conditions; and

d. determining an alarm condition based on said assigned severity level.

Claim 38 (original): The method of claim 37 further comprising the initial step of establishing wireless communication with said one or more remote sensing units.

Claim 39 (original): The method of claim 38 wherein said one or more remote sensing units form a mesh network.

Claim 40 (original): The method of claim 38 wherein steps a-d are executed by a processing unit located on said railcar.

Claim 41 (original): The method of claim 40 wherein said processing unit located on said railcar is a part of said mesh network.

Claim 42 (original): The method of claim 38 further comprising the step of transmitting said alarm condition to a location remote from said railcar.

Claim 43 (original): The method of claim 38 further comprising the step of transmitting said data received from said one or more sensing units to a location remote from said railcar.

Claim 44 (original): The method of claim 38 further comprising the steps of:

a. receiving data from a plurality of railcars;

b. applying a heuristic to said received data to determine deviations from nominal operating conditions;

c. assigning a severity level to said deviations from nominal operating conditions;

d. determining an alarm condition based on said assigned severity level;

e. transmitting said raised alarm to a display unit on a train of which said plurality of railcars are a part.

Claim 45 (original): The method of claim 42 further comprising the steps of

a. determining a recommended course of action based on said alarm condition;

and

b. transmitting said recommended course of action to a display unit on a train of which said railcar is a part.

Claim 46 (canceled)

Claim 47 (original): A method of monitoring a temperature of a desired part of a railcar, comprising:

(a) sensing the temperature of a part of the railcar other than the desired part by use of a temperature sensor in thermal communication with said other part;

(b) determining the temperature of the desired part by use of the temperature sensed in step (a);

(c) determining if said temperature of the desired part is outside an acceptable range of temperatures; and

(d) transmitting an alarm if in step (c) it is determined that the temperature of the desired part is outside an acceptable range.

Claim 48 (original): A method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, further comprising the step of determining the temperature of the ambient air, which temperature is used in the determination of step (b).

Claim 49 (original): A method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, wherein steps (a) through (d) are carried out by a single unit attached to said railcar.

Claim 50 (original): The method of claim 37 wherein steps (a) through (d) can be carried out at different event engines distributed among at least two of said sensor unit, a communication management unit, and a mobile or land base station.

Claim 51 (new): A method for monitoring the operation of a railcar performed by a communication management unit disposed on said railcar comprising the steps of:

a. wirelessly receiving data from one or more sensing units which periodically collect readings from one or more sensors disposed on said railcar;

b. heuristically analyzing said received data to determine if an actual failure exists on said railcar or to predict potential or imminent failures based on a statistical analysis of said received data; and

c. communicating the results of said analysis to an off-railcar location.

Claim 52 (new): The method of claim 51 wherein each of said sensing units can make a determination of an alarm condition based on data collected by the sensing unit, said method further comprising the step of:

a. wirelessly receiving notice of said alarm condition from said sensing unit; and

b. communicating said alarm condition to an off-railcar location.

Claim 53 (new): The method of claim 51 further comprising the steps of:

a. making a determination of an alarm condition based on data received from two or more of said sensing units; and

b. communicating said alarm condition to an off-railcar location.

Claim 54 (new): The method of claim 51 further comprising the step of placing said one or more sensing units in a stand-by state when said one or more sensing units is not reading data from any of said sensors or transmitting data.

Claim 55 (new): The method of claim 51 further comprising the step of joining a mesh network consisting of one or more sensing units located on said railcar.

Claim 56 (new): The method of claim 51 further comprising the step of joining a mesh network consisting of communication management units located on other railcars.

Claim 57 (new): The system of claim 51 further comprising the steps of:

a. saving data received from said one or more sensing units in memory; and

b. comparing data received with said saved data to identify trends or deviations from normal readings of said data stored in memory.

Claim 58 (new): A method for monitoring the operation of a railcar comprising:

a. collecting data at periodic intervals about one or more operating parameters of said railcar using one or more sensor units provided on said railcar;

b. communicating said collected data to a communication management unit;

c. analyzing said collected data by applying heuristics thereto to (i) determine if an actual failure exists and (ii) to predict potential or imminent failures based on a statistical analysis of said collected data.

Claim 59 (new): The method of claim 58 further comprising the steps of:

assessing the collected data to determine if an alarm condition exists; and

wirelessly communicating said alarm condition to an off railcar location.

Remarks

The amendments are supported by the specification and claims as originally filed, and thus no new matter is added. Applicant requests entry of the amendments to the claims prior to the initial examination of the application.

Respectfully submitted,

January 5, 2017

/gah/

Gary Hecht
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Dennis M. Carleton
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Attorneys for Applicant

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Email: ghecht@foxrothschild.com

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POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:

☒ Practitioners associated with Customer Number: 29880

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignments documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:

☐ The address associated with Customer Number:

OR

☐	Firm or Individual Name		
	Address		
	City	State	Zip
	Country		
	Telephone	Email	

Assignee Name and Address: Amsted Rail Company, Inc.
311 South Wacker Drive
Chicago, IL 60602

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of the practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature	Edward J Brosius	Date	4-30-2015
Name	Edward Brosius	Telephone	312-819-8482
Title	SECRETARY		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: A. Martin et al.

Application No./Patent No.: 15/158,018 Filed/Issue Date: 05-18-2016

Titled: SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

AMSTED RAIL COMPANY, INC., a CORPORATION

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

   ☐ The extent (by percentage) of its ownership interest is _____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☑ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel 038113, Frame 0048, or for which a copy thereof is attached.

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

   1. From: _____ To: _____

      The document was recorded in the United States Patent and Trademark Office at

      Reel _____, Frame _____, or for which a copy thereof is attached.

   2. From: _____ To: _____

      The document was recorded in the United States Patent and Trademark Office at

      Reel _____, Frame _____, or for which a copy thereof is attached.

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

4. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

5. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

6. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☐ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/gah/	01-05-2016
Signature	Date
Gary A. Hecht	36,826
Printed or Typed Name	Title or Registration Number

[Page 2 of 2]

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Patent Application Fee Transmittal

Application Number:	15158018
Filing Date:	18-May-2016
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Filer:	Gary A. Hecht/Patricia Frisoli
Attorney Docket Number:	037659.00062 (P36736B US)

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
CLAIMS IN EXCESS OF 20	1202	2	80	160
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**160**

Electronic Acknowledgement Receipt

EFS ID:	27975154
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht/Patricia Frisoli
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	037659.00062 (P36736B US)
Receipt Date:	05-JAN-2017
Filing Date:	18-MAY-2016
Time Stamp:	10:19:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$160
RAM confirmation Number	010517INTEFSW10201600
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Second_Preliminary_Amendment_.pdf	37442 916f832a72099173b65796e875fbe8c4272bc647	yes	7

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Preliminary Amendment	1	1
	Claims	2	6
	Preliminary Amendment	7	7

Warnings:					
Information:					
2	Power of Attorney	Power_of_Attorney.pdf	329135 2f8b651c72396dead2c8d8f08113c82c4f77a6fb	no	1
Warnings:					
Information:					
3	Assignee showing of ownership per 37 CFR 3.73	Statement_under_3_73c.pdf	158812 7bbdf94517d68b81276726d3e0396849c69f5bfa	no	3
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	30560 209a06d402e9bcdde81c1e036514d9a9b83b0271	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	555949		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Acknowledgement Receipt

EFS ID:	27975154
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht/Patricia Frisoli
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	037659.00062 (P36736B US)
Receipt Date:	05-JAN-2017
Filing Date:	18-MAY-2016
Time Stamp:	10:19:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$160
RAM confirmation Number	010517INTEFSW10201600
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Second_Preliminary_Amendment_.pdf	37442 916f832a72099173b65796e875fbe8c4272bc647	yes	7
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Preliminary Amendment		1	1	
	Claims		2	6	
	Preliminary Amendment		7	7	
Warnings:					
Information:					
2	Power of Attorney	Power_of_Attorney.pdf	329135 2f8b651c72396dead2c8d8f08113c82c4f77a6fb	no	1
Warnings:					
Information:					
3	Assignee showing of ownership per 37 CFR 3.73	Statement_under_3_73c.pdf	158812 7bbdf94517d68b81276726d3e0396849c69f5bfa	no	3
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	30560 209a06d402e9bcdde81c1e036514d9a9b83b0271	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	555949		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

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New International Application Filed with the USPTO as a Receiving Office

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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/158,018	05/18/2016	Andrew H. Martin	037659.00062 (P36736B US)

CONFIRMATION NO. 1036

29880
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

POA ACCEPTANCE LETTER

OC000000088346503

Date Mailed: 01/09/2017

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 01/05/2017.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/cnguyen/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/158,018	05/18/2016	Andrew H. Martin	037659.00062 (P36736B US)

CONFIRMATION NO. 1036

29880
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

PUBLICATION NOTICE

OC000000089420196

Title:SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

Publication No.US-2017-0050651-A1
Publication Date:02/23/2017

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4436423

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
ANDREW MARTIN	03/17/2016
WILLIAM D. LEFEBVRE	03/23/2016
BRENT M. WILSON	03/10/2016

RECEIVING PARTY DATA

Name:	AMSTED RAIL COMPANY, INC.
Street Address:	311 S. WACKER, SUITE 5300
City:	CHICAGO
State/Country:	ILLINOIS
Postal Code:	60606

PROPERTY NUMBERS Total: 1

Property Type	Number
Application Number:	15158018

CORRESPONDENCE DATA

Fax Number: (312)819-8484

Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.

Phone: 312-819-8482
Email: ebrosius@amsted.com
Correspondent Name: EDWARD J. BROSIUS
Address Line 1: 180 N. STETSON AVE., SUITE 1800
Address Line 2: TWO PRUDENTIAL PLAZA
Address Line 4: CHICAGO, ILLINOIS 60601

NAME OF SUBMITTER:	EDWARD J. BROSIUS
SIGNATURE:	/EDWARD J. BROSIUS/
DATE SIGNED:	05/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 5
source=1-1#page1.tif
source=1-1#page2.tif
source=1-1#page3.tif

source=1-1#page4.tif
source=1-1#page5.tif

ASSIGNMENT AND AGREEMENT
Joint Inventors

WHEREAS, **Andrew Martin**, County of Chester, State of Pennsylvania, **William D. LeFebvre**, County of Chester, State of Pennsylvania, and **Brent M. Wilson**, County of Madison, State of Illinois, hereinafter called the "Assignors", have invented certain new and useful improvements in a **SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE** for a full description of which reference is here made to an application for Letters Patent of the United States identified as attorney's **Case No. IX007 and U.S. Patent Application No.: 13/842427**, and

WHEREAS, Amsted Rail Company, Inc., a corporation organized and existing under the laws of the State of Delaware, having an office and place of business at 311 S. Wacker, Suite 5300, Chicago, Illinois 60606, hereinafter called the "Assignee", is desirous of acquiring the entire right, title and interest in and to said invention, the application above identified, and in, to and under Letters Patent which may be obtained for said invention, as hereinafter more fully set forth.

NOW, THEREFORE, TO ALL WHOM IT MAY CONCERN, be it known that for and in consideration of the sum of One Dollar ($1.00), and other valuable and legally sufficient considerations, the receipt of which by the said Assignors from the said Assignee is hereby acknowledged, the said Assignors have sold, assigned and transferred, and by these presents do sell, assign and transfer unto the said Assignee, and its successors, assigns, and legal representatives, the entire right, title and interest for the United States in and to the invention and application herein identified, and any Letters Patent of the United States that may issue for said invention, together with the entire right, title and interest in and to said invention and application

for Letters Patent and Letters Patent therefor in all countries foreign to the United States; to have and to hold for the sole and exclusive use and benefit of the said Assignee, its successors, assigns and legal representatives, to the full end of the term or terms for which any and all of said Letters Patent for said invention may issued.

And the said Assignors do hereby covenant and agree, for themselves and their legal representatives, that they will assist their said Assignee in the prosecution of the application herein identified; in the making and prosecution of any other application for Letters Patent that the said Assignee may elect to make covering the invention herein identified, as hereinbefore set forth; in vesting in the said Assignee like exclusive title in and to all such other applications and Letters Patent; and in the prosecution of any interference which may arise involving said invention, or any application or Letters Patent herein contemplated; and that they will execute and deliver to the said Assignee any and all additional papers which may be requested by the said Assignee to fully carry out the terms of this Assignment.

And the said Assignors do hereby covenant with said Assignee, its successors, assigns and legal representatives that the rights and property herein conveyed are free and clear of any adverse assignment, grant, mortgage, license or other encumbrance, and that they have the full right to convey to the same in manner and form as herein expressed.

IN TESTIMONY WHEREOF, the said Assignor has hereunto set his hand on this 17 day of March, 2016.

Andrew Martin

STATE OF Pennsylvania)
) ss.
COUNTY OF Chester)

I, Debra J Winkler, a Notary Public in and for the County and State aforesaid, do hereby certify that Andrew Martin personally known to me to be the same person whose name is subscribed to the foregoing instrument, appeared before me this day in person and acknowledged that he signed and delivered the said instrument as his free and voluntary act for the uses and purposes therein set forth.

IN WITNESS WHEREOF, I have hereunto set my hand and Notarial Seal this 17 day of March, 2016.

Notary Public

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Debra J Winkler, Notary Public
West Chester Borough, Chester County
My Commission Expires February 17, 2017

IN TESTIMONY WHEREOF, the said Assignor has hereunto set his hand on this _____ day of 23 March, 2016.

William D. LeFebvre

STATE OF Pennsylvania)
) ss.
COUNTY OF Chester)

I, Debra J Winkler, a Notary Public in and for the County and State aforesaid, do hereby certify that William D. LeFebvre personally known to me to be the same person whose name is subscribed to the foregoing instrument, appeared before me this day in person and acknowledged that he signed and delivered the said instrument as his free and voluntary act for the uses and purposes therein set forth.

IN WITNESS WHEREOF, I have hereunto set my hand and Notarial Seal this 23rd day of March, 2016.

Debra J Winkler
Notary Public

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Debra J Winkler, Notary Public
West Chester Borough, Chester County
My Commission Expires February 17, 2017

IN TESTIMONY WHEREOF, the said Assignor has hereunto set his hand on this ____ day of 10 MAR, 2016.

Brent M. Wilson

STATE OF Illinois)
) ss.
COUNTY OF Madison)

I, Christine Cummins, a Notary Public in and for the County and State aforesaid, do hereby certify that Brent M. Wilson personally known to me to be the same person whose name is subscribed to the foregoing instrument, appeared before me this day in person and acknowledged that he signed and delivered the said instrument as his free and voluntary act for the uses and purposes therein set forth.

IN WITNESS WHEREOF, I have hereunto set my hand and Notarial Seal this 10 day of March, 2016.

Notary Public

"OFFICIAL SEAL"
Christine Cummins
Notary Public, State of Illinois
My Commission Expires 10/7/2017

RECORDED: 03/28/2016

PATENT
REEL: 038113 FRAME: 0054

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/158,018	05/18/2016	Andrew H. Martin	037659.00062 (P36736B US)	1036

29880 7590 06/29/2017

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

EXAMINER	
SOOFI, YAZAN A	

ART UNIT	PAPER NUMBER
3668	

NOTIFICATION DATE	DELIVERY MODE
06/29/2017	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocket@foxrothschild.com

Office Action Summary	Application No. 15/158,018	Applicant(s) MARTIN ET AL.	
	Examiner YAZAN SOOFI	Art Unit 3668	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *05/18/2016*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *37-45 and 47-59* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *37-45 and 47-59* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *05/18/2016* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

DETAILED ACTION

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions

Status of Claims

Claims 37-45 and 47-59 of U.S. Application No.15158018 filed on 05/18/2016.

Claim Rejections - 35 USC § 103

1. The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

2. Claims **37-45 and 47-59** are rejected under 35 U.S.C. 103(a) as being unpatentable over **Searle et al [US 2008/0195265 A1]**, hereinafter referred to as Searle, in view of **Baker [US 6,339,397]**, hereinafter referred to as Baker.

As to **claims 37, 44 and 51**, Searle discloses a method of monitoring operational characteristics of a railcar comprising the steps of:

a. receiving data or processed information regarding said operational characteristic from one or more sensing units on said railcar, said sensing units monitoring an operational characteristic of said railcar **([see at least 0072 and 104], " There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the**

wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.").;

b. applying a heuristic to said received data to determine deviations from nominal operating conditions **([see at least 0072 and 104], "There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis."**);

Searle does not explicitly disclose wherein determining high level alarms based on data and alarms collected from said communication management unit. Searle in view of official notice does disclose collecting data and alarm from said communication management unit and displaying alarm condition. However Baker teaches determining high level alarms based on data and alarms collected from said communication management unit **([see at least column 5, lines 1-10], "data is transmitted in digital form from the receiver to the microprocessor 84. This**

information includes latitude, longitude, heading, velocity, time, and elevation. Other defined data inputs such as multiple alarm states, high and low priority alarm alerts, and miscellaneous external measurements may be programmed into micro controller 84 through the user defined status inputs designated generally at 90."). Both Searle illustrate similar methods in which monitor railcar parameters. Baker does disclose activating, monitoring, controlling and communicating based on sensed data, but does don't detail an alarm condition being communicated. Baker is introduced to teach determining high level alarms based on data and alarms collected from said communication management unit.

It would have been obvious to one of ordinary skill in the art at the time the invention to modify the invention of Searle in view of official notice, to incorporate determine an alarm level, as taught by Baker, for the purpose improving monitoring of railcars if an incident occurs, the device will alert needed personal.

As to **claims 38**, Searle discloses a method, further comprising the initial step of establishing wireless communication with said one or more remote sensing units **([see at least 0080, 0099 and 0116], "The core of the TINS is a RF/Digital wireless communications backbone which links the monitoring and processing hardware and software of the bogie units with the server and each other. The units are installed on each end of a bogie and monitor a range of parameters which detect the above conditions...").**

As to **claims 39**, Searle discloses a method, wherein said one or more remote sensing units form a mesh network. **([see at least 0115], is a schematic of the six components of the**

server namely a network protocol parser and generator, a service layer, an automatic network control and data gathering, real time trending, data storage and trending and a user interface. The protocol generator and parser generates request packets for the data radio and parses response packets for the service layer to interpret. The service layer provides individual status of the wheel with alarm reporting, individual status of the wheel without alarm reporting, and network status and alarm reporting on the entire network").

As to **claims 40**, Searle discloses a method, wherein steps a-d are executed by a processing unit located on said railcar **([see at least 0072-0082], "If a monitored condition exceeds a predetermined threshold or parameter the processor will generate an alarm which is transmitted via a RF network to the server")**.

As to **claims 41**, Searle discloses a method, wherein said processing unit located on said railcar is a part of said mesh network. **([see at least Fig. 2, 0080, 0099 and 0116], "The core of the TINS is a RF/Digital wireless communications backbone which links the monitoring and processing hardware and software of the bogie units with the server and each other. The units are installed on each end of a bogie and monitor a range of parameters which detect the above conditions...").**

As to **claims 42 and 52**, Searle discloses a method, further comprising the step of transmitting said alarm condition to a location remote from said railcar **([see at least Fig. 2, 0072, 0080 and 104], "There are two temperature sensors, one for sensing the temperature**

of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.").

As to **claims 43 and 53**, Searle discloses a method, further comprising the step of transmitting said data received from said one or more sensing units to a location remote from said railcar **([see at least Fig. 2, 0072, 0080 and 104], "There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.")**.

As to **claims 45**, Searle discloses a method, further comprising the steps of a. determining a recommended course of action based on said alarm condition;
and b. transmitting said recommended course of action to a display unit on a train of which said railcar is a part **([see at least 0072, 0166 and 0171], "If a monitored condition exceeds a predetermined threshold or parameter the processor will generate an alarm which is transmitted via a RF network to the server. The server then notifies the driver via a control console, of the specific exception, including the condition, the position of the bogie in the train consist, the last ten minutes of trend information and a menu of corrective actions to be taken.")**

As to **claims 47**, Searle discloses a method of monitoring a temperature of a desired part of a railcar, comprising: (a) sensing the temperature of a part of the railcar other than the desired part by use of a temperature sensor in thermal communication with said other part; (b) determining the temperature of the desired part by use of the temperature sensed in step (a); (c) determining if said temperature of the desired part is outside an acceptable range of temperatures; and (d) transmitting an alarm if in step (c) it is determined that the temperature of the desired part is outside an acceptable range **([see at least 0072 and 104], "There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-**

pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.").

As to **claims 48**, Searle discloses a method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, further comprising the step of determining the temperature of the ambient air, which temperature is used in the determination of step (b). **([see at least 0072 and 104], "There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.")**.

As to **claims 49**, Searle discloses a method monitoring a temperature of a desired part of a railcar in accordance with claim 47, wherein steps (a) through (d) are carried out by a single unit attached to said railcar **([see at least 0072 and 104], "There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by**

infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.").

As to **claims 50**, Searle discloses a method wherein steps (a) through (d) can be carried out at different event engines distributed among at least two of said sensor unit, a communication management unit, and a mobile or land base station **([see at least 0072 and 104], "There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.")**..

As to **claims 54**, Baker discloses a method further comprising the step of placing said one or more sensing units in a stand-by state when said one or more sensing units is not reading data

from any of said sensors or transmitting data **([see at least column 5, lines 23-32], "In order to extend the life and reduce required power of tracking unit 10, the micro controller, GPS receiver, and transmitter 92 are maintained in an "off" condition until periodically "awakened" with an "alarm condition" or a periodic "wake up" signal from a clock. Clock 94 is a very low powered timing circuit. Thus, only the clock is powered during "idle" periods, vastly reducing the power required to run the unit and enabling the unit to operate using small solar panels which recharge small storage batteries").**

As to **claims 55**, Searle discloses a method further comprising the step of joining a mesh network consisting of one or more sensing units located on said railcar **([see at least 0115], is a schematic of the six components of the server namely a network protocol parser and generator, a service layer, an automatic network control and data gathering, real time trending, data storage and trending and a user interface. The protocol generator and parser generates request packets for the data radio and parses response packets for the service layer to interpret. The service layer provides individual status of the wheel with alarm reporting, individual status of the wheel without alarm reporting, and network status and alarm reporting on the entire network").**

As to **claims 56**, Searle discloses a method further comprising the step of joining a mesh network consisting of communication management units located on other railcar **([see at least 0115], is a schematic of the six components of the server namely a network protocol parser and generator, a service layer, an automatic network control and data gathering, real time**

trending, data storage and trending and a user interface. The protocol generator and parser generates request packets for the data radio and parses response packets for the service layer to interpret. The service layer provides individual status of the wheel with alarm reporting, individual status of the wheel without alarm reporting, and network status and alarm reporting on the entire network").

As to **claims 57**, Searle discloses a method further comprising the steps of:

a. saving data received from said one or more sensing units in memory (**[see at least 0073]**); and

b. comparing data received with said saved data to identify trends or deviations from normal readings of said data stored in memory **([see at least 0072 and 104], "There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.")**..

As to **claims 58**, Brake discloses a method for monitoring the operation of a railcar comprising:

a. collecting data at periodic intervals about one or more operating parameters of said railcar using one or more sensor units provided on said railcar; b. communicating said collected data to

a communication management unit**([see at least column 5, lines 23-32], "In order to extend the life and reduce required power of tracking unit 10, the micro controller, GPS receiver, and transmitter 92 are maintained in an "off" condition until periodically "awakened" with an "alarm condition" or a periodic "wake up" signal from a clock. Clock 94 is a very low powered timing circuit. Thus, only the clock is powered during "idle" periods, vastly reducing the power required to run the unit and enabling the unit to operate using small solar panels which recharge small storage batteries")** and Searle teaches c. analyzing said collected data by applying heuristics thereto to (i) determine if an actual failure exists and (ii) to predict potential or imminent failures based on a statistical analysis of said collected data **([see at least 0072, 0104, 0166 and 0171], "There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.")**..

As to **claims 57**, Searle discloses a method further comprising the steps of:

assessing the collected data to determine if an alarm condition exists; and

wirelessly communicating said alarm condition to an off railcar location. **([see at least Fig. 2, 0080, 0099 and 0116], "The core of the TINS is a RF/Digital wireless communications backbone which links the monitoring and processing hardware and software of the bogie units with the server and each other. The units are installed on each end of a bogie and monitor a range of parameters which detect the above conditions...").**

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to YAZAN SOOFI whose telephone number is (313)446-6632. The examiner can normally be reached on Flex.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Fadey Jabr can be reached on (571) 272-1516. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/YAZAN SOOFI/
Primary Examiner, Art Unit 3668

Notice of References Cited	Application/Control No. 15/158,018	Applicant(s)/Patent Under Reexamination MARTIN ET AL.	
	Examiner YAZAN SOOFI	Art Unit 3668	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-6,339,397 B1	01-2002	Baker; David A.	B61L25/021	342/357.64
*	B	US-2013/0342362 A1	12-2013	Martin; Andrew	B61L15/0027	340/870.16
*	C	US-2008/0195265 A1	08-2008	Searle; Donald Stephen	B61K9/04	701/19
	D	US-				
	E	US-				
	F	US-				
	G	US-				
	H	US-				
	I	US-				
	J	US-				
	K	US-				
	L	US-				
	M	US-				

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15158018	MARTIN ET AL.
	Examiner	Art Unit
	YAZAN SOOFI	3668

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	06/24/2017								
	37	✓								
	38	✓								
	39	✓								
	40	✓								
	41	✓								
	42	✓								
	43	✓								
	44	✓								
	45	✓								
	46	-								
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	56	✓								
	57	✓								
	58	✓								
	59	✓								

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L25	99	"6339397"	USPAT	OR	OFF	2017/06/24 14:20
L26	20	((sensor or sensing) with railcar with temperature) and (remote) and network and alarm	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/06/24 14:25
L27	2	"20080195265"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/06/24 15:03
S1	1	(13/842427).APP.	US-PGPUB; USPAT	OR	OFF	2014/09/18 09:58
S2	0	("andrewnear1martin").PN.	US-PGPUB; USPAT	OR	OFF	2014/09/18 09:59
S3	670	andrew near1 martin	US-PGPUB; USPAT	OR	ON	2014/09/18 09:59
S4	7	S3 and railcar	US-PGPUB; USPAT	OR	ON	2014/09/18 09:59
S5	546	lat?lon	US-PGPUB; USPAT	OR	ON	2014/10/28 16:10
S6	63	S5 and (railcar or train)	US-PGPUB; USPAT	OR	ON	2014/10/28 16:10
S7	3	S5 and (railcar or train) and (temperature near1 sensor)	US-PGPUB; USPAT	OR	ON	2014/10/28 16:10
S8	19667	(railcar or train) and (temperature near1 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:12
S9	3308	(railcar or train) and (temperature near1 sensor) and magnet	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:13
S10	1695	S9 and wireless	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2014/10/28 16:13

			EPO; JPO; DERWENT; IBM_TDB			
S11	985	S10 and alarm	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:13
S12	887	S11 and memory	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:13
S13	524	S12 and mesh	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:14
S14	489	S13 and (satellite or cellular)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:15
S15	66010	(temperature near3 threshold)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:15
S16	144	S14 and (temperature near3 threshold)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:15
S17	0	S16 and (mount near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:18
S18	1	S16 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:18
S19	1	S13 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT;	OR	ON	2014/10/28 16:18

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S20	7	S10 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:18
S21	2160	(railcar or train) and (temperature near1 sensor) and (temperature near3 threshold)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S22	2000833	18and wireless	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S23	793	S21 and wireless	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S24	691	S23 and memory	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S25	9	S24 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S26	3	S5 and (railcar or train) and (temperature near3 sensor)	US-PGPUB; USPAT	OR	ON	2014/10/28 16:22
S27	3	S5 and (railcar or train) and (temperature near3 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:22
S28	57	microstrain and (railcar or train) and (temperature near3 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2014/10/28 16:24

			DERWENT; IBM_TDB			
S29	1	S28 and (temperature near3 threshold)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:24
S30	4	"12154641"	US-PGPUB; USPAT	OR	ON	2014/10/28 16:27
S31	286	(strain near2 sensor) and (temperature near2 sensor) and (pressure near2 sensor)and (load near2 sensor)and (magnetic near2 sensor)and (vibration near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:53
S32	1	S31 and piezio	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:53
S33	68	piezoresistive near2 microphone	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:54
S34	1	S31 and S33	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:54
S35	5	S33 and train	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:54
S36	5	LAT-LON near2 LLC	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:37
S37	113	LAT-LON	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:38

S38	348764	2and (railcar or train)	US-PGPUB; USPAT	OR	ON	2014/10/29 08:38
S39	3	S37 and (railcar or train)	US-PGPUB; USPAT	OR	ON	2014/10/29 08:38
S40	10	S37 and (railcar or train)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:39
S41	1	S40 and alarm	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:45
S42	0	S41 and sensor	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:46
S43	10	S37 and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:52
S44	4233	(railcar or train or locomotive) near3 monitoring	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:52
S45	296	S44 and(temperature near1 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:52
S46	15	S45 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:53
S47	2	railrider	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:58

S48	1	"13842427"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 09:19
S49	4	"8244411"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 09:40
S50	2	"12861713"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 09:44
S51	1	"13842427"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 09:45
S52	0	(vibration near2 sensor) and (hand? brake near4 sensor) and (load near2 cell near3 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:50
S53	0	(vibration near2 sensor) and (hand? brake near4 sensor) and (load near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:50
S54	49244	(vibration near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:50
S55	11	(hand?brake near4 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S56	478	S54 and (brake near3 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2014/10/29 12:51

			DERWENT; IBM_TDB			
S57	174	S56 and(load near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S58	104	S57 and(hall near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S59	96	S58 and(pressure near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S60	98	S58 and(strain near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S61	96	S59 and(strain near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S62	96	S59 and(temperaturenear2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S63	96	S61 and(temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S64	96	S63 and(acceleration)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S65	95	S63 and(gyroscope)	US-PGPUB; USPAT; USOCR;	OR	ON	2014/10/29 12:53

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S66	0	S63 and(peizio)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:53
S67	95	S63 and(resistive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:53
S68	96	S63 and(microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:53
S69	1	S63 and(resistive near2 microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:54
S70	1	S68 and railcar	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:54
S71	95	S68 and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:54
S72	1	S68 and (railcar or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:57
S73	0	((peizioresistive or peizo) near2 microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:57
S74	0	(piezioresistive near2 microphones)	US-PGPUB;	OR	ON	2014/10/29

			USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			12:58
S75	4	((piezioresistive or piezio) near2 microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:58
S76	4	((piezioresistive or piezio) near3 microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:59
S77	7344	high near2 alarm	US-PGPUB; USPAT	OR	ON	2014/10/29 14:14
S78	338	(high near2 alarm) and(temperature near3 threshold)	US-PGPUB; USPAT	OR	ON	2014/10/29 14:17
S79	42	S78 and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 14:17
S80	1	S78 and (railcar or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 14:19
S81	32	S77 and (railcar or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 14:20
S82	1717	(701/19).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:08
S83	0	S78 and S82	US-PGPUB; USPAT	OR	ON	2014/10/29 15:08
S84	0	("andrewnear1martin").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	OFF	2014/10/29 15:09

			IBM_TDB			
S85	676	andrew near1 martin	US-PGPUB; USPAT	OR	ON	2014/10/29 15:09
S86	1	S78 and S85	US-PGPUB; USPAT	OR	ON	2014/10/29 15:09
S87	8158	(701/1).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:17
S88	1448	(340/870.16).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:17
S89	526	(374/152).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:17
S90	11742	S82 or S87 or S88 or S89	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 15:18
S91	4	S78 and S90	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 15:18
S92	16	"7688218"	USPAT	OR	OFF	2015/08/12 13:46
S93	25	"2005105536"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 13:48
S94	2	"20080195264"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:14
S95	2	"20080195265"	US-PGPUB; USPAT; USOCR; FPRS;	OR	OFF	2015/08/12 14:14

			EPO; JPO; DERWENT; IBM_TDB			
S96	4341	(probe or sensor) near3 ((external or outside) near3 housing)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:31
S97	1120	S96 and (temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:32
S98	103	S97 and (railcar or train)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:32
S99	335	S96 with (temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:44
S100	1	S99 with (magnet$5)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:45
S101	9	S99 and (railcar or train)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:46
S102	557	(probe) near3 ((external or outside) near3 housing)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:01
S103	523408	11and (temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:02
S104	83	S102 and (temperature near2 sensor)	US-PGPUB; USPAT;	OR	OFF	2015/08/12 15:02

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S105	90	("20150083869" | "5446451" | "6441324" | "6487478" | "20050259619" | "20110282540" | "20120051643" | "20090173840" | "3718040" | "5440184" | "8751290" | "6339397" | "8244411" | "5503030" | "6184798" | "8672273" | "4812826" | "5810485" | "6301531" | "6535135" | "7688218" | "5682139" | "5381090" | "8212685" | "5691980" | "6161962" | "6179471" | "6324899" | "6668216" | "7698962" | "20110270475" | "20070241610" | "8370006" | "7336156").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:03
S106	0	S102 and S105	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:04
S107	0	S105 and ((probe) near3 (external or outside))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:04
S108	1	S105 and (probe)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:05
S109	0	S105 and ((temperature near3 sensor) near3 (external or outside))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:12
S110	14	S105 and ((temperature near3 sensor))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:12
S111	7	(temperature near2 sensor) with (external near3 housing) with magnet$5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:23

S112	6	(temperature near2 sensor) with (magnet$5 near3 (mount or attach or install))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:28
S113	9574	(temperature near2 sensor) with (magnet$5)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:31
S114	3725	(temperature near2 sensor) near4 (magnet$5)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:31
S115	100	S114 and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:33
S116	2	"13993085"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 16:27
S117	3	"20100220250"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 16:37
S118	25	"2005105536"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 09:52
S119	36	searle near2 donald	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 09:54
S120	15	S119 and rail	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	OFF	2015/08/19 09:54

			DERWENT; IBM_TDB			
S122	25	"2005105536"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 12:31
S123	2	"20080195265"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 12:33
S124	90	"6339397"	USPAT	OR	OFF	2015/08/19 18:14
S125	0	(temperature near3 sensor) with ((touch$3 or contact$3) near5 surface near5 railcar)	USPAT	OR	OFF	2015/08/19 18:26
S126	0	(temperature near3 sensor) with ((touch$3 or contact$3) near5 surface near5 railcar)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 18:26
S127	0	(temperature near3 sensor) with (surface near5 railcar)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 18:26
S128	0	(temperature near3 sensor) with (surface near5 railcar)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 18:26
S129	11	(temperature near3 sensor) with (railcar)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 18:26
S130	1	"13842427"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 19:03
S131	1920	(b61l15/0027).cpc.	US-PGPUB; USPAT; USOCR; FPRS;	OR	OFF	2016/02/05 14:40

			EPO; JPO; DERWENT; IBM_TDB			
S149	232	(strain near2 sensor) and (temperature near2 sensor) and (pressure near2 sensor)and (load near2 sensor)and (magnetic near2 sensor)and (vibration near2 sensor) and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2016/02/05 16:58
S150	3767	((temperature near2 sensor) with (housing or cover)) and ((monitor$ or sens$3 or detect$3) near3 temperature) and (circuitry)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2016/02/05 17:00
S151	1	((temperature near2 sensor) with (housing or cover)) and ((monitor$ or sens$3 or detect$3) near3 temperature) and (circuitry) and ((probe) near6 (external or outside) near6 (magnet$5))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2016/02/05 17:02

6/ 24/ 2017 4:21:16 PM
C:\ Users\ ysoofi.USPTO\ Documents\ EAST\ Workspaces\ 15158018.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15158018	MARTIN ET AL.
	Examiner	Art Unit
	YAZAN SOOFI	3668

CPC- SEARCHED		
Symbol	Date	Examiner
b61l5/0027	6/24/2017	/Y.A.S/

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
701	19	6/24/2017	/Y.A.S/
340	870.16	6/24/2017	/Y.A.S/

SEARCH NOTES		
Search Notes	Date	Examiner
Google patent search	6/24/2017	/Y.A.S/
Inventor search	6/24/2017	/Y.A.S/
EPO search	6/24/2017	/Y.A.S/
East text search	6/24/2017	/Y.A.S/

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

	/YAZAN SOOFI/ Primary Examiner.Art Unit 3668

PTO/SB/08a (03-15)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15158018
Filing Date	2016-05-18
First Named Inventor	MARTIN ET AL.
Art Unit	3744
Examiner Name	
Attorney Docket Number	037659.00062(P36736B US)

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3854417		1974-12-17	MacDonnell et al.	
	2	4134464		1979-01-16	Johnson et al.	
	3	4296707		1981-10-27	Kennedy	
	4	4368927		1983-01-18	Billingsley et al	
	5	4801288		1989-01-31	Schmitt et al.	
	6	4905795		1990-03-06	Rains	
	7	5038605		1991-08-13	Tews et al.	
	8	5394137		1995-02-28	Orschek	

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	9	5410911		1995-05-02	Severinsson	
	10	5603556		1997-02-18	Klink	
	11	5701974		1997-12-30	Kanjo et al.	
	12	6006868		1999-12-28	Klink	
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	20	6823242	B1	2004-11-23	Ralph	
	21	7114596	B2	2006-10-03	Borugian	
	22	7180019	B1	2007-02-20	Chiou et al.	
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	24	8033236	B2	2011-10-11	Michel et al.	
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	27	3718040		1973-02-27	Freeman et al.	
	28	4812826		1989-03-14	Kaufman et al.	
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	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

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	32	5503030		1996-04-02	Bankestrom	
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	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

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	46	7336156	B2	2008-02-26	Arita et al.	
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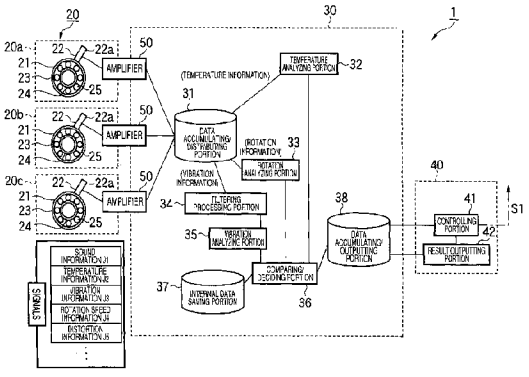
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(54) **METHOD AND DEVICE FOR MONITORING STATUS OF MECHANICAL EQUIPMENT AND ABNORMALITY DIAGNOSING DEVICE**

(57) An abnormality diagnosis system for diagnosing a presence or absence of an abnormality of a bearing unit for a railway vehicle axle, comprises a sensing/processing portion for outputting a signal generated from the bearing unit as an electric signal, a calculating/processing portion for making an abnormality diagnosis of the bearing unit based on an output of the sensing/processing portion, a result outputting portion for outputting a decision result of the calculating/processing portion, and a controlling/processing portion for feeding back a control signal to a control system of the railway vehicle based on the decision result.

FIG. 1



EP 1 548 419 A1

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Description

<Technical Field>

[0001] The present invention relates to a machinery facility condition monitoring method and system and an abnormality diagnosis system and, more particularly, a machinery facility condition monitoring method and system and an abnormality diagnosis system capable of monitoring conditions such as an abnormality, and so forth in a machinery facility such as a railway vehicle facility, a machine tool, a windmill, a reduction gear, an electric motor, or the like including at least one of a rotating body and a sliding member such as a rolling bearing, a sliding bearing, a ball screw, a linear guide, a linear ball bearing, and the like without decomposition of the machinery facility.

<Background Art>

[0002] In the prior art, in order to prevent generation of the failure due to the wear or the failure of the rotating body or the sliding member, a thorough overhaul and a visual inspection are applied periodically to the machinery facility such as the railway vehicle facility, the machine tool, the windmill, or the like. In the thorough overhaul and the visual inspection, the rotating body or the sliding member is removed from the machinery facility and decomposed after the facility is operated for a predetermined period, and then the skilled expert who handling the inspection checks a degree of the wear, the presence or absence of the flaw, or the like of respective constituent parts with a skilled eye. As major defects that are found by the inspection, in the case of the bearing unit, there are the indentation due to the capture of the foreign matter, etc., the flaking due to the rolling contact fatigue, other wear, and others. Also, in the case of the gear, there are the fracture or wear of the teeth, or the like. When the person who handles an inspection detects an abnormality such as unevenness, wear, and the like., which are not found in a new rotating body or sliding member, such person exchanges the defective parts for the new one and then assembles the rotating body or the sliding member once again (see the catalog "ROLLING BEARING" (CAT.No.1101e, page B340 to page B351) issued by Nippon Seiko K.K.).

[0003] However, in the method of decomposing the overall machinery facility and inspecting the failure with the eye of the person in charge, a decomposing operation of removing the rotating body or the sliding member from the machinery facility and a fitting operation of fitting again the inspected rotating body or sliding member into the machinery facility require much time and labor. Thus, such a problem existed that a substantial increase in an upkeep cost required for maintaining, managing, or the like the machinery facility is brought upon.

[0004] In particular, in the case of the windmill, most of the windmills are used in an offshore area and also the number of the installed windmills is large. It is the existing circumstances of maintaining/managing operations of the windmill that the person in charge of the maintenance goes to the installation location of the windmill and then conducts the inspection of rotating parts of the windmill there. For this reason, such a problem existed that it take an enormous time and cost to maintain/manage the windmill and thus a maintenance efficiency is poor. Also, it is possible that the inspection itself causes the defect of the rotating body or the sliding member. For instance, the indentation that has not been put before the inspection is made on the rotating body or the sliding member when the machinery facility is reassembled after the decomposition and the inspection, and so forth. Also, since the person in charge of the inspection must check a number of bearings with the eye within a limited time, there existed the problem that such a possibility still remains that such person fails to find the defect. In addition, since a decision level of the defect varies between individuals and thus exchange of the parts is carried out even though the defect is not found substantially, the above inspection entails a useless cost.

[0005] Also, in order to overcome the disadvantages caused by such visual inspection, it is studied that the sensor for sensing the sound or the vibration generated during the rotation of the bearing is provided on the body of the vehicle in which the bearing is used, and then the abnormality such as the wear, the failure, or the like of the bearing is sensed based on the sensed signal of the sensor.

[0006] However, in the case where the sensor is fitted onto the body of the vehicle, an SN ratio of the sensed signal from the sensor is worsened because the sensor is provided away from the bearing. Thus, there existed such a problem that it is difficult to sense/decide the abnormality with high precision.

[0007] Also, as an bearing unit in the prior art, in a bearing unit 1100 having a sensor module shown in FIG.50, a module hole 1103 is formed on an outer peripheral surface of an outer ring 1102 of a rolling bearing 1101, and then a module 1104 into which a speed sensor, a temperature sensor, and an acceleration sensor are installed is inserted/fixed into the module hole 1103. Then, sensed signals generated from respective sensors in the module 1104 are transmitted to a remote processing unit provided in the locomotive, which pulls the freight cars and the passenger cars in which the rolling bearings 1101 are provided, via the communication channel.

[0008] As to the speed, the instantaneous speed of the journal is sensed based on the pulse generated by the rotating wheel, and then such speed and the speed of other bearings that are operating under the same conditions are compared

with each other. Thus, the overall period history to which the bearing assembly is subjected is saved/recorded. As to the temperature, such temperature and the temperature of other bearings that are operating under the same conditions are compared with each other by a simple level detection. As to the vibration, a simple RMS measurement of an energy level is carried out over a predetermined period of time, and then such energy level and the past energy level stored in a processing unit are compared with each other. Thus, such energy level and the energy level of other bearings that are operating under the same conditions are compared with each other (see JP-T-2001-500597 (pp.10 to 16, Fig.1)).

[0009] Also, as another configurative example of the bearing unit, in an abnormality sensing unit 1110 of the rolling bearing unit shown in FIG.51, a sensor fitting hole 1113 is formed in the lower end portion of an outer ring 1112 of a double row tapered roller bearing 1111, and then a sensor unit 1117 having a rotation speed sensor 1114, a temperature sensor 1115, and an acceleration sensor 1116 therein is inserted/supported into the sensor fitting hole 1113 (for example, see 1P-A-2002-295464 (pp.4 to 5, Fig.1)).

[0010] In addition, as other configurative example of the bearing unit, in a sensor built-in rotation supporting member 1120 shown in FIG.52, a sensor fitting hole 1123 is formed in the lower end portion of an outer ring 1122 of a double row tapered roller bearing 1121, and then a sensor unit 1126 having a rotation speed sensor 1124 and a temperature sensor 1125 therein is inserted/supported into the sensor fitting hole 1123 (for example, see JP-A-2002-292928 (pp. 4 to 5, Fig.1)).

[0011] Further, as other configurative example, an abnormality sensing unit 1130 of the bearing unit shown in FIG. 53 has a pickup 1132 for converting a mechanical vibration of a bearing 1131 into an electric vibration to output, an automatic gain control amplifier 1133 for amplifying an output of the pickup 1132, and a 1 to 15 kHz bandpass filter 1134 for removing noises generated from the driving system and other mechanical systems from the output of the amplifier 1133. Also, the unit 1130 has a root- mean-square calculator 1135 for calculating a root mean square value of the output of the bandpass filter 1134 and supplying the value to a gain control terminal of the automatic gain control amplifier 1133, an envelope circuit 1136 for receiving an output of the bandpass filter 1134, a root-mean-square calculator 1137 for receiving an output of the envelope circuit 1136, and an alarm circuit 1138 for receiving an output of the root-mean-square calculator 1137 and issuing an alarm by using a lamp or a contact output when such output value exceeds a predetermined value (for example, see JP-A-2-205727 (pp.2 to 3, Fig.1)).

[0012] Furthermore, as other configurative example, an abnormality diagnosis system 1140 of the rolling bearing shown in FIG.54 has a configuration that includes a microphone 1142 arranged in vicinity of a rolling bearing 1141, an amplifier 1143, an electronic device 1144, a speaker 1145, and a monitor 1146. The electronic device 1144 is a calculating/processing unit, and has a transducer 1147 as a converting portion, a HDD 1148 as a recording portion, an abnormality diagnosing portion 1149 as a calculating/processing portion, and an analog converting/outputting portion 1150 (for example, see JP-A- 2000-146762 (pp.4 to 6, Fig.1)).

[0013] Besides, as other configurative example, in an abnormality diagnosing method and an abnormality diagnosing system 1160 of the bearing shown in FIG.55, an electric signal waveform that a sensor 1161 outputs is converted into the digital file by an analog/digital converter 1162, then is sent out to a waveform processing portion 1163, and then is subjected to the enveloping process by the waveform processing portion 1163 to get an envelope spectrum. Then, an inner ring flaw component, an outer ring flaw component, and a rolling element flaw component, which are particular frequency components of the bearing constituent parts, are extracted from the envelope spectrum by the waveform processing portion 1163 in the extracting step by using predetermined equations. Then, a calculating portion 1164 executes the calculating step, a deciding portion 1165 executes the comparing step, an outputting portion 1166 outputs the decided result, and a speaker 1167 and a monitor 1168 inform the inspector of the result (for example, see JP-A-2001-021453 (pp.5 to 6, Fig.1)).

[0014] However, in the configurations of the bearing unit set forth in JP-T-2001-500597 and JP-A-2002-295464, since the sensor fitting hole is provided in the outer ring, the type of the outer rings constituting the bearing is increased such as the outer ring in which the hole is not provided and the outer ring in which the hole is provided. As a result, there is a possibility of generating the installing error, and the like, and also a lot of man-hours are needed to manage the parts. Also, it is possible that the outer ring with the hole hinders the sealing performance in the bearing.

[0015] Also, in the abnormality diagnosis system set forth in JP-A-2-205727, JP-A-2000-146762, and JP-A-2001-021453, merely the measure against the vibration noise is disclosed. In the case where the bearing is used to support the axle of the railway vehicle, it is possible that this diagnosis system decides a great shock generated when the railway vehicle passes over the rail joint as an abnormal signal. Thus, the abnormality decision may be largely affected.

[0016] Also, in order to overcome the disadvantages caused by the overhaul inspection or the visual inspection, there is proposed a monitoring system that includes a sensor for sensing the sound or the vibration generated during the rotation of the bearing and an information processing system for analyzing a sensed signal of the sensor to decide whether or not the abnormality is generated and uses a personal computer as the information processing system (for example, see JP-A-2002- 71519).

[0017] However, the personal computer used as the information processing system in the monitoring system in the

prior art has normally such a configuration that a motherboard and an interface for receiving an output of the sensor are installed into a general-purpose casing. Thus, the information processing system needs a relatively large installing space and also has a tendency that does not endure the vibration, and the like well.

[0018] For this reason, in order to prevent an influence of the vibration on the bearing unit, etc., a space in which the personal computer is provided must be secured in the position that is distant from the bearing unit, etc. to some extent. In addition, this monitoring system becomes large in size. Therefore, in the case of the machinery facility in which the assurance of the large installing space is difficult, such a problem has arisen that such monitoring system is of little utility.

[0019] Also, in order to prevent a deterioration of the SN ratio of the signal sensed by the sensor, it is preferable that the sensor should be incorporated into the constituent parts itself of the bearing unit if possible. However, the personal computer that cannot stand up to the external vibration, and the like and is large in size must be separated as far as possible away from the bearing unit, or the like as the vibration generating source. As a result, the personal computer is apart from the sensor at a predetermined distance or more, and thus it is possible that the problem such as a reduction in a sensing precision due to the influence of the external noise on the information transmission path between the sensor and the personal computer, or the like is caused.

[0020] The present invention has been made in view of the above problems, and it is an object of the present invention to provide a high-precision machinery facility abnormality diagnosis system capable of deciding the presence or absence of an abnormality in a state of normal use without decomposition of a facility like a machinery facility such as a railway vehicle facility, a machine tool, a windmill, or the like, which requires much time and labor to decompose, and thus capable of reducing maintenance/administrative costs and being hardly affected by the noise, and the like.

<Disclosure of the Invention>

[0021] The present invention can be attained by configurations described in the following.

(1) An abnormality diagnosis system for diagnosing a presence or absence of an abnormality of a bearing unit for a railway vehicle axle, comprising:

a sensing/processing portion for outputting a signal generated from the bearing unit as an electric signal;
a calculating/processing portion for making an abnormality diagnosis of the bearing unit based on an output of the sensing/processing portion;
a result outputting portion for outputting a decision result of the calculating/processing portion; and
a controlling/processing portion for feeding back a control signal to a control system of the railway vehicle based on the decision result.

(2) An abnormality diagnosis system according to (1), wherein the calculating/processing portion includes
a data accumulating/distributing portion for accumulating the electric signal fed from the sensing/ processing portion and distributing the signal to an appropriate distributing route according to a type of the electric signal,
an analyzing portion for calculating a predetermined physical quantity in regarding to the bearing unit based on the electric signal distributed from the data accumulating/ distributing portion,
a first data saving portion for saving bearing unit data in regarding to the bearing unit,
a comparing/deciding portion for making the abnormality diagnosis of the bearing unit by comparing/referring an analyzed result of the analyzing portion with the bearing unit data saved in the first data saving portion,
a second data saving portion for saving the analyzed result of the analyzing portion and a decision result of the comparing/deciding portion.

(3) An abnormality diagnosis system according to (2), wherein the analyzing portion includes
a filtering processing portion for removing a noise component of the electric signal fed from the calculating/ processing portion or extracting a particular frequency component to output, and
a frequency analyzing portion for executing a frequency analysis of a signal output from the filtering processing portion, and
the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on a result of the frequency analysis of the frequency analyzing portion.

(4) An abnormality diagnosis system according to (2) or (3), wherein the analyzing portion has a temperature analyzing portion that calculates a temperature of the bearing unit based on the signal output from the data accumulating portion and
the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on the temperature calculated by the temperature analyzing portion.

(5) An abnormality diagnosis system according to any one of (2) to (4), wherein the analyzing portion has a rotation

analyzing portion that calculates a rotation speed of the bearing unit based on the signal output from the data accumulating portion, and

the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on the rotation speed calculated by the rotation analyzing portion.

(6) An abnormality diagnosis system according to any one of (1) to (5), wherein the calculating/processing portion outputs data saved in the second data saving portion to the controlling/processing portion in response to the abnormality diagnosis result.

(7) An abnormality diagnosis system according to any one of (1) to (6), wherein the filtering processing portion extracts only a frequency component of 1 kHz or less.

(8) An abnormality diagnosis system according to any one of (1) to (7), wherein a sensing element of the sensing/processing portion is arranged on a stationary portion of the bearing unit in a loading range.

(9) An abnormality diagnosis system according to any one of (1) to (8), wherein the data accumulating/distributing portion does not output the electric signal containing a noise component, which exceeds a predetermined level, to the analyzing portion.

(10) An abnormality diagnosis system according to any one of (1) to (9), wherein the comparing/deciding portion makes the abnormality diagnosis of the bearing unit by comparing levels of a frequency due to the abnormality and its higher harmonics with a reference value.

(11) An abnormality diagnosis system according to any one of (1) to (10), wherein the comparing/deciding portion decides that the abnormality is generated when at least one of peak values of the frequency due to the abnormal and its higher harmonics is larger than a predetermined reference value.

(12) An abnormality diagnosis system according to any one of (1) to (11), wherein the comparing/deciding portion estimates a degree of damage of the bearing unit based on the peak values of the frequency due to the abnormal and its higher harmonics.

(13) An abnormality diagnosis system according to any one of (1) to (12), wherein the comparing/deciding portion makes the abnormality diagnosis by comparing the levels of the frequency due to the abnormal and its higher harmonics.

(14) An abnormality diagnosis system according to any one of (1) to (13), wherein the comparing/deciding portion makes the abnormality diagnosis based on a square mean or a partial overall of a frequency band containing the frequency due to the abnormal.

(15) An abnormality diagnosis system according to any one of (1) to (14), wherein the comparing/deciding portion makes the abnormality diagnosis by applying a cepstrum analysis to a frequency spectrum.

(16) An abnormality diagnosis system according to any one of (1) to (15), wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion and the calculating/processing portion and the controlling/processing portion via a cable that has waterproof, oil-resistant, dustproof, rust-preventive, and moisture-proof functions, and heat-resistant, voltage-proof, and electromagnetic noise-resistant properties respectively.

(17) An abnormality diagnosis system according to any one of (1) to (15), wherein a radio communicating device is provided to the sensing/processing portion and the calculating/ processing portion and the calculating/processing portion and the controlling/processing portion respectively, and the signal is transmitted therebetween by using the radio communicating device via radio.

(18) An abnormality diagnosis system according to any one of (1) to (15), wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion and the calculating/processing portion and the controlling/processing portion via the cable that has waterproof, oil-resistant, dustproof, rust-preventive, and moisture-proof functions, and heat-resistant, and electromagnetic noise-resistant properties respectively, or the signal is transmitted therebetween by using the radio communicating device.

(19) An abnormality diagnosis system according to any one of (1) to (18), wherein the abnormality diagnosis is made in real time.

(20) An abnormality diagnosis system according to any one of (1) to (18), wherein the abnormality diagnosis is made at a time different from a vehicle traveling time, based on data accumulated in the accumulating portion.

(21) An abnormality diagnosis system according to any one of (1) to (20), wherein the presence or absence of the abnormality of a bearing in the bearing unit and an abnormality occurring location are diagnosed.

(22) An abnormality diagnosis system according to any one of (1) to (20), wherein a flat portion of a wheel is diagnosed.

(23) An abnormality diagnosis system according to any one of (1) to (20), wherein the presence or absence of the abnormality of a gear in the bearing unit and an abnormality occurring location are diagnosed.

(24) An abnormality diagnosis system for a machinery facility having a rotating body, comprising:

a sensor unit having a sensor fitted to a constituent parts of the rotating body to sense a physical quantity of

the rotating body in a rotating operation;
a calculating/processing portion for deciding a presence or absence of an abnormality of the rotating body by analyzing an output signal of the sensor unit and then comparing an analyzed result with predetermined reference data; and
a controlling/processing portion for displaying the analyzed result of the calculating/processing portion and a decision result of the calculating/processing portion, and controlling an operation of the machinery facility in response to the decision result.

(25) An abnormality diagnosis system according to (24), wherein the sensor unit has an output amplifying means for amplifying the output signal of the sensor.
(26) An abnormality diagnosis system according to (24) or (25), wherein the sensor unit has a radio communicating means for transmitting the output signal to the calculating/ processing portion via radio.
(27) An abnormality diagnosis system according to (26), wherein the calculating/processing portion and the controlling/processing portion are provided to a monitoring base station that is remote from the rotating body.
(28) An abnormality diagnosis system according to (27), wherein the sensor unit is fitted to a bearing of a railway vehicle, and
the sensor unit diagnoses the abnormality of the bearing.
(29) A machinery facility abnormality diagnosis system for sensing a presence or absence of an abnormality of a sliding member or a rotating body in a machinery facility, comprising:

a sensor unit having one of plural sensing elements for sensing a signal emitted from the machinery facility; and
a calculating/processing portion for executing a calculating process to decide the presence or absence of the abnormality in the machinery facility based on an output of the sensing element;

wherein the calculating/processing portion is composed of a microcomputer.
(30) A machinery facility abnormality diagnosis system according to (29), wherein the sensor unit is incorporated into the sliding member or the rotating body.
(31) A machinery facility abnormality diagnosis system according to (30), wherein the microcomputer is fitted to the sliding member or the rotating body or a mechanism parts that supports the sliding member or the rotating body.
(32) A machinery facility abnormality diagnosis system according to (29), wherein the microcomputer and the sensor unit are mounted on a single device board, and are fitted to the sliding member or the rotating body or a mechanism parts that supports the sliding member or the rotating body as a single processing unit.
(33) A machinery facility abnormality diagnosis system according to any one of (29) to (32), wherein the calculating/ processing portion is installed in a single casing.
(34) A machinery facility abnormality diagnosis system according to (33), wherein the sensor unit is arranged integrally in the casing.
(35) A machinery facility abnormality diagnosis system according to any one of (29) to (34), wherein the sensing element senses at least one of temperature, vibration displacement, vibration speed, vibration acceleration, force, distortion, acoustic, acoustic emission, ultrasonic waves, and rotation speed.
(36) A machinery facility abnormality diagnosis system according to any one of (29) to (35), wherein the calculating/ processing portion includes central processing unit, amplifier, analog/digital converter, filter, comparator, pulse counter, timer, interruption controller, ROM, RRAM, digital/analog converter, communication module, and external interface.
(37) A machinery facility abnormality diagnosis system according to any one of (29) to (36), wherein the calculating/ processing portion executes at least one process or more of calculation of feature parameters of a standard deviation and a peak factor, envelope detection, FFT, filtering, wavelet transform, short-time FFT, calculation of a feature frequency due to a defect of the rotating body and comparison/decision.
(38) A condition monitoring method for a machinery facility having at least one of a rotating body and a sliding member, comprising the steps of:

analyzing a predetermined physical quantity of the machinery facility based on a signal generated from the machinery facility;
provisionally diagnosing a presence or absence of an abnormality of the machinery facility by comparing/ allocating an analyzed result with information serving as references to decide whether or not the abnormality is present in the machinery facility, every first time period; and
diagnosing the presence or absence of the abnormality of the machinery facility and an abnormal location, by executing a total evaluation, which decides the abnormality when a number of times the abnormality is provisionally diagnosed exceeds a threshold value, after a comparison/allocation is executed predetermined

number of times or based on a compared/allocated result obtained every second time period.

(39) A condition monitoring method for a machinery facility having at least one of a rotating body and a sliding member, comprising the steps of:

analyzing a predetermined physical quantity of the machinery facility based on a signal generated from the machinery facility;
provisionally diagnosing a presence or absence of an abnormality of the machinery facility by comparing/allocating an analyzed result with information serving as references to decide whether or not the abnormality is present in the machinery facility, every first time period; and
diagnosing the presence or absence of the abnormality of the machinery facility and an abnormal location, by executing a total evaluation, which decides a degree of the abnormality according to a number of times the abnormality is provisionally diagnosed, after a comparison/allocation is executed predetermined number of times or based on a compared/allocated result obtained every second time period.

(40) A machinery facility condition monitoring method according to (38) to (39), wherein the signal is A/D-converted into a digital signal, then a process of analyzing a frequency of the digital signal is executed, and then a frequency component generated due to a damage of the machinery facility and calculated based on an operating signal of the machinery facility is compared/allocated with a frequency component derived based on actually measured data every first time period.
(41) A machinery facility condition monitoring method according to (40), wherein the signal is subjected to an amplifying process and a filtering process.
(42) A machinery facility condition monitoring method according to (40) or (41), wherein at least one of the rotating body and the sliding member of the machinery facility is any one of rolling bearing, ball screw, linear guide, and linear ball bearing, and the operating signal of the machinery facility is either a rotation speed signal in the rolling bearing and the ball screw or a moving speed signal in the linear guide and linear ball bearing.
(43) A machinery facility condition monitoring system for a machinery facility having at least one of a rotating body and a sliding member and using the condition monitoring method set forth in (38) or (39), comprising:

at least one sensing/processing portion for sensing a signal generated from the machinery facility;
a calculating/processing portion having a microcomputer that executes a calculating process to decide a condition of the machinery facility based on the signal output from the sensing/processing portion; and
a controlling/processing portion having at least one of a result outputting portion that outputs a decision result of the calculating/processing portion and a controller that feeds back a control signal to a control system of the machinery facility based on the decision result.

(44) A machinery facility condition monitoring system according to (43), wherein at least one of the sensing/processing portion and the microcomputer is installed into the rotating body and the sliding member.
(45) A machinery facility condition monitoring system according to (43) or (44), wherein at least one of the rotating body and the sliding member is a bearing to which a radial load is applied, and
the sensing/processing portion is fixed in a radial load loading range of a bearing housing that is fitted onto a raceway ring of the bearing.
(46) An abnormality diagnosis system for a railway vehicle bearing unit using the machinery facility condition monitoring system set forth in any one of (43) to (45).
(47) An abnormality diagnosis system for a windmill bearing unit using the machinery facility condition monitoring system set forth in any one of (43) to (45).
(48) An abnormality diagnosis system for a machine tool spindle bearing unit using the machinery facility condition monitoring system set forth in any one of (43) to (45).
(49) A machine equipment abnormality diagnosis system comprising:

a sensing/processing portion having a sensor unit that is fixed to a bolt screwed into a housing of the machine equipment and outputs a signal generated from the machine equipment as an electric signal;
a calculating/processing portion for making an abnormality diagnosis of the machine equipment based on an output of the sensing/processing portion; and
a controlling/processing portion for feeding back a control signal to a control system of the machine equipment based on a result of the abnormality diagnosis.

(50) A machine equipment abnormality diagnosis system according to (49), wherein the calculating/processing

portion includes

the calculating/processing portion includes

a data accumulating/distributing portion for accumulating the electric signal fed from the sensing/ processing portion and distributing the signal to an appropriate distributing route according to a type of the electric signal,

an analyzing portion for calculating a predetermined physical quantity in regarding to the machine equipment based on the electric signal distributed from the data accumulating/ distributing portion,

a first data saving portion for saving machine equipment data in regarding to the machine equipment,

a comparing/deciding portion for making the abnormality diagnosis of the machine equipment by comparing the physical quantity calculated by the analyzing portion with the machine equipment data saved in the first data saving portion,

a second data saving portion for saving the analyzed result of the analyzing portion and a result of the abnormality diagnosis of the comparing/deciding portion.

(51) A machine equipment abnormality diagnosis system according to (49) or (50), wherein the calculating/processing portion and the controlling/processing portion are composed of a microcomputer or an IC chip.

(52) A machine equipment abnormality diagnosis system according to any one of (49) to (51), wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion or the calculating/processing portion and the controlling/processing portion without a wire connection.

(53) A bearing unit including an inner ring having an inner ring raceway surface, an outer ring having an outer ring raceway surface, a plurality of rolling elements arranged relatively rotatably between the inner ring raceway surface and the outer ring raceway surface, and a retainer for holding rollably the rolling elements, whereby a bearing to which a radial load is applied is arranged in a bearing housing,

the bearing unit comprising:

an abnormality sensing means provided in a loading range of the bearing housing, for sensing an abnormality from at least one selected from a vibration sensor and a temperature sensor installed/fixed in a single case.

(54) A bearing unit according to (53), wherein a flat portion is provided to a part of an outer peripheral surface of the bearing housing on a loading range side, and the abnormality sensing means is fixed to the flat portion.

(55) A bearing unit according to (54), wherein the abnormality sensing means is arranged on an outer diameter portion of the bearing housing on the loading range side in a center portion of a bearing width.

(56) A bearing unit according to (53), wherein the abnormality sensing means is arranged on an outer diameter portion of the bearing housing on the loading range side in a width area of the inner ring raceway surface or the outer ring raceway surface.

(57) A bearing unit according to any one of (53) to (56), wherein a case of the abnormality sensing means has a signal carrying means that sends out a sensed signal, and a decision result outputting portion that decides a presence or absence of the abnormality based on the signal sent out via the signal carrying means and output a decision result.

(58) A bearing unit according to any one of (53) to (57), wherein the abnormality sensing means is embedded/fixed on a recess portion formed on the bearing housing, and then secured by molding a clearance between the abnormality sensing means and the recess portion.

(59) A bearing unit according to (58), wherein the abnormality sensing means is fixed to the recess portion via a spacer.

(60) A bearing unit according to any one of (53) to (59), wherein a filtering processing portion for removing an unnecessary frequency band from a vibration waveform from the vibration sensor, an envelope processing portion for detecting an absolute value of a filtered waveform transferred from the filtering processing portion, a frequency analyzing portion for analyzing a frequency of a waveform transferred from the envelope processing portion, a comparing/collating portion for comparing a frequency generated due to a damage calculated based on a rotation speed with a frequency derived based on actually measured data, and a result outputting portion for identifying a presence or absence of the abnormality and an abnormal location based on a compared result in the comparing/collating portion are provided.

<Brief Description of the Drawings>

[0022]

FIG.1 is a view showing a railway vehicle abnormality diagnosis system according to a first embodiment of the present invention;

FIG.2 is a block diagram showing an internal structure of a sensor unit;

FIG.3 is a view showing a data accumulating/distributing portion;
FIG.4 is a table showing relational expressions indicating relationships between defects of respective members of a bearing and abnormal vibration frequencies generated in respective members;
FIG.5 is a view showing a relationship between a loading range and a non-loading range in the bearing;
FIG.6 is a view showing a time-variant waveform of an oscillating signal sensed from the bearing in the first embodiment;
FIG.7 is a view showing a frequency spectrum of the vibration signal sensed from the bearing in the first embodiment;
FIG.8 is a view showing a frequency spectrum of the vibration signal sensed from the bearing in the first embodiment after an enveloping process;
FIG.9 is a flowchart showing a process flow in a first method;
FIG.10 is a graph showing a frequency spectrum when no abnormality is generated;
FIG.11 is a graph showing a frequency spectrum when the abnormality is generated in an outer ring;
FIG.12 is a graph showing a relationship between the frequency spectrum and a reference value when a retainer has a flaw;
FIG.13 is a flowchart showing a process flow in a second method;
FIG.14 is a view explaining the second method;
FIG.15 is a flowchart showing a process flow in a third method;
FIG.16 is a view showing a frequency spectrum when an outer ring has the flaw;
FIG. 17 is a view explaining a fourth method;
FIG.18 is a graph showing a relationship between a size of flaking and a level difference between peaks appearing on the actually measured frequency spectrum data and a reference level;
FIG. 19 is a flowchart showing a process flow in a fifth method;
FIG.20 is a view showing frequency spectrum levels and a reference line;
FIG.21 is a flowchart showing a process flow in a sixth method;
FIG.22 is a graph showing a frequency spectrum when the abnormality is generated in the outer ring;
FIG.23 is a graph showing a frequency spectrum when no abnormality is generated in the outer ring;
FIG.24 is another graph showing a frequency spectrum when the abnormality is generated in the outer ring;
FIG.25 is another graph showing a frequency spectrum when no abnormality is generated in the outer ring;
FIG.26 is a block diagram showing an internal configuration of a sensor unit in a railway vehicle abnormality diagnosis system according to a second embodiment of the present invention;
FIG.27 is a view showing the railway vehicle abnormality diagnosis system according to the second embodiment of the present invention;
FIG.28 is a block diagram showing a schematic configuration of a rotating body abnormality diagnosis system according to a third embodiment of the present invention;
FIG.29 is a block diagram showing a schematic configuration of a rotating body abnormality diagnosis system according to a fourth embodiment of the present invention;
FIG.30 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a fifth embodiment of the present invention;
FIG.31 is a block diagram showing a schematic configuration of a microcomputer shown in FIG.30;
FIG.32 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a sixth embodiment of the present invention;
FIG.33 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a seventh embodiment of the present invention;
FIG.34(a) is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to an eighth embodiment of the present invention;
FIG.34(b) is a side view showing a bearing fitting state in FIG.34(a);
FIG.35(a) is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a ninth embodiment of the present invention;
FIG.35(b) is a side view showing a bearing fitting state in FIG.35(a);
FIG.36 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a tenth embodiment of the present invention;
FIG.37 is a sectional view showing a machinery facility to which a condition monitoring system according to an eleventh embodiment of the present invention is applied;
FIG.38 is a schematic view showing the condition monitoring system according to the eleventh embodiment;
FIG.39 is a block diagram of a calculating/processing portion in FIG.38;
FIG.40 is a flowchart showing procedures of a diagnosis process in a condition monitoring method;
FIG.41 is a view showing a bearing housing of a railway vehicle bearing unit serving as a machinery facility to

which an abnormality diagnosis system according to a twelfth embodiment of the present invention is applied;
FIG.42 is a view showing a railway vehicle abnormality diagnosis system in the twelfth embodiment;
FIG.43 is a view showing a variation of the abnormality diagnosis system according to the twelfth embodiment of the present invention;
FIG.44 is a view showing another variation of the abnormality diagnosis system according to the twelfth embodiment of the present invention;
FIG.45 is a schematic view showing a bearing unit according to a thirteenth embodiment of the present invention;
FIG.46 is a signal processing system diagram in an abnormality sensing means in the bearing unit shown in FIG.45;
FIG.47 is a signal processing system diagram using a method different from FIG.46;
FIG.48 is a sectional view showing a bearing unit according to a fourteenth embodiment of the present invention;
FIG.49 is a sectional view showing a bearing unit according to a fifteenth embodiment of the present invention;
FIG.50 is a sectional view showing a bearing unit in the prior art;
FIG.51 is a sectional view showing another bearing unit in the prior art;
FIG.52 is a sectional view showing still another bearing unit in the prior art;
FIG.53 is a block diagram showing another configurative example in the prior art;
FIG.54 is a block diagram showing still another configurative example in the prior art; and
FIG.55 is a block diagram showing yet still another configurative example in the prior art.

<Best Mode for Carrying Out the Invention>

[0023] A machinery facility condition monitoring method and system and an abnormality diagnosis system according to the present invention will be explained in detail with reference to the accompanying drawings hereinafter.

<First Embodiment>

[0024] FIG.1 shows a railway vehicle abnormality diagnosis system according to a first embodiment of the present invention. An abnormality diagnosis system 1 includes a sensing/processing portion 20 having sensor units 22 each provided to each row of a rolling bearing 21 to output a condition of each row as an electric signal, a calculating/processing portion 30 for calculating/processing the electric signals output from the sensor units 22 to decide the condition such as defect, abnormality, or the like of a railway vehicle facility 10, and a controlling/processing portion 40 for controlling and outputting the decided result of the calculating/processing portion 30.

[0025] The abnormality diagnosis system 1 senses the generation of the abnormality due to the wear or the failure of a plurality of rolling bearings 21 in the bearing unit that bears the axle of the railway vehicle. Each rolling bearing 21 has an outer ring 23 as a stationary portion that is fitted into the vehicle body side, an inner ring 24 fitted onto the axle and rotated together with the axle, and rolling elements 25 such as balls, rollers, or the like held between an outer ring raceway formed on the inner peripheral surface side of the outer ring 23 and an inner ring raceway formed on the peripheral surface side of the inner ring 24 by a retainer (not shown) and arranged reliably between both raceways. Also, the sensor unit is secured to the outer ring 23 of each rolling bearing 21. In FIG.1, the sensing/ processing portion 20 is constructed by sensing portions 20a, 20b, 20c each consisting of the sensor unit 22 secured to each rolling bearing 21.

[0026] The sensor unit 22 has sensors as a plurality of sensing elements that sense various information generated from the machinery facility during the running, e.g., sound J1, temperature J2, vibration (vibration displacement, vibration speed, vibration acceleration) J3, rotation speed J4, distortion J5 generated on the outer ring of the bearing, AE (acoustic emission), moving speed, force, ultrasonic wave, etc., as physical quantities that are changed in response to a rotating condition of the bearing 21. Each sensor outputs the sensed physical quantity to the calculating/processing portion 30 as the electric signal.

[0027] Here, since the calculating/processing portion 30 can distribute/process appropriately the electric signals every sensed information, respective sensing elements are arranged independently in different locations respectively. Thus, a plurality of sensing elements for sensing independently the particular signals such as sound, temperature, vibration, rotation speed, distortion, AE, moving speed, force, ultrasonic wave, and others may be employed in combination. Alternately, a composite sensor unit constructed by installing a plurality of sensing elements into an inside of a housing to sense simultaneously plural types of signals may be employed as the sensor unit 22, in place of independent arrangement of a plurality of sensing elements. Also, a multidirectional simultaneous vibration sensor for sensing the vibration in the multiple directions by one sensor may be employed as the vibration sensor.

[0028] In addition, in order to execute the sensing at a high SN ratio, the signal can be sensed with good sensitivity by fitting the sensor unit 22, especially a vibration sensing element 22d (see FIG.2(a)), to a portion to which a load is applied (loading range) and thus the higher-precision measurement can be attained. Where the "loading range" denotes an area in which the load is applied to the rolling elements, as shown in FIG.5. In the case where the sensor unit is

fitted inevitably to a non-loading range when the space used to fit the sensor is absent in the loading range, a high-tension cable that generates noises is provided to the loading range, or the like, the measurement can be carried out by enhancing a signal sensing sensitivity by virtue of a filtering process executed by a filtering processing portion 34 described later, or the like.

[0029] In the present embodiment, as shown in FIG.2(a), the sensor unit 22 has such a structure that various sensing elements 22b, 22c, and 22d are installed into a unit case 22a. Then, explanation will be made hereunder under the assumption that the temperature sending element 22b for sensing the temperature of the bearing 21, the rotation sensing element 22c for sensing the rotation speed of the inner ring (axle) of the bearing 21, and the vibration sensing element 22d for sensing the vibration generated in the bearing 21 are provided in the unit case 22a.

[0030] Respective sensing elements 22b to 22c amplify the electric signals corresponding to the sensed vibration, temperature, and rotation speed via an amplifier 50 as an output amplifying means, and then output the signals to the calculating/processing portion 30. The amplifier 50 may be provided in the unit case 22a of the sensor respectively as shown in FIG.2(b), or the amplifier 50 may be provided between the sensor unit 22 and the calculating/processing portion 30 respectively as shown in FIG.1, or the amplifier 50 may be provided to an interior of the calculating/processing portion 30. It is preferable that amplifiers 22e, 22f, and 22g should be provided to the sensing elements 22b, 22c, and 22d in the unit case 22a respectively. There is such a possibility that the noise is superposed on the signal during when the signal output from the sensor unit 22 is being transmitted to the calculating/processing portion 30 via the cable, and thus the reliability of measurement is lowered. In this event, if a signal level is amplified in advance via the amplifier 50, the signal is hard to accept the influence of the noise and thus the reliability can be improved.

[0031] The signal is transmitted between the sensor unit 22 and the calculating/processing portion 30 via the cable. In order to improve a measuring precision such as reduction of noise, etc., it is preferable that the cable should have waterproof, oil-resistant, dustproof, rust-preventive, moisture-proof, heat-resistant, and electromagnetic noise-resistant properties. Similarly, in order to improve a measuring precision such as reduction of noise, etc., it is preferable that respective sensing elements 22b to 22d in the sensor unit 22 should have waterproof, oil-resistant, dustproof, rust-preventive, moisture-proof, heat-resistant, and electromagnetic noise-resistant properties. For example, if all sensing elements are incorporated into the sensor unit and then the waterproof, oil-resistant, dustproof, rust- preventive, moisture-proof, heat-resistant, and electromagnetic noise-resistant properties are provided to the unit case 22a of the sensor unit 22, these properties can be embodied.

[0032] The calculating/processing portion 30 is a unit that executes the calculating process of the electric signals as the outputs that are received from respective sensing elements (the temperature sensing element 22b, the rotation sensing element 22c, and the vibration sensing element 22d in the present embodiment) in the sensor unit 22, and then identifies the presence or absence of the abnormality of the bearing and an abnormality occurring location by comparing the analyzed result analyzed by the calculating process and the reference data. Here, the reference data denote reference values of various physical quantities that are sensed by respective sensing elements in the normal condition of the bearing 21 serving as the diagnosed object. More particularly, the reference data contain the information about a frequency component generated by the wear or the failure of the particular portion of the bearing 21, and the like, in addition to the information of the normal bearing 21 about sound, temperature, vibration, rotation speed, distortion, AE, moving speed, force, ultrasonic wave, and the like.

[0033] For instance, the calculating/processing portion 30 may be constructed by using the personal computer or the general- purpose computer into which the existing operating system and the software applications used to execute the abnormality diagnosis. Otherwise, the calculating/processing portion 30 may be constructed as an arithmetic unit that are composed of processing and saving circuits provided independently to respective portions.

[0034] The calculating/processing portion 30 includes a data accumulating/distributing portion 31, a temperature analyzing portion 32, a rotation analyzing portion 33, the filtering processing portion 34, a vibration analyzing portion 35, a comparing/deciding portion 36, an internal data saving portion 37 serving as a first data saving portion, a data accumulating/outputting portion 38 serving as a second data saving portion. Then, configurations and functions of respective portions of the calculating/processing portion 30 will be explained in detail hereunder.

[0035] FIG.3 is a view showing the data accumulating/ distributing portion 31 serving as a first data accumulating portion. The data accumulating/distributing portion 31 has a data accumulating portion 31a, a sampling portion 31b, and a sampling reference setting portion 31c. The data accumulating portion 31a is a data saving medium that save the output signals from the sensing elements 22b to 22d every signal, and can be constructed by various memories, the hard disk, and the like.

[0036] The data accumulating portion 31a receives the signals sent out from the sensing elements 22b to 22d, and then stores temporarily such signals and also allocates such signals to any of the analyzing portions 32, 33, 34 in response to the type of signal. Various signals are A/D-converted into digital signals by an A/D converter (not shown) at the preceding stage to the data accumulating/distributing portion 31. In this event, the A/D conversion and the amplification may be applied in reverse order.

[0037] The sampling reference setting portion 31b sets the reference values that are used to exclude areas, in which

the influence of the noise appears largely, from the analog signal being output from the vibration sensing element 22d, based on the information derived from an external inputting portion 100. Here, the inputting portion 100 is an inputting means such as a mouse, a keyboard, or the like, and the user can set arbitrarily the reference values via the inputting portion 100.

[0038] The sampling portion 31c cuts out vibration, temperature, and rotation speed data serving as the time-variant data into a predetermined length data, and then executes the sampling to output the signal to the analyzing portions in the subsequent stage. When the output signal from the vibration sensing element 22d contains the larger noise than the reference value being set by the sampling reference setting portion 31b, the sampling portion 31c does not execute the sampling of the signal in a period of time containing such noise not to output the signal to the filtering processing portion 34. More particularly, the sampling portion 31c detects two points A and B at which the signal level exceeds a certain predetermined value, and then controls not to output the data to the filtering processing portion 34 and the vibration analyzing portion 35 in a time interval A to B. Accordingly, it is possible not to execute the frequency analysis within the time interval that contains the data on which the large noise is superposed, so that a possibility of executing the false abnormality diagnosis can be reduced. In this case, the sampling reference setting portion 31b and the sampling portion 31c are not always provided. Also, if the similar effect can be achieved, these portions may be arranged in another location, e.g., the preceding stage of the data accumulating portion 31a, or the like.

[0039] The temperature analyzing portion 32 calculates the temperature of the bearing based on the output signal fed from the temperature sensing element 22b, and then sends out the calculated temperature to the comparing/deciding portion 36. The temperature analyzing portion 32 has a temperature transformation table responding to characteristics of the sensing elements, for example, and calculates the temperature data based on a level of the sensed signal.

[0040] The rotation analyzing portion 33 calculates the rotation speed of the inner ring 24, i.e., the axle based on the output signal fed from the rotation sensing element 22c, and then sends out the calculated rotation speed to the comparing/deciding portion 36. For example, when the rotation sensing element 22c is composed of an encoder fitted to the inner ring 24, a magnet fitted to the outer ring 23, and a magnetism sensing element, a signal output from the rotation sensing element 22c is given as a pulse signal that responds to a shape of the encoder and the rotation speed. The rotation analyzing portion 33 contains a predetermined transformation function or transformation table in response to the shape of the encoder, and calculates the rotation speed of the inner ring 24 and the axle from the pulse signal based on the function or the table.

[0041] The vibration analyzing portion 35 executes the frequency analysis of the vibration generated in the bearing 21 based on the output signal from the vibration sensing element 22d. More specifically, the vibration analyzing portion 35 is composed of an FFT computing portion that calculates the frequency spectrum of the vibration signal and calculates the frequency spectrum of the vibration in compliance with the FFT algorithm. The calculated frequency spectrum is fed to the comparing/ deciding portion 36. Also, the vibration analyzing portion 35 may be constructed to execute the enveloping process as the preprocessing prior to the FFT to calculate the envelope of the vibration signal and thus attain a reduction of the noise. The vibration analyzing portion 35 also outputs the envelope data obtained after the enveloping process to the comparing/deciding portion 36, as the case may be.

[0042] Normally the abnormal frequency bands of the vibration caused due to the rotation of the bearing are decided depending upon a size of the bearing, the number of rolling elements, etc. Respective relationships between the defect of respective members of the bearing and the abnormal vibration frequencies generated in respective members are given as shown in FIG.4. In the frequency analysis, the maximum frequency that permits the Fourier transform (Nyquist frequency) is decided in response to a sampling time, and thus preferably the frequency that is in excess of the Nyquist frequency should not be contained in the vibration signal. Therefore, the present embodiment is constructed such that the filtering processing portion 34 is provided between the data accumulating/distributing portion 31 and the vibration analyzing portion 35, a predetermined frequency band is cut out from the vibration signal by the filtering processing portion 34, and the vibration signal containing only the cut-out frequency band is sent out to the vibration analyzing portion 35. When the axle is being rotated at a low speed in the railway vehicle, only the frequency component of 1 kHz or less, for example, may be extracted.

[0043] Also, the filtering processing portion 34 may be arranged in such a manner that the portion first causes the vibration analyzing portion 35 to calculate the frequency spectrum without the filtering process, then estimates previously the frequency band in which the peak will be observed, and then executes the filtering process in answer to the frequency band to execute newly the frequency analysis. With this arrangement, the unnecessary noise can be eliminated effectively and thus the high-precision frequency analysis can be executed.

[0044] FIG.6 is a view showing a time-variant waveform of an oscillating signal as the vibration information J3 in regarding to the vibration of the rolling bearing 21 sensed by the sensor unit 22 in the present embodiment, FIG.7 shows the frequency spectrum of the vibration signal sensed by the vibration analyzing portion 35 in the present embodiment, and FIG.8 shows the frequency spectrum of the vibration signal sensed by the vibration analyzing portion 35 in the present embodiment after the enveloping process.

[0045] In this manner, the vibration analyzing portion 35 applies the frequency analysis to the vibration signal and calculates the frequency spectrum shown in FIG.7 or FIG.8. The strong spectrum is observed at a predetermined frequency period from FIG.8. It is understood from the relational expression given in FIG.4 that this corresponds to a frequency component generated due to the damage of the outer ring 23 of the rolling bearing 21.

[0046] In FIG.3, the temperature analyzing portion 32, the rotation analyzing portion 33, and the vibration analyzing portion 35 are illustrated. But respective analyzing portions may be provided in response to the information that are sensed by respective sensing elements in the sensor unit 22.

[0047] The comparing/deciding portion 36 compares the frequency spectrum of the vibration sensed by the vibration analyzing portion 35 with the reference value saved in the internal data saving portion 37 or the reference value calculated from the frequency spectrum to decide whether or not the abnormal vibration is being generated. Where the reference values are the data of the frequency components generated due to the wear or the failure of the particular location of the bearing or predetermined values contained in the spectrum calculated every frequency spectrum. In order to expect an accuracy of the decision, the comparing/deciding portion 36 refers to the analyzed result of the temperature and the rotation speed obtained by the temperature analyzing portion 32 and the rotation analyzing portion 33 and specification data of various data of the bearing accumulated in the internal data saving portion 37, etc., simultaneously with the decision based on the comparison between the frequency components.

[0048] More particularly, if it is decided based on the frequency spectrum of the vibration that the abnormality occurs, the comparing/deciding portion 36 checks the temperature of the bearing and then decides that the serious abnormality is being generated if the temperature exceeds a predetermined value. Also, if only any one indicates the abnormality, the comparing/ deciding portion 36 decides that any abnormality occurs. Then, if both results are normal, the comparing/ deciding portion 36 decides that no abnormality occurs. If only any one indicates the abnormality, it may be decided that the abnormality occurs when the results are not varied after the decision is made in plural number of times. The comparing/deciding portion 36 outputs the result of the abnormality diagnosis to the data accumulating/outputting portion 38.

[0049] As the particular abnormality diagnosis process executed by the comparing/deciding portion 36 based on the vibration information, following methods will be listed.

(1) Method of using root-means-square values of the envelope data as the reference value

[0050] The present method calculates the frequency components generated at the time of abnormality based on the expressions in FIG.4. Then, the root-means-square values of the envelope data are calculated and then the reference values used in the comparison are calculated from the root-means-square values. Then, the frequencies that are in excess of the reference values are calculated and then compared with the frequency components generated at the time of abnormality. Then, explanation will be made with reference to FIG.9 hereunder.

[0051] First, the vibration of the bearing is sensed by the vibration sensing element 22d installed in the sensor unit 22a (step S101). The sensed signal is amplified by a predetermined amplification factor and then converted into the digital signal by an A/D converter (step S102). The vibration signal converted into the digital signal is saved in the data accumulating/ distributing portion 31 in a predetermined format (step S103).

[0052] Then, the frequency spectrum of the digital signal is calculated (step S104). Then, the filtering processing portion 34 selects a filter bandwidth that is applied to the digital signal, based on the calculated frequency spectrum (step S105). Then, the filtering processing portion 34 executes the filtering process to remove the frequency components other than the selected filter band (step S106), and then outputs the digital signal after the filtering process to the vibration analyzing portion 35. Then, the vibration analyzing portion 35 applies the enveloping process to the digital signal after the filtering process (step S107). Then, the frequency spectrum of the digital signal after the enveloping process is calculated (step S108).

[0053] At the same time, the root-means-square value of the digital signal after the enveloping process is calculated (step S109). Then, the reference value used in the abnormality diagnosis is calculated based on the root-means-square value (step S112). Where the root-means-square value is calculated as a square root of a square mean of the frequency spectrum after the enveloping process. The reference value is calculated as follows based on the root-means-square value in accordance with an Equation (1) or (2).

$$(\text{Reference value}) = (\text{Root-means-square value}) + \alpha \quad (1)$$

$$(\text{Reference value}) = (\text{Root-means-square value}) \times \beta \quad (2)$$

α, β: predetermined value variable according to the type of data

[0054] Then, frequencies generated due to the abnormality of the bearing are calculated based on a table shown in FIG.4 (step S110). Then, levels of abnormal frequency components of respective members corresponding to the calculated frequencies, i.e., an inner ring flaw component Si (Zfi), an outer ring flaw component So (Zfc), a rolling element flaw component Sb (2fb), and a retainer component Sc (fc) are extracted (step S111). Then, respective components Si, So, Sb, Sc are compared with the reference value calculated in step S112 (step S113). Then, if all component values are smaller than the reference value, it is decided that no abnormality is generated in the bearing (step S114). In contrast, if any component exceeds the reference value, it is decided that the abnormality is generated in the concerned location (step S115).

[0055] FIG.10 is a graph showing the frequency spectrum when no abnormality is generated, and FIG.11 is a graph showing the frequency spectrum when the abnormality is generated in the outer ring. In an example in FIG.10, the reference value was derived as -29.3 dB from the envelope data. If the inner ring flaw component Si(Zfi), the outer ring flaw component So (Zfc), the rolling element flaw component Sb (2fb), and the retainer component Sc (fc) are compared with a line of the reference value depicted in FIG.10, the levels of all components are smaller than the reference value. As a result, it is decided that this bearing is normal. In contrast, in the case in FIG.11, since the outer ring flaw component So (Zfc) is protruded largely from the reference value, it can be decided that the abnormality is generated in the outer ring of the bearing.

[0056] Also, FIG.12 is a graph showing a relationship between the frequency spectrum and the reference value when the retainer has the flaw. In FIG.12, a peak that is larger than the reference value is observed at a frequency fo corresponding to the flaw of the retainer. In this manner, since the presence or the absence of the peak of the generated frequency can be decided by the comparison between levels in the frequencies due to the bearing and the reference value, even a small peak shown in FIG. 12 can be diagnosed appropriately.

[0057] Here, the root-mean-square value is employed, but either a mean value such as the running means, or the like or a peak factor (=peak level/mean value) may be employed.

(2) Method of calculating a peak of the spectrum and then comparing a peak frequency and an abnormal frequency

[0058] The present method calculates the frequency components generated at the time of abnormality based on the expressions in FIG.4. Then, it is collated whether or not the peaks, which exceed a predetermined occurring number of times or exceeds the reference value, among the frequency spectrum calculated by the comparing/deciding portion 36 correspond to the frequency components at which the abnormality occurs. Then, explanation will be made in detail with reference to a flowchart shown in FIG.13 hereunder.

[0059] Since the process flows up to step S108 are similar to those set forth in the method (1), their explanation will be omitted herein. In the present method, first the peak value of the resultant frequency spectrum is calculated (step S109). Here, in order to derive the peak of the frequency, at first difference data indicating a difference between a level of a data point in each frequency component and a level of a preceding data point in each frequency component is calculated. Then, an inflection point at which a sign of the difference data is changed from plus to minus is found out, and then it is decided that the peak value appears at the frequency values in regarding to the difference data that give positive/negative criterions. In this case, only the frequency spectrum a ridge (inclination) of which shows a steep and sharp peak is selected as the object of the peak values that are necessary for the diagnosis. For this reason, only when a gradient is larger or smaller than a predetermined reference value (e.g., 1 or -1), it is decided that the frequency spectrum gives the peak.

[0060] FIG.14 is a view showing the frequency spectrum. In FIG.14, a point B out of three successive points A (X_0, Y_0), B (X_1,Y_1), C (X_2,Y_2) gives the peak. In this case, since difference data δ_1 between A and B is given as $\delta_1=Y_1-Y_0>0$ and the difference data δ_2 between B and C is given as $\delta_2=Y_2-Y_1<0$, the difference data is changed from positive to negative. Then, if a gradient $(Y_1-Y_0)/(X_1-X_0)>1$ or a gradient $(Y_2-Y_1)/(X_2-X_1)<-1$ is satisfied here, it is decided that the point B gives the peak.

[0061] Then, the abnormal frequency is calculated from the specification of the bearing based on FIG.4 (step S202). Then, the levels of the abnormal frequency components of respective members corresponding to the calculated frequency, i.e., the inner ring flaw component Si (Zfi), the outer ring flaw component So (Zfc), the rolling element flaw component Sb (2fb), and the retainer component Sc (fc) are extracted (step S203). Then, it is decided by comparing the peak frequency with the frequencies generated at the time of abnormality whether or not the peak frequency agrees with the calculated abnormal frequency (step S204). Then, if a certain peak corresponds to the abnormal frequency, it is decided that the abnormality is generated in the member that corresponds to the concerned abnormal frequency (step S206). In contrast, if the peak corresponds to no frequency, it is decided that no abnormality is generated (step S205).

(3) Method of using a fundamental frequency and a particular harmonic

[0062] The present method compares peak frequencies of a primary value as a fundamental frequency of the abnormal frequency component, a secondary value having a twice frequency of the fundamental frequency, and a quaternary value having a quadruple frequency of the fundamental frequency with the frequencies generated at the time of abnormality respectively, and then decides finally that the abnormality is generated if it is decided that the abnormality is generated at at least two frequencies, or decides that no abnormality is generated if the frequency at which it is decided that the abnormality is generated is one or less. Then, explanation will be made in detail with reference to FIG. 15 hereunder.

[0063] The process flow required until the frequency spectrum is calculated and the frequencies generated due to the abnormality are calculated is similar to the process flow in the method (1). In the present method, as shown in FIG. 15, first it is decided in the comparison whether or not the spectrum value exceeds the reference value at the frequency of the fundamental component (primary component) generated at the time of abnormality (step S301). If the spectrum value exceeds the reference value, it is decided that the primary components coincide with each other. Then, the process goes to step S302. In contrast, if the primary components do not coincide with each other, the process goes to step S311.

[0064] In step S302, it is decided whether or not the spectrum value exceeds the reference value at the frequency of the secondary component that has the twice frequency of the fundamental component generated at the time of abnormality. If the spectrum value exceeds the reference value, it is decided that the secondary components coincide with each other. Then, in step S322, it is decided finally that the abnormality is generated in the concerned location. In contrast, in S302, if the secondary components do not coincide with each other, the process goes to step S312.

[0065] Also, in step S311, it is decided whether or not the spectrum value exceeds the reference value at the frequency of the secondary component that has the twice frequency of the fundamental component generated at the time of abnormality. If the spectrum value exceeds the reference value, it is decided that the secondary components coincide with each other. Then, the process goes to step S312. In contrast, if the secondary components do not coincide with each other, the process goes to step S321, wherein it is decided finally that the abnormality is not generated in the concerned location.

[0066] In step S312, it is decided whether or not the spectrum value exceeds the reference value at the frequency of the quaternary component that has the quadruple frequency of the fundamental component generated at the time of abnormality. If the spectrum value exceeds the reference value, it is decided that the quaternary components coincide with each other. Then, in step S321, it is decided finally that the abnormality is generated in the concerned location. In contrast, if the quaternary components do not coincide with each other, it is decided finally that the abnormality is not generated in the concerned location.

[0067] FIG. 16 is a view showing the frequency spectrum when the outer ring has the flaw. It is understood that harmonics that are the natural-number multiple of Zfc as the fundamental frequency are observed. It is appreciated that, if the reference value is -10 dB in this case, the spectrum value exceeds the reference value at all the primary, secondary, and quaternary components. Therefore, according to the process in the present method, it is decided that the abnormality is generated in the outer ring.

[0068] Normally, such a situation may be considered that a large peak generated accidentally due to the influence of the noise, or the like is observed at the frequencies corresponding to the abnormality. According to the process in the present method, if the peak value does not exceed the reference value at at least two frequencies out of the primary, secondary, and quaternary components, it is not decided that the abnormality is generated. Thus, it is possible to reduce a possibility of misjudgment.

[0069] In the flowchart shown in FIG.15, the comparison is made in order of the primary, secondary, and quaternary components. But the comparison is made in order of the larger peak level. In this case, if the largest peak is smaller than the reference value, it can be decided at that time that no abnormality is generated, and thus a calculation time can be shortened. Also, a combination of the primary value, the secondary value, and the tertiary value or a combination of the secondary value, the quaternary value, and the sexenary value may be used as the combination of frequency components.

(4) Method conducting an abnormality diagnosis and estimating a degree of the damage

[0070] In the methods (1) to (3), the presence or absence of the abnormality is diagnosed. But a size of the damage can be estimated as follows. FIG.17 is a view showing the frequency spectrum after the enveloping process. In FIG. 17, the large peak is observed at the frequency Zfc, and thus it is understood that the damage is generated in the outer ring. A size of the damage generated in the outer ring in which the abnormality occurs can be estimated by comparing a peak value Ln at this Zfc and a reference level L_0 as a mean value of the overall frequency spectrum.

[0071] FIG.18 shows a relationship between a size of flaking and a level difference between peaks appearing on the

actually measured frequency spectrum data d1 and the reference level when the flaking as the damage of the raceway ring is generated in the rolling bearing. In this manner, normally the level difference is increased in proportion to a size of the damage. Therefore, conversely the size of the damage can be estimated if the level difference between the peak on the actually measured frequency spectrum data d1 and the reference level is sensed. In this event, an increase of the peak level on the actually measured frequency spectrum data d1 becomes most conspicuous at the peak that corresponds to the primary value of the frequency components. Therefore, when the abnormality is sensed, an extent of the damage can be estimated by calculating a level difference I between a primary value Ln of the harmonic components and a reference level L_0. Thus, an exchange timing of the damaged parts can be decided in response to the extent of the damage. As a result, exchange of the parts can be carried out at an appropriate timing without the excessive exchange of parts or maintenance, and thus an upkeep cost can be reduced.

(5) Method of using a level difference of a natural-number multiple harmonic component of the fundamental frequency as a reference value

[0072] The present method counts the number of times 2, 3, 4,..., n-degree levels having 2, 3, 4,..., n-tuple frequencies of the fundamental frequency respectively exceed the reference value of the primary level as the fundamental frequency of the abnormal frequency components, and then decides that the abnormality is generated when these 2, 3, 4,..., n-degree levels exceed the reference value in a predetermined number or more. More particularly, the counting is carried out when the n-degree value is {(primary level)-(n-1-)·a} (dB) or more with respect to the primary level. Where a is an arbitrary value. Then, explanation will be made with reference to a flowchart shown in FIG.19 hereunder.

[0073] FIG.19 is a flowchart showing a process flow in the present method. In the present method, the processes required until the frequency spectrum is calculated are identical to the processes in step S101 to step S108 in the flowchart in FIG.9. The processes in step S108 et seq. are shown in FIG.19.

[0074] First, the abnormal frequency due to the abnormality in the bearing is calculated every part (outer ring, inner ring, rolling element, or retainer) of the bearing by referring to the expressions (step S401). Then, the level of the frequency spectrum corresponding to the abnormal frequency is extracted (step S402). Then, levels of the frequency spectra that correspond to the natural-number multiple (2, 3, ..., n-tuple) frequencies of the abnormal frequency are extracted respectively (step S403). Here, assume that secondary, tertiary, quaternary, and quinary components having twice, thrice, quadruple, and quintuple frequencies of the abnormal frequency as the base are extracted.

[0075] Then, the levels of the secondary, tertiary, quaternary, and quinary components are checked on the basis of the primary component as the base (step S404). Here, if the levels of respective components exceed {(primary level)-3(n-1)} (dB), the count indicating that the abnormality is generated is executed. More particularly, the count indicating that the abnormality is generated is executed in respective components in following cases.

(level of the secondary component)>
(level of the primary component)-3
(level of the tertiary component)>
(level of the primary component)-6
(level of the quaternary component)>
(level of the primary component)-9
(level of the quinary component)>
(level of the primary component)-12

[0076] Then, the final abnormality decision is made by checking whether or not the count number of times indicating that the abnormality is present exceeds the predetermined number of times (step S405). Here, it is decided finally that the abnormality is generated if the count number of times indicating that the abnormality is present exceeds two times, while it is decided finally that no abnormality is generated if the count number of times is once or less.

[0077] FIG.20 is a view showing a relationship between a level of the frequency spectrum and a reference line when the inner ring of the cylindrical roller bearing (outer diameter 215 mm, inner diameter 100 mm, width 47 mm, and number of roller 14) is rotated at about 300 min^{-1}. In FIG.20, a straight line is a criterion line obtained by connecting the above reference values by a line. In the case where the bearing has the flaw, the values of the secondary components or more are in excess of the criterion line, but the peak level of the secondary and quaternary compositions, which correspond to the roller missing sound also generated in the normal condition, fall below this criterion line. Since normally the higher order components of the roller missing sound (rolling element missing sound) are low rather than the case where the outer ring has the flaw, most of the sound values fall below this criterion line, as shown in FIG.20. As a result, even when the peaks of the roller missing sound, or the like appear at the same frequencies as the case where the outer ring has the defect, it is possible to decide whether or not the bearing is abnormal or normal, with good precision by comparing the levels of the higher order components mutually.

(6) Method of using a square mean or a partial overall of a level every frequency band

[0078] The present method executes the abnormality diagnosis by using not the peak level value itself of the frequency caused due to the abnormality but a square mean or a partial overall of the level of the frequency band containing the frequency caused due to the abnormality. Here, the square mean Vi and the partial overall Si are given by following equations. Where V_{RMS} and S_{OA} are the square mean and the partial overall in the full frequency band respectively. The overall denotes a total sum in the particular specified interval.

<Formula 1>

$$Vi = \frac{1}{m}\sum_{k=1}^{m}(P_k - \bar{P}_m)^2 \qquad ...(1)$$

$$Si = \sum_{k=1}^{m} P_k \qquad ...(2)$$

$$V_{RMS} = \frac{1}{N}\sum_{i=1}^{N}(P_i - \bar{P})^2 \qquad ...(3)$$

$$S_{OA} = \sum_{i=1}^{N} P_i \qquad ...(4)$$

where

$$N \cdot \Delta f < \frac{f_s}{2} \qquad (5)$$

m: cut-out frequency bandwidth (number of data)
/Pm: spectrum mean value in the interval m
Pi: spectrum value at the frequency i
/P: spectrum mean value in the interval N
fs: sampling frequency
Δ f: width of neighboring frequencies (frequency resolution)

[0079] FIG.21 is a flowchart showing a process flow in the present method. In the present method, the processes required until the frequency spectrum is calculated are identical to the processes in step S101 to step S108 in the flowchart in FIG.9. The processes in step S108 et seq. are shown in FIG.21.

[0080] First, the abnormal frequency caused due to the abnormality in the bearing is calculated by referring to the expressions shown in FIG.4 every part (outer ring, inner ring, rolling element, or retainer) of the bearing (step S501). Then, the square mean (Vi) or the partial overall (Si) in the frequency band containing the calculated frequency, and a normalized value as the square mean (V_{RMS}) or the partial overall (S_{OA}) of the overall frequency spectrum band are calculated (step S502). Then, a quotient value obtained by dividing the square mean (Vi) or the partial overall (Si) in the primary component bandwidth by the normalized value (V_{RMS} or S_{OA}) or a difference value between them is calculated (step S503).

[0081] Then, it is decided whether or not the quotient value or the difference value is within the normal range, more particularly whether or not the quotient value or the difference value exceeds a predetermined value, by comparing/collating the quotient value or the difference value with the saved reference data (step S504). Then, if the quotient value or the difference value is more than or less than a predetermined reference value, it is decided that the abnormality is generated, and then the abnormality occurring location is identified based on the frequency band (step S505). Here, it may be determined by the actual measurement that the abnormality decision should be made depending on whether the above value is more than the predetermined reference value or is less than the predetermined reference value. Except the above case, it is decided that no abnormality is generated (step S506).

[0082] The above method will be explained by referring to the actual measured result. FIG.22 is a graph showing the frequency spectrum when the abnormality is generated in the outer ring, and FIG.23 is a graph showing the frequency spectrum when no abnormality is generated in the outer ring. The abnormal peak frequency band is present near the left end (around 10 to 20 Hz) of FIG.22. The square mean value Va of the overall spectrum is 0.016. Also, the square mean value Vn of the overall spectrum corresponding to FIG.20 is 0.008. Suppose that the frequency bandwidth extracted with respect to the abnormal frequency band (fundamental frequency) generated due to the flaw of the outer ring is 2 Hz, the value derived by normalizing the square mean value by V in this bandwidth is 90.78 in the case in FIG.22 and is 38.47 in the case in FIG.23. It is understood that, when the abnormality is generated, the normalized value is about 2.4 times larger than that in the normal condition. Therefore, if a predetermined threshold value is provided either between 90.78 and 38.47 or to a ratio between the normal condition and the abnormal condition, it can be decided that the abnormality is generated in the outer ring when the normalized value is larger than the threshold value.

[0083] Meanwhile, FIG.24 and FIG.25 show examples in which plural bands are employed. FIG.24 is a graph showing an envelope frequency spectrum of the machinery facility having the roller bearing, which has the damage in its outer ring, and the normal gear (the number of teeth; 31). In FIG.24, five frequency peaks are observed and also the secondary component to the quinary component are observed in every integral multiple of the fundamental frequency. FIG.25 shows an observed data in the normal condition corresponding to FIG.24, and no singular frequency is found.

[0084] Then, the above approach is also applied to the data in FIG.24 and FIG.25. The value derived by normalizing a sum of the square mean values in respective bands of the fundamental frequency to the quinary component, which are generated due to the flaw of the outer ring, by the square mean value of the overall spectrum is given as 11.64 in the case in FIG.24 and 5.19 in the case in FIG.25. Here, the quinary harmonic means the fifth peak that is counted from the fundamental frequency. It is understood that, when the abnormality is generated, the normalized value is about 2.2 times larger than that in the normal condition. Therefore, if a predetermined threshold value is provided either between 11.64 and 5.19 or to a ratio between the normal condition and the abnormal condition, it can be decided that the abnormality is generated in the outer ring when the normalized value is larger than the threshold value.

[0085] The above processes are the particular processing pattern when the decision to check whether or not the abnormality is caused is made by the comparing/deciding portion 36. The comparing/deciding portion 36 may be constructed to execute the abnormality diagnosis by using plural deciding methods out of these methods. In order to improve an accuracy of the abnormality diagnosis, it is preferable that the abnormality should be decided by using plural deciding methods.

[0086] The data accumulating/outputting portion 38 is a saving portion for saving the decision result of the comparing/deciding portion 36, and is composed of a hard disc, a memory medium, or the like. The data accumulating/outputting portion 38 outputs the decision result to a controlling portion 41 and a result outputting portion 42. The data accumulating/ outputting portion 38 is constructed to output the result to the controlling/processing portion 40 in real time, but is not limited to this. The data accumulating/outputting portion 38 may be constructed to output periodically to the controlling/ processing portion 40, or may be constructed to output the result only when the result is necessary for an operation of the controlling/processing portion 40 (when it is decided that the abnormality occurs), as explained in the following.

[0087] The controlling/processing portion 40 has the result outputting portion 42 as a displaying means for displaying the analyzed result or the decision result of the calculating/ processing portion 30 in a predetermined display mode, and the controlling portion 41 for feeding back a control signal S1 to a control system, which controls an operation of a driving system of the vehicle into which the bearing 21 is incorporated, in response to the decision result of the comparing/deciding portion 36.

[0088] More specifically, the result outputting portion 42 informs of the analyzed result or the decision result of the calculating/processing portion 30 by a monitor, an image display, or a printing output to a printer, and also informs of the result by flashing an alarm lamp or operating an alarm when the decision result of the calculating/processing portion 30 indicates that the abnormality is generated.

[0089] For example, when the decision result of the calculating/ processing portion 30 indicates that the abnormality is generated, the controlling portion 41 feeds a control signal S1 instructing a travel stop of the vehicle, a reduction of the speed, or the like to a travel controller of the vehicle in answer to a degree of the abnormality. In the present

embodiment, a plurality of sensor units 22 sense continuously a condition of the bearing in the bearing unit, and the calculating/processing portion 30 executes the abnormality diagnosis sequentially based on the sensed data. Therefore, the controlling/ processing portion 40 informs immediately of the abnormality when the abnormality occurs, and then performs the control of the vehicle. That is, a flow of sensing, analyzing, deciding and result outputting processes are carried out in real time.

[0090] Now, the sensor unit 22 may be constructed to execute the measurement constantly or may be constructed to execute the measurement every predetermined time. Also, instead of the real-time abnormality diagnosis, only the measurement and the accumulation of measured data may be executed during the traveling of the vehicle and then the analysis may be executed later in another location. For example, only the measurement may be carried out in the daytime and then the analysis, the decision, and the result output may be carried out together with in the nighttime.

[0091] As explained above, the axle bearing unit abnormality diagnosis system 1 in the present embodiment is the abnormality diagnosis system that diagnoses the presence or absence of the abnormality of the bearing unit of the railway vehicle axle bearing unit, and includes the sensing/processing portion 20 having a plurality of sensing elements for outputting the signal generated from the bearing unit as the electric signal, the calculating/processing portion 30 performs the calculating process to execute the abnormality diagnosis of the bearing unit based on the output of the sensing/processing portion 20, the result outputting portion 42 for outputting the decision result from the calculating/ processing portion 30, and the controlling portion 41 for feeding back the control signal to the control system of the railway vehicle based on the decision result.

[0092] Also, in the abnormality diagnosis system 1 in the present embodiment, the outputs of the sensor units 22 incorporated in advance into the bearings 21 are analyzed by respective analyzing portions 32, 33, 35 of the calculating/ processing portion 30 to check whether or not the abnormality is caused due to the wear or the failure of the constituent parts of the bearing 21. Then, the abnormality diagnosis system 1 decides the presence or absence of the abnormality by comparing the analyzed result with the reference data prepared previously in the internal data saving portion 37.

[0093] Accordingly, this abnormality diagnosis system 1 can decide whether or not the abnormality due to the wear or the failure of the constituent parts of the sensor built-in bearing 21 is present. Therefore, the presence or absence of the abnormality can be decided in the normal condition of use not to decompose the sensor built-in bearing 21 itself or the railway vehicle itself containing the bearing 21. As a result, a frequency of overhauling/assembling operations that take a lot of time and labor can be reduced, and thus maintenance/ administrative costs can be reduced.

[0094] Also, the decision is made mechanically based on the analysis and the comparison executed by specified calculating processes. Therefore, the decision is seldom varied owing to a degree of expertise or individual differences of the person in charge of inspection rather than the visual inspection in the prior art, and thus the reliability of the diagnosis to check the presence or absence of the abnormality can be improved.

[0095] Also, the sensor units 22 are installed directly into the outer ring, or the like as the constituent parts of the rotating body constituting the rolling bearing 21, and then the sensors can sense physical quantities generated from the rolling bearing 21 with high sensitivity. Therefore, such a possibility can be reduced that peaks of the frequency components of the sound or the vibration generated by other articles around the rolling bearing 21 exert a harmful influence upon an SN ratio of the signal sensed by the sensor, and thus improvement of analysis/decision precisions can be attained by improving the SN ratio of the output signal of the sensor.

[0096] As a consequence, such a possibility can be eliminated that, for example, the sensed signal of the sensor unit 22 is largely distorted by the peak of the frequency component of the noise generated when the railway vehicle passes over the rail joint, the vibration generated from the devices, and the like regardless of the bearing 21, and the like. Also, reduction of a computing load and reduction of a loss of time required for the analysis can be achieved by improving the SN ratio of the output signal of the sensor unit, and thus improvement of the analysis/decision precisions and the acceleration of the process can be achieved.

[0097] Also, in the present embodiment, since the amplifiers that which amplify the sensor output respectively are built in the sensor unit 22, the output signal of the sensor unit 22 has already been amplified to have the large amplitude. Therefore, the influence of the noise superposed on the signal transmission path between the sensor unit 22 and the calculating/processing portion 30, or the like can be suppressed. As a result, reduction of a process precision due to the noise can be prevented, and thus the reliability of the abnormality diagnosis can be improved.

[0098] In this event, the abnormality diagnosis system 1 in the present embodiment diagnoses the presence or absence of the abnormality of the bearing in the bearing unit and the abnormality occurring location, but the system is not limited to this configuration. The system may be constructed to diagnose the flat portion of the axle, or may be constructed to diagnose the presence or absence of the abnormality of the gear in the bearing unit and the abnormality occurring location. Therefore, various large-size rotating bodies that take a lot of time and labor to remove and fit the parts can be chosen as the object of the abnormality diagnosis in the present invention.

[0099] As above, the approaches (1) to (6) are described as the particular processes of the abnormality diagnosis executed by the comparing/deciding portion 36 based on the vibration information. But the present invention is not limited to the above approaches. The abnormality diagnosis may be executed by analyzing the frequency spectrum

by virtue of the cepstrum analysis.

<Second Embodiment>

[0100] Next, a machinery facility abnormality diagnosis system according to a second embodiment of the present invention will be explained in detail hereunder. In this case, the same reference symbols are affixed to the portions similar to those in the first embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0101] In the present embodiment, as shown in FIG.27, a sensing/ processing portion 51 consisting of sensing portions 51a, 51b, 51c each having a sensor unit 52 that communicates with the calculating/processing portion 30 via radio is provided in place of the sensing/processing portion 20. The sensing portions 51a, 51b, 51c are constructed by fitting the sensor unit 52 onto the outer ring 23 of the bearing 21 respectively. In the sensor unit 52, a temperature sensing element 52b, a rotation sensing element 52c, a vibration sensing element 52d, and a transmitting portion 52h for radio communication are fitted into an interior of a sensor case 52a. An amplifier for amplifying the signals sensed by the sensing elements 52b to 52d by a predetermined amplification factor may be provided to the sensing element respectively. The transmitting portion 52h transmits the signals to a receiving portion 60 provided in the calculating/ processing portion 30 via radio.

[0102] With the above arrangement, the sensor unit can be fitted to the bearing unit without regard to the wiring between the sensing/processing portion 51 and the calculating/processing portion 30, and the like. Therefore, a margin for arrangement of the sensors is increased and thus it can be facilitated to fit the sensor unit to the position that enhances a sensing precision. The calculating/processing portion 30 and the controlling/processing portion 40 may be connected via radio communication by providing the similar transmitter portion and receiver portion.

[0103] Other configurations and operations are similar to those in the first embodiment.

<Third Embodiment>

[0104] FIG.28 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a third embodiment of the present invention. In a rotating body abnormality diagnosis system 60, the sensor unit installed into the sensor built-in bearing 21 that bears the axle is improved in the abnormality diagnosis system 1 in the first embodiment, and also a installing mode of the calculating/processing portion 30 and the controlling/ processing portion 40, which execute predetermined processes based on the output signal of the sensor unit, are devised.

[0105] The particular configurations of the processing methods of the calculating/processing portion 30 and the controlling/ processing portion 40 are similar to those in the first embodiment. Therefore, the same reference numbers are affixed to the common configurations, and thus explanation of the calculating/processing portion 30 and the controlling/ processing portion 40 will be omitted herein.

[0106] A sensor unit 61 in the present embodiment is similar to the first embodiment in that, as shown in FIG.28, the sound J1, the temperature J2, the vibration J3, the rotation speed J4, the distortion J5, AE, the moving speed, the force, the ultrasonic wave, and others and that these sensed signals are amplified by the amplifier 50 (not shown) to output.

[0107] The sensor unit 60 in the present embodiment has a radio communication device that transmits the output signal fed from the amplifier 50 via radio. An output of the sensor unit 60 is sent out to a signal transmitting/receiving device 63 via radio communication.

[0108] For example, the signal transmitting/receiving device 63 is provided to sides of railway tracks, away stations, etc. at an appropriate interval within an effective range of a radio signal along the traveling route of a railway vehicle 65 on which the sensor built-in bearing 21 is mounted. The signal transmitting/receiving device 63 sends out the signal received from the sensor unit 61 to an information processing center 67 via cable or radio communication.

[0109] The information processing center 67 has the calculating/ processing portion 30 and the controlling/processing portion 40. The information processing center 67 receives the output signals of the sensor units 61 via the signal transmitting/ receiving device 63 and accumulates the signals in the data accumulating/distributing portion 31 in the calculating/ processing portion 30. Then, the data accumulating/ distributing portion 31 distributes the received signals to respective analyzing portions 32, 33, 35 in the calculating/ processing portion 30. Predetermined processes are applied to the distributed signals in respective analyzing portions 32, 33, 35.

[0110] The identification information (ID information) used to identify the sensor unit that outputs the signal are contained in the output of the sensor unit 61. The calculating/ processing portion 30 and the controlling/processing portion 40 decide from which bearing 21 the received output is sent out, based on the identification information to discriminate the data and execute the process and the accumulation every bearing. As a result, the information processing center 67 causes the calculating/processing portion 30 and the controlling/ processing portion 40 to share with a plurality of railway vehicles 65, and thus performs the central management of the abnormality diagnosis of a plurality of bearings 21.

[0111] Also, a radio communication device (not shown) for feeding back a control signal S1 to a control system of the railway vehicle 65 via radio communication is added to the controlling/processing portion 40 provided in the information processing center 67.

[0112] In the above abnormality diagnosis system 60, a margin for arrangement of the calculating/processing portion 30 and the controlling/processing portion 40 can be enhanced rather than the case where the output of the sensor unit 61 is transmitted to the calculating/processing portion via the signal line provided on the railway vehicle having the bearings, and thus the install of the rotating body abnormality diagnosis system 60 can be facilitated.

[0113] Also, since the identification information (ID information) are contained in the signal output from the sensor unit 61, the calculating/processing portion 30 and the controlling/processing portion 40 in the information processing center 67 can be shared with a plurality of railway vehicles 65. Thus, the central management of the abnormality diagnosis of a large number of bearings 21 can be carried out and thus improvement in an efficiency of the abnormality diagnosing process of the bearing 21 and reduction in a cost of the abnormality diagnosing equipment can be attained.

[0114] Other configurations and operations are similar to those in the first embodiment.

<Fourth Embodiment>

[0115] FIG.29 shows a schematic configuration of a machinery facility abnormality diagnosis system according to a fourth embodiment of the present invention. In this case, the same reference symbols are affixed to the portions similar to those in the first embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0116] In a machinery facility abnormality diagnosis system 70 in the fourth embodiment, the sensor built-in bearing 21 shown in the first embodiment is used as the bearing that bears the axle of the railway vehicle 65, and then the data sensed by the sensor unit 22 incorporated into the bearing 21 are analyzed/decided by a calculating/processing portion 73 and a controlling/processing portion 75 provided in an information processing center 71 that is provided away from the railway vehicle 65.

[0117] In the calculating/processing portion 73, constituent means for analyzing/deciding the signals output from the sensor unit 22 are common to the first embodiment, but the data accumulating/distributing portion 31 for accumulating temporarily the output data from the sensor unit 22 and also distributing the data to the analyzing portions 32, 33, 35 in response to the data type can be detachably attached easily.

[0118] Also, the railway vehicle 65 is equipped with an accumulating portion connector (not shown). The data accumulating/distributing portion 31 attached to this accumulating portion connector can accumulate the signals output by the sensor units 22 in the bearings 21 therein.

[0119] In this abnormality diagnosis system 70, the data accumulating/distributing portion 31 that accumulates the outputs of the sensor units 22 therein is removed from the railway vehicle 65 and then is carried into the information processing center 71 and connected to the calculating/ processing portion 73 in the information processing center 71. Then, various data stored in the data accumulating/distributing portion 31 are analyzed/decided by the calculating/ processing portion 73, and then the result outputting portion 27 in the controlling/processing portion 75 informs the caretaker, or the like of the decision result and the analyzed result in the calculating/processing portion 73.

[0120] After the analysis/decision of the accumulated data are completed, the data accumulating/distributing portion 31 is subjected to the maintenance such as erase of the used data, or the like, as the case may be, and then is returned to the railway vehicle 65 to use again.

[0121] The abnormality diagnosis system 70 having the above configuration is unsuited to the real-time analysis/ decision. But this system is suited to the case where the data accumulated in the data accumulating/distributing portion 31 are kept safe for a long term or are analyzed in detail.

[0122] Also, like the case of the third embodiment, the calculating/processing portion 73 and the controlling/ processing portion 75 provided in the information processing center 71 can be shared with a number of vehicles. Therefore, the abnormality diagnosis system 70 is suited to reduction in the cost of equipment required to execute the abnormality diagnosis.

[0123] Other configurations and operations are similar to those in the first embodiment.

<Fifth Embodiment>

[0124] FIG.30 shows a machinery facility abnormality diagnosis system according to a fifth embodiment of the present invention. In this event, the same reference symbols are affixed to the portions similar to those in the first embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0125] A machinery facility abnormality diagnosis system 80 in the fifth embodiment detects generation of the abnormality generated due to the wear or the failure of constituent parts of the rolling bearing 21 from the rolling bearing 21 that bears the axle of the railway vehicle. In other words, the rolling bearing 21 that bears the axle corresponds to at least one of the rotating body and the sliding member as the diagnosed object from which the presence or absence

of the abnormality is sensed, and the carriage or the railway vehicle whose axle is supported by the rolling bearings 21 corresponds to a machinery facility 90 that contains one or plural rotating bodies or sliding members.

[0126] In the case of the present embodiment, the bearing 21 is the sensor built-in bearing in which the sensor unit 22 for sensing various physical quantities such as sound, vibration, or the like generated in the rotating operation of the bearing and outputting them as the electric signal is fitted into the outer ring as the constituent parts of the bearing. A plurality of the sensor built-in bearings 21 are used in one vehicle.

[0127] The machinery facility abnormality diagnosis system 80 in the present embodiment includes a plurality of sensor units 22 provided every bearing 21, a microcomputer 81 as the calculating/processing portion that decides the presence or absence of the abnormality in the bearing 21 by analyzing the outputs of the sensor units 22 based on predetermined calculating processes and then comparing the analyzed result with reference data prepared in advance, and the controlling/processing portion 40 for displaying the analyzed result and the decision result of the microcomputer 81 in a predetermined display mode and feeding back the control signal to the control system of the railway vehicle in response to the decision result.

[0128] The physical quantity in the sliding operation (rotating operation) of the bearing 21 as the sliding member is the physical quantity that is changed in response to the rotating condition of the bearing 3. For example, various information such as sound and vibration generated by the bearing 3, rotation speed and temperature, distortion generated on the constituent parts of the sliding member, and the like may be considered.

[0129] Like the first embodiment, the sensor unit 22 includes one or plural sensing elements that sense a lot of information such as sound J1, temperature J2, vibration (vibration displacement, vibration speed, vibration acceleration) J3, rotation speed J4 of the bearing, distortion J5 generated on the outer ring of the bearing, AE, moving speed, force, ultrasonic wave, etc. as the physical quantity that is changed in response to the rotating condition of the bearing 21. Then, the sensor unit 22 sends out these sensed information to the microcomputer (calculating/processing portion) 81 as the sensed signals.

[0130] The sensor unit 22 has such a configuration that various sensors are installed/bold every sensed information in the sensor case 22a secured to the outer ring of the bearing. Also, an output amplifying means for amplifying the output signals of respective sensors to output is built in the sensor case 22a.

[0131] The reference data that are compared with the analyzed result are various physical quantities that are sensed in the normal condition of the bearing 21 as the diagnosed object by the sensor unit. More particularly, there are information such as frequency components generated by the wear and the failure of the particular location of the bearing 3, and the like, in addition to sound information of the normal bearing 21, temperature information of the bearing, vibration information, rotation speed information of the bearing, distortion information generated on the outer ring of the bearing, and others.

[0132] The microcomputer 81 is a one-chip microcomputer or a one-board microcomputer that is developed for the system in the present embodiment. The similar processes to those executed in the inside of the calculating/processing portion 30 are executed in the inside of the microcomputer 81. More specifically, as shown in FIG.31, the microcomputer 81 has the data accumulating/distributing portion 31, the temperature analyzing portion 32, the rotation analyzing portion 33, the filtering processing portion 34, the vibration analyzing portion 35, the comparing/deciding portion 36, and the internal data saving portion 37, and executes the calculating process of the electric signals as the output received from the sensor to identify the presence or absence of the abnormality of the bearing and the abnormality occurring location, as explained in the first embodiment. Then, the microcomputer 81 outputs the abnormality diagnosis result to the controlling/processing portion 40. In the present embodiment, the analyzed result in the analyzing portions 32, 33, 35 and the decision result in the comparing/deciding portion 36 are output directly to the controlling/processing portion 40. But the data accumulating/ outputting portion may be provided, like the first embodiment.

[0133] The controlling/processing portion 40 has the result outputting portion 42 as the displaying means for the analyzed result and the decision result in the microcomputer 81 in a predetermined display mode, and the controlling portion 41 for feeding back the control signal S1 to the control system, which controls an operation of a driving mechanism of the vehicle into which the bearings 21 are incorporated, in response to the decision result of the comparing/deciding portion 36. The operations/effects of the controlling/processing portion are similar to those explained in the first embodiment.

[0134] In the machinery facility abnormality diagnosis system 80 in the present embodiment explained as above, the presence or absence of the abnormality due to the wear and the failure of the constituent parts of the rolling bearing 21 can be decided by analyzing the output of the sensor unit 22, which is incorporated previously into the rolling bearing 21 as the sliding member, by virtue of the microcomputer 81 as the information processing device and then comparing the analyzed result with the reference data prepared previously. Therefore, the abnormality can be decided still in the normal condition of use without overhaul of the rolling bearing 21 itself and the railway vehicle itself.

[0135] As a result, a frequency of the troublesome overhauling/ assembling operations can be reduced and thus the maintenance/ administrative costs can be reduced. Also, since the decision is made mechanically based on the analysis and the comparison executed by specified calculating processes, the decision is hardly varied owing to a degree of

expertise or individual differences of the person in charge of inspection rather than the visual inspection in the prior art, and thus the reliability of the diagnosis to check the presence or absence of the abnormality can be improved.

[0136] Also, the information processing portion is constructed by using the microcomputer 81, and the microcomputer 81 itself can be prepared as a one-chip or one-board small dedicated unit. Therefore, the overall system can be down-sized considerably in comparison with the monitoring system that uses the general- purpose personal computer as the information processing device, and thus an occupied space required for the equipment can be reduced. As a result, the installation of the information processing portion into the machinery facility containing the sliding member (i.e., railway vehicle, or the like) can be facilitated.

[0137] Also, the sensor unit 22 is incorporated directly into the outer ring as the constituent parts constituting the rolling bearing 21, or the like, and thus the sensor unit 22 can sense the physical quantity generated by the rolling bearing 21 with high sensitivity. Therefore, such a possibility can be reduced that the peaks of the frequency components of the sound or the vibration generated by other articles surrounding the rolling bearing 21 exert the harmful influence upon the SN ratio of the signal sensed by the sensor, and thus improvement of the analysis/decision precisions can be attained by improving the SN ratio of the output signal of the sensor.

[0138] In addition, since the information processing portion can be formed in a compact size and also there is no need to use the large general-purpose casing, or the like, an earthquake- proof property as the information processing device can be improved easily. As a result, the information processing portion as well as the sensor unit 22 can be arranged in close vicinity to the rolling bearing 21, and thus the reliability of the abnormality diagnosis can be improved because the rolling bearing 21 and the microcomputer 81 are arranged closely to avoid the influence of the external noise.

[0139] Also, in the present embodiment, an output amplifying means (amplifier) for amplifying the output signal to output is built in the sensor unit itself. In this event, the output amplifying means for amplifying the sensor output may be connected between the sensor unit 22 and the microcomputer 81, or may be built in the microcomputer 81 side.

<Sixth Embodiment>

[0140] FIG.32 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a sixth embodiment of the present invention.

[0141] A machinery facility abnormality diagnosis system 100 in the present embodiment is constructed such that a single microcomputer 81 processes the information of a plurality of sensor units 22. Since remaining configurations are similar to those in the fifth embodiment, the same reference numbers as those in the fifth embodiment are affixed to the common configurations, and thus explanation of the microcomputer 81 and the controlling/processing portion 40 will be omitted herein.

[0142] In case the microcomputer 81 has an enough processing performance in reserve, the single microcomputer 81 is caused to process the information of a plurality of sensor units 22 in this manner. Therefore, the number of equipments of the expensive microcomputer 81 can be reduced and a cost reduction can be attained.

[0143] In the above embodiments, install positions of the microcomputer 81 are not particularly mentioned. It is preferable that the microcomputer 81 as well as the sensor unit 22 should be fitted to the rotating body or the sliding member or the mechanism parts for supporting the sliding member. By doing this, such a system instating mode can be realized that both the sensor unit 22 and the microcomputer 81 are arranged in close vicinity to each other on the same constituent member. Therefore, a length of the signal line between the sensor unit 22 and the microcomputer 81 is not extended, and thus generation of the disadvantages caused by interwining of the signal line, and the like can be prevented.

[0144] Also, the influence of the external noise upon the signal transmission line between the sensor unit 22 and the microcomputer 81 can be reduced, and thus the reliability of the sensed signal can be improved.

<Seventh Embodiment>

[0145] FIG.33 shows a machinery facility abnormality diagnosis system according to a seventh embodiment of the present invention.

[0146] In a machinery facility abnormality diagnosis system 110 in the seventh embodiment, the microcomputer 81 and the sensor unit 22 are mounted on a single device substrate and then fitted to the constituent parts of the rolling bearing 21 as a single processing unit 112. Since the rolling bearing 21 and the controlling/processing portion 40 to which the microcomputer 81 outputs the decision result may have the same configuration as those in the above embodiments, their explanation will be omitted herein. According to the abnormality diagnosis system 110 constructed in this manner, the fitting of the monitoring system to the machinery facility 90 can be completed by fitting the single processing unit 112 thereto, and thus a fitting workability can be improved.

[0147] In the machinery facility abnormality diagnosis system according to the present invention, the sensor unit 22

and the microcomputer 81 are not connected via the signal cable, or the like, and the signal may be transmitted/received via radio communication. When doing this, a margin for arrangement of the microcomputer 81 and the controlling/processing portion can be enhanced rather than the case where the output of the sensor unit 22 is transmitted to the microcomputer 81 via the signal cable that is provided on the equipment containing the sliding member, and thus the installation of the machinery facility abnormality diagnosis system can be further facilitated.

<Eighth Embodiment>

[0148] FIG.34(a) and FIG.34(b) show a machinery facility abnormality diagnosis system according to an eighth embodiment of the present invention.

[0149] In a machinery facility abnormality diagnosis system 151 of the eighth embodiment, a diagnosis unit 161 constructed by mounting a microcomputer containing a CPU 152 to execute the calculating process, an amplifier circuit (Amp) 153, A/D converters (ADCs) 154, 155, external memories (RAM, ROM, ROM) 156, 157, 158, and the communication circuits (LANIF, SCI) 159, 160 on a board (not shown) is installed into a case (casing) 161A. Then, a piezoelectric sensor 162, a temperature sensor 163, and a rotating pulse generator 164 are fitted to the bearing 21 as the sensors.

[0150] The piezoelectric sensor 162 detects a vibration acoustic signal generated when the rolling elements (not shown) of the bearing 21 pass over the flaw on the raceway ring (not shown), an AE (acoustic emission) signal generated when the minute crack is developing, or the like, and converts such signal into a voltage or charge signal. The voltage or charge signal is amplified at about 20 to 40 dB by a pre-amplifier (preamplifier circuit) 165 arranged in close vicinity to the piezoelectric sensor 162. Then, the signal after catered into the case 161 is converted into a voltage signal, a level of which corresponds to an input range of the A/D converter 154, by the amplifier circuit 153. The voltage signal converted by the amplifier circuit 153 is input into the A/D converter 154 via a bandpass filter (BPF) 166 and then is fed to a predetermined port of the microcomputer including the CPU 152. The A/D converter 154 is an external high-precision A/D converter with a 16-bit resolution.

[0151] Because the analog bandpass filter 166 is put at the preceding stage of the A/D converter 154 to pass the frequency of 1 kHz to 10 kHz, the low-frequency mechanical vibration and the aliasing caused due to an upper limit frequency in the A/D conversion can be prevented. This filtering function can be replaced with a digital filter such as PLD, or the like that is put at the subsequent stage of the A/D converter. Such preprocess filtering may be executed in the CPU calculation, but the preprocess filtering is separated from the CPU calculation because a processing speed and a program size are influenced.

[0152] Since the A/D converted value is obtained as the signed integer, a full-wave rectified waveform can be derived by calculating an absolute value of a finite-time wave. Because the full-wave rectified waveform is finite, the FFT operation is executed after an influence of both ends is lessened by applying the Window process. Since a floating-point operational unit is not provided to the microcomputer containing the CPU 152, a fixed point operation that can be calculated by using the integer only is used.

[0153] The resultant frequency distribution is compared with the frequency of an envelope having a damping waveform decided by the rotating speed and the number of the rolling elements in order of higher intensity. At this time, bearing specifications stored in the external memories 157, 158 and the speed value derived from the rotating pulse generator 164 are employed.

[0154] The piezoelectric sensor 162 can get acoustic/elastic wave/AE signals. But its sampling frequency is set to 100 kHz for the purpose of sensing the flaking/damage mainly.

[0155] The voltage signal generated by the temperature sensor 163 is input into the A/D converter 155 via the amplifier circuit (not shown) and is given to a predetermined port of the microcomputer including the CPU 152. The A/D converter 155 is an external high-precision A/D converter with 10-bit resolution. The temperature sensor 163 and the rotating pulse generator 164 are set to a sampling frequency that is lower than that of the piezoelectric sensor 162.

[0156] The external memory 156 is formed of RAM, and the external memories 157, 158 are formed of ROM. Also, the communication circuit 159 is composed of a LAN interface, and is connected to a LAN line (Local Area Network) 167 via a twisted pair, a coaxial cable, an optical fiber cable, or the like. When a radio LAN is employed, the communication circuit 159 is connected to the LAN line 167 via radio. The communication circuit 160 gives a serial communication interface, and is connected to a program loading/diagnostic data transmitting and receiving terminal 168.

[0157] The communication circuit 160 is used to transmit/receive in serial an extent of coincidence between the sensed frequency and respective flaw frequencies of the outer ring, the inner ring, the rolling elements, and the retainer of the bearing 21. A parallel-type communication circuit may be employed if it is used within a short distance. Preferably a dedicated IC for ensuring a security should be interposed in the communication line.

[0158] The machinery facility abnormality diagnosis system 151 further includes a timer counter (TMUCNT) 169, a direct memory access controller (DMA) 170, an interruption controller (INTC) 171, a D/A converter (DAC) 172, and an active gain control (AGC) 173. The D/A converter 172 is connected to a diagnostic output connector and/or display 174.

[0159] The timer counter 169 counts up a pulse signal generated by the rotating pulse generator 164 and then gives the number of counted pulses to a predetermined port of the microcomputer including the CPU 152.

[0160] The interruption controller 171 and the timer counter 169 are used to feed the signal to the microcomputer including the CPU 152 at a predetermined sampling period. Normally the data are transferred to the external memory 156 via the microcomputer including the CPU 152. But the direct transfer may be applied by the direct memory access controller 170 to shorten extremely the sampling period.

[0161] When the operator can come close to the diagnosis unit 161 or when the diagnosis unit 161 can be put near the machine operator, the diagnostic output connector and/or display 174 is used to give the LED display or the liquid crystal screen display via the LCD driver, give the sound output using the D/A output, or the like.

[0162] In the machinery facility abnormality diagnosis system 151, all the data digitized by the signal processing are calculated by the microcomputer including the CPU 152, and various processing programs are loaded on the external memories 157, 158 attached separately. Also, since at least one machinery facility abnormality diagnosis system 151 is used in one unit of the bearing 21, the specifications (dimensions of respective portions, material, number of the rolling elements, lubricant, date of manufacture) of the bearing 21 and the specifications (frequency characteristic, sensitivity) of the sensors 162, 163, 164 are stored in the external memories 157, 158.

[0163] Also, since RMS, peak, crutosis, peak factor, etc. are assigned to predetermined addresses of the external memory 156 as amplitude parameters, the external device can inquire about the data by using the communication function.

[0164] In the machinery facility abnormality diagnosis system 151, the piezoelectric sensor 162, the temperature sensor 163, and the rotating pulse generator 164 for sensing acoustic/ elastic wave, ultrasonic wave, and mechanical vibration, for example, are fitted to the bearing 21, and then the diagnosis unit 161 capable of amplifying/digitizing the signals generated by these sensors, then applying the calculating process to the signals by virtue of the microcomputer containing the CPU 152, and then outputting the calculated result is installed into the single case 161A. For this reason, the condition of the bearing 21 can be monitored with a simple configuration without overhaul and also the defect or the abnormality of the bearing 21 can be inspected. As a result, time and labor required to overhaul and assemble the bearing 21 can be reduced and the damage of the bearing 21 caused by the overhauling and the assembling can be prevented. In addition, since the monitoring can be executed effectively with good precision, the higher-precision diagnosis can be carried out and thus the defect that the visual inspection could overlook can be found. Also, the diagnosis unit 161 can be installed into various machinery equipments other than the bearing 21 because such diagnosis unit 161 can be formed in a compact size by using small-size sensors, the microcomputer, IC, and the circuit board, and the diagnosis unit 161 can be installed flexibly into various machinery equipments because such diagnosis unit 161 can have a communication capability, so that the diagnosis unit 161 can contribute to the reduction in a cost aspect and the energy saving measure. Since the ultrasonic pulse echo approach can be utilized by providing not only a function of amplifying the signals from respective sensors but also a function of sending the pulse signal to the piezoelectric sensor 162, for example, to the diagnosis unit 161, the damage of the mechanical sliding surface in the stationary time and the metal contact condition between the sliding surfaces in the running time can be sensed/diagnosed.

[0165] Also, in the machinery facility abnormality diagnosis system 151, one or more out of temperature, vibration displacement, vibration speed, vibration acceleration, force, distortion, acoustic, acoustic emission, ultrasonic wave, and rotating speed can be sensed by the piezoelectric sensor 162, the temperature sensor 163, and the rotating pulse generator 164. Therefore, the condition of the bearing 21 can be monitored without fail and also the defect or abnormality of the bearing 21 can be inspected without fail.

[0166] Also, in the machinery facility abnormality diagnosis system 151, the microcomputer containing the CPU 152, the amplifier circuit 153, the A/D converter circuits 154, 155, the external memories 156, 157, 158, the communication circuits 159, 160, the timer counter 169, the direct memory access controller 170, the interruption controller 171, the D/A converter 172, and the active gain control 173 are employed in the calculating process. Therefore, the diagnosis system that is excellent in a cost aspect can be realized by using a combination of the general-purpose parts without custom parts.

[0167] Also, in the machinery facility abnormality diagnosis system 151, one process or more out of calculation of feature parameters of a standard deviation and a peak factor, envelope detection, FFT, filter, wavelet transform, short-time FFT, and calculation of a feature frequency due to the defect of the rotating body and the comparing/deciding processes can be executed in a digital fashion. Therefore, since the monitoring can be executed effectively with good precision, the higher- precision diagnosis can be carried out and thus the defect that the visual inspection could overlook can be found surely.

<Ninth embodiment>

[0168] FIG.35(a) and FIG.35(b) show a machinery facility abnormality diagnosis system according to a ninth embodiment of the present invention.

[0169] In a machinery facility abnormality diagnosis system 181 of the ninth embodiment, an impact sensor 183 that is formed as a bimorph of a piezoelectric ceramic element is installed a case 182A of a diagnosing unit 182, and also the impact sensor 183 and the temperature sensor 163 are arranged integrally in the case 182A. Since other configurations are similar to those in the eighth embodiment, the same reference numbers as those in the eighth embodiment are affixed to the common configurations, and thus explanation about them will be omitted herein.

[0170] In the machinery facility abnormality diagnosis system 181, an impact generated when the bearing 21 goes down is detected. Normally, the feature parameter computing expressions for the natural impulse elastic waves generated at the time of failure of the bearing 21 are stored in the external memory 158. If the feature parameter decided based on a waveform signal, which is digitized via the impact sensor 183, an amplifier filter portion 184, and the A/D converter 155 as the high-precision external A/D converter with 10-bit resolution, and the rotation speed has the dimension, mean value of the vibration value, standard deviation (rms), maximum value, peak (average of ten values counted from the maximum absolute value), etc. are calculated previously. Meanwhile, if the feature parameter is dimensionless, wave waveform, peak factor, impact index, skewness, crutosis, etc. are calculated previously. The approach of sensing the defect of the bearing 21 from the frequency domain data, which is obtained by the FFT operation by the microcomputer including the CPU 152, is similar to the seventh embodiment. In this event, the impact sensor 183 and the amplifier filter portion 184 may be integrated as far as the frequency band permits.

[0171] The data of cross frequency of the feature parameter in other frequency domain, extreme frequency, degree of irregularity, degree of contain of the rotating frequency, degree of contain of the rotating frequency harmonics, degree of contain of the defect feature frequency component powers of respective parts of the bearing 21, etc. are registered in the external memory 156, and then are updated in a predetermined period.

[0172] The degradation diagnosis of the bearing 21 by the feature parameters may be executed by the microcomputer including the CPU 152 in the case 182A. Alternately, if the diagnosis is recognized by using the regression analysis in which a large number of parameters are related complicatedly or the learning algorithm using the neural network, the data may be processed by transmitting the data to the computer, into which the recognition program is installed, separately via the LAN line 167, or the like. Otherwise, it is preferable that the custom IC exclusively used for the recognition program or another microcomputer should be added.

[0173] In the machinery facility abnormality diagnosis system 181, the diagnosis unit 182 can be constructed by using small- size electronic parts, small-size sensors, and short wirings in addition to the microcomputer including the CPU 152. Thus, such diagnosis unit 182 can be installed into the space-saving case 182A and thus the inspection/diagnosis can be executed by such diagnosis unit 182 incorporated into the bearing 21. Also, the diagnosis unit 182 can be constructed in a compact size, and a cost can be further reduced by omitting the signal line extended from the sensors to the calculating/processing device.

<Tenth Embodiment>

[0174] FIG.36 shows a machinery facility abnormality diagnosis system according to a tenth embodiment of the present invention.

[0175] In a machinery facility monitoring system 191 of the tenth embodiment, a DSP (digital signal processor, capable of executing a product-sum operation in a filtering operation and a data transfer at a high speed) 192 is incorporated into the calculating/processing portion.

[0176] In this embodiment, the eighth and ninth embodiments are revised such that the DSP 192 takes charge of the digital signal processing such as digital filtering, FFT, and the like and also the microcomputer containing the CPU 152 executes other processes. Also, for the same purpose, the calculating/processing portion can be constructed by using a PLD (programmable logic device) without the DSP.

[0177] In the above embodiment, the sliding member that is diagnosed to check whether or not the abnormality is present is not limited to the rolling bearing. More particularly, the sliding bearing, and the like correspond to the sliding member in addition to various rolling bearings. Also, constituent parts of the longitudinal motion mechanism such as the ball screw, the linear guide, etc. correspond to the sliding member as the diagnosis object of the present invention. Also, various large-size rotary sliding members such as the gear or the wheel of the railway vehicle, etc., which take enormous time and labor to remove and fit, can be selected as the abnormality diagnosis object of the present invention.

[0178] In the above embodiment, the machinery facility abnormality diagnosis system itself is equipped with the controlling/processing portion that feeds back the signal responding to the decision result to a controller that controls an operation of the mechanism, into which the sliding members are incorporated, of the machinery facility such that the sensing of the abnormality by this abnormality diagnosis system leads quickly to the maintenance and the operation management of the machinery facility. However, the controlling/ processing portion may be constructed as the independent equipment (system) that can be connected to the abnormality diagnosis system.

<Eleventh Embodiment>

[0179] Next, a machinery facility condition monitoring system according to an eleventh embodiment of the present invention will be explained hereunder. In this event, the same reference symbols are affixed to the portions similar to those in the fifth embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0180] As shown in FIG.37, a railway vehicle facility 210 as a machinery facility, to which a condition monitoring system 230 (see FIG.38) is applied, includes a double row tapered roller bearing 211 as at least one of the rotating body and the sliding member as the sensed object and a bearing housing 212 constituting a part of the railway vehicle carriage.

[0181] The double row tapered roller bearing 211 has a pair of inner rings 214, 214 having inner ring raceway surfaces 215, 215 inclined like a tapered outer surface on their outer peripheral surfaces, a single outer ring 216 having a pair of outer ring raceway surfaces 217, 217 inclined like a tapered inner surface on an inner peripheral surface, tapered rollers 218 as a plurality of rolling elements arranged in double rows between the inner ring raceway surfaces 215, 215 of the inner rings 214, 214 and the outer ring raceway surfaces 217, 217 of the outer ring 216, annular pressed retainers 219, 219 for holding reliably the tapered rollers 218, and a pair of sealing members 220, 220.

[0182] The bearing housing 212 has a housing 221, a front lid 222 fitted to a front end portion of the housing 221, and a rear lid 223 fitted to a rear end portion of the housing 221.

[0183] An axle 224 is press-fitted into the inner ring of the double row tapered roller bearing 211. A radial load imposed by weights of various members, etc. and any axial load are applied to the double row tapered roller bearing 211. An upper area of the outer ring 216 serves as a loading range. Where the loading range denotes an area in which the load is applied to the rolling element.

[0184] The housing 221 constitutes a side frame of the railway vehicle carriage, and is formed like a circular ring to cover the outer peripheral surface of the outer ring 216. A pair of recess portions 225, 225 are formed on the outer peripheral surface of the housing 221 in the center portion of each row of the double row tapered roller bearing 211 in the axial direction. The recess portions 225, 225 receive therein the sensor units 22, 22 constituting a part of the condition monitoring system 230 and having the same configuration as the first embodiment.

[0185] Next, the condition monitoring system 230 of the eleventh embodiment will be explained hereunder. The condition monitoring system 230 is different from the fifth embodiment only in the process that is executed by a comparing/deciding portion 252 in a calculating/processing portion 250 constructed by the microcomputer, but the processes in the sensing/ processing portion 20 and the controlling/processing portion 40 are equivalent to the abnormality diagnosis system in the fifth embodiment. In other words, the condition monitoring system 230 includes the sensing/ processing portions 20, 20 having the sensor units 22, 22 provided to the rows of the double row tapered roller bearing 211 respectively to output the condition of respective rows as the electric signal, the calculating/processing portions 250, 250 for calculating/processing the electric signals output from the sensor units 22, 22 to decide the conditions such as the defect, the abnormality, or the like of the railway vehicle facility 210, and the controlling/processing portion 40 for controlling/ outputting the decision result of the calculating/processing portions 250, 250.

[0186] The sensor units 22, 22 has sensors as a plurality of sensing elements that can sense the information such as sound J1, temperature J2, vibration J3, rotation speed J4, distortion J5, AE (acoustic emission), moving speed, force, ultrasonic wave, etc., which are generated from the machinery facility during the running, as the physical quantity that changes in response to the rotating state of the bearing 211 and then output the information to the calculating/ processing portions 250, 250 as the electric signal. Here, since the calculating/ processing portions 250, 250 can appropriately distribute/ process the electric signals every sensed information, a plurality of sensing elements for sensing independently the particular signal such as sound, temperature, vibration, rotation speed, distortion, AE, moving speed, force, ultrasonic wave, or the like respectively may be employed in combination as the sensor units 22, 22, otherwise a composite sensor unit capable of sensing a plurality of information at the same time may be employed as the sensor unit 22.

[0187] Also, the fitting position of the sensor unit 22 is selected on the outer peripheral portion of the housing 221 in the loading range of the radial load. Therefore, when the damage is caused on the bearing raceway surface, for example, a collision force generated when the rolling element passes over the damaged portion is larger in the loading range than the non-loading range. Thus, the abnormal vibration can be sensed in the loading range of the bearing with good sensitivity.

[0188] In addition, the sensor unit 22 is fitted into the recess portion 225 formed in the housing 221. Therefore, since the sensor unit 22 is never affected by the fitting state of the sensor unit 22 and the surrounding environment (noise, moisture, wind pressure, etc.), the signal can be sensed at a high SN ratio (noise-to-signal ratio) with high precision. Here, the sensor unit 22 may be incorporated into the rotating body, the sliding member, or the like.

[0189] Also, it is preferable that the function or the process of waterproof, oil-resistant, dustproof, rust-preventive, moisture-proof, heat-resistant, and electromagnetic noise- resistant properties should be added or applied to the sensor unit 22 to lessen the influence of the noise. In addition, it is more preferable that an amplifier function should be built

in the sensing/processing portions 20, 20 and thus there is no need to provide the special amplifier and the anxiety in regard to the entering of the noise from the intermediate cable, or the like can be removed.

[0190] The calculating/processing portions 250, 250 execute the calculating/processing operations to decide the condition such as the defect, the abnormality, or the like of the machinery facility based on the electric signals output from the sensing/ processing portions 20, 20. Such operations are executed by the microcomputer. The microcomputer consists of an IC chip on which CPU, MPU, DSP, etc. are mounted, a memory, and the like.

[0191] As shown in FIG.39, each of the calculating/processing portions 250, 250 includes the data accumulating/distributing portion 31, the temperature analyzing portion 32, the rotation analyzing portion 33, the filtering processing portion 34, the vibration analyzing portion 35, the comparing/deciding portion 252, and the internal data saving portion 37. These portions except the comparing/deciding portion 252 have the equivalent functions to those in the first embodiment.

[0192] The data accumulating/distributing portion 31 receives the electric signals fed from respective sensing elements and accumulates them temporarily, and also has collecting and distributing functions of allocating the signal to any of the analyzing portions 32, 33, 35 in response to the type of the signal. Various signals are A/D-converted into the digital signal by an A/D converter (not shown) before they are fed to the data accumulating/distributing portion 31, then are amplified by an amplifier (not shown), and then are sent to the data accumulating/distributing portion 31. In this event, the A/D conversion and the amplification may be applied in reverse order.

[0193] The temperature analyzing portion 32 calculates the temperature of the bearing 211 based on the output signal from the sensing element that senses the temperature information J2, and then transmits the calculated temperature to the comparing/deciding portion 252. The analyzing portion 32 has a temperature conversion table that responds to characteristics of the sensing elements, and calculates the temperature data based on a level of the sensed signal.

[0194] The rotation analyzing portion 33 calculates the rotation speed of the inner ring 214, i.e., the axle 224, based on the output signal from the sensing element that senses the rotation speed information J4, and then transmits the calculated rotation speed to the comparing/deciding portion 252. In this case, when the sensing element is composed of an encoder fitted to the inner ring 214, a magnet fitted to the outer ring 216, and a magnetism sensing element, the signal output from the sensing element is given as a pulse signal that responds to a shape of the encoder and the rotation speed. The rotation analyzing portion 33 has a predetermined transformation function or transformation table in response to a shape of the encoder, and then calculates the rotation speed of the inner ring 214 and the axle 224 in compliance with the function or the table.

[0195] The vibration analyzing portion 35 executes the frequency analysis of the vibration generated in the bearing 211, based on the output signal from the sensing element that senses the vibration information J3. More particularly, the vibration analyzing portion 35 is an FFT calculating portion for calculating the frequency spectrum of the vibration signal, and calculates the frequency spectrum of the vibration based on the FFT algorithm. Then, the calculated frequency spectrum is transmitted to the comparing/deciding portion 252. Also, the vibration analyzing portion 35 may execute the absolute-value process and the envelope process as the preprocessing of FFT, and may convert the frequency spectrum into the frequency component necessary for the diagnosis only. The vibration analyzing portion 35 may also output the envelope data obtained after the envelope process to the comparing/deciding portion 252, as the case may be.

[0196] Normally, the abnormal frequency band of the vibration generated due to the rotation of the bearing are decided depending upon a size of the bearing, the number of the rolling elements, etc. The relationships between the defects of respective members of the bearing and the abnormal vibration frequencies generated in respective members are given as shown in FIG.4. In the frequency analysis, the maximum frequency at which the Fourier transform can be applied (Nyquist frequency) is decided according to the sampling time. Thus, preferably the frequency that is in excess of the Nyquist frequency should not be contained in the vibration signal. Therefore, the present embodiment is constructed such that the filtering processing portion 34 is provided between the data accumulating/distributing portion 31 and the vibration analyzing portion 35, then a predetermined frequency band is cut out by the filtering processing portion 34, and then the vibration signal containing only the cut-out frequency band is transmitted to the vibration analyzing portion 35. When the axle is rotating at a low speed in the railway vehicle, only the frequency component of 1 kHz or less, for example, may be extracted.

[0197] In FIG.39, the temperature analyzing portion 32, the rotation analyzing portion 33, and the vibration analyzing portion 35 are illustrated. The analyzing portions may be provided in answer to the information that are sensed by respective sensing elements in the sensor unit.

[0198] The comparing/deciding portion 252 compares/collates the results analyzed by the temperature analyzing portion 32, the rotation analyzing portion 33, and the vibration analyzing portion 35 with the information as the diagnosis reference, which is used to check the presence or absence of the abnormality of the bearing, every first time period t_1 to provisionally diagnose whether or not the abnormality is generated in the bearing. Also, the comparing/deciding portion 252 transmits the provisional diagnosis results, which have been compared/collated every first time period t_1,

to the internal data saving portion 37 to save them.

[0199] In addition, when the comparing/deciding portion 252 has executed the comparison/decision predetermined number of times or a second time period t_2 that is longer than the first time period t_1 has elapsed, such comparing/deciding portion 252 makes the total evaluation, in which the bearing is considered as the abnormal state when the number of times the bearing is diagnosed provisionally as the abnormality exceeds a threshold value, based on the provisional diagnosis results saved in the internal data saving portion 37, and thus diagnoses the presence or absence of the abnormality in the bearing and its abnormal location. In this event, the total evaluation may be constructed to decide an extent of abnormality based on the number of times the bearing is diagnosed provisionally as the abnormal state and then diagnose the presence or absence of the abnormality and its abnormal location.

[0200] More specifically, the comparing/deciding portion 252 compares/collates the frequency spectrum of the vibration calculated by the vibration analyzing portion 35 with the reference values saved in the internal data saving portion 37 every first time period t_1 to provisionally diagnose whether or not the abnormal vibration is being generated. Where the reference values are data values of frequency components due to the wear and the damage of the particular location of the bearing calculated based on the rotation speed signal of the period signal as the operating signal of the machinery facility.

[0201] As the provisional diagnosis processing method executed by the comparing/deciding portion 252 based on the vibration information, any one of above methods (1) to (3) and (5) to (6) may be employed.

[0202] The comparing/deciding portion 56 executes the comparison/collation every first time period t_1 by using the above methods (1) to (3) and (5) to (6), and then transmits the provisional diagnosis result about the presence or absence of the abnormality to the internal data saving portion 37 to save the result therein. Also, when the comparing/deciding portion 252 has executed the comparison/decision predetermined number of times or a second time period t_2 that is longer than the first time period t_1 has elapsed, such comparing/deciding portion 252 makes the total evaluation, in which the bearing is considered as the abnormal state when the number of times the bearing is diagnosed provisionally as the abnormality exceeds a threshold value, based on the provisional diagnosis results saved in the internal data saving portion 37, and thus diagnoses the presence or absence of the abnormality in the bearing and its abnormal location.

[0203] In this case, the result of each sensed object in the comparing/deciding portion 56 may be saved in a storing medium such as memory, HDD, or the like, or the result may be transmitted to the controlling/processing portion 60.

[0204] The controlling/processing portion 40 has the result outputting portion 42 as a displaying means for displaying the analyzed result and the decision result of the calculating/ processing portions 250, 250 in a predetermined display mode, and the controller 41 for feeding back the control signal responding to the decision result of the comparing/deciding portion 252 to the control system that controls the operation of the driving mechanism of the vehicle into which the bearing 211 is fitted.

[0205] More particularly, the result outputting portion 42 informs of the analyzed result and the decision result of the calculating/processing portion 250 by the monitor, the image display, the printing output to the printer, and also informs of the abnormality by the alarm device such as the light, the buzzer, or the like when the decision result of the comparing/deciding portion 252 indicates that the abnormality exists.

[0206] For example, when the decision result of the comparing/ deciding portion 252 indicates that the abnormality is present, the controller 41 feeds the control signal indicating the travel stop of the vehicle, the reduction of speed, or the like to a travel controller of the vehicle in response to an extent of the abnormality. In the present embodiment, a plurality of sensor units 22 measures continuously the condition of the bearing of the bearing unit, and the calculating/processing portion 250 conducts sequentially the abnormality diagnosis based on the measured data. Therefore, the controlling/processing portion 40 informs of the abnormality immediately to execute the control of the vehicle when the abnormality occurs. In other words, a flow of sensing, analyzing, deciding, and result outputting are carried out in real time.

[0207] In this case, any means may be employed to transmit the signal between the sensing/processing portion 20, the calculating/processing portion 250, and the calculating/ processing portion 250 if the signal can be transmitted/received precisely. The cable may be employed or the radio may be employed in light of the network.

[0208] Next, the diagnosis process in the condition monitoring method in the present embodiment will be explained with reference to FIG.40 hereunder.

[0209] First, a counter in the microcomputer is initialized into n=0 (step S601), and the diagnosis is started. Then, the signal such as the sound, the vibration, or the like generated from the railway vehicle facility 210 and sensed by the sensor in the sensing/processing portion 20 is input into the microcomputer (step S602). Then, the signal generated from the railway vehicle facility 210 is converted into the digital signal by the A/D converter (step S603). Then, the digital signal is subjected to the amplifying process by the amplifier (step S604). After the amplifying process is executed, the counted value of the counter is set to n=n+1 (step S605). Then, the filtering process is applied to the amplified digital signal by the filtering processing portion 34 (step S606), and thus the noise component is removed or the particular frequency component is extracted.

[0210] Then, the digital signal, after the filtering processing, is sent to the vibration analyzing portion 35, and the analyzing process such as the enveloping process, the frequency analysis, etc. are executed there (steps S607, S608). Thus, the frequency components based on the actually measured data representing the signals sensed from the railway vehicle facility 210 are derived. Meanwhile, the rotation speed signal of the railway vehicle facility 210 is sensed by the sensor in the sensing/processing portion 20 (step S609). Then, a theoretical frequency component generated due to the damage of the railway vehicle facility 210 and serving as a reference value is calculated based on the rotation speed signal (step S610). Then, the frequency components based on the actually measured data are compared/collated with the theoretical frequency component calculated in step S610 by the comparing/deciding portion 252 every first time period t_1 according to any of the above approaches (1) to (3) and (5) to (6) (step S611), and the provisional diagnosis to check whether or not the abnormality is present in the particular location of the railway vehicle facility is executed. The result is saved together with the counter value n in the internal data saving portion 37 (step S612).

[0211] Then, the counter value n is compared with a predetermined number of times N (step S613). Then, if the counter value n is smaller than the predetermined number of times N, the process goes back to step S602 and then the processes in steps S602 to S612 are repeated. In contrast, if the counter value n is in excess of the predetermined number of times N, the evaluation in which the bearing is considered as the abnormal state when the number of times the bearing is diagnosed as the abnormal state in the provisional diagnosis exceeds the threshold value (referred to as the "total evaluation" hereinafter) is executed by using N saved results, and thus the presence or absence of the abnormality in the railway vehicle facility 210 and its location are diagnosed (step S614). Then, the diagnosis result is saved or is fed to the controlling/processing portion 40, and then the diagnosis result is displayed (step S615) or the feedback control is applied by the controlling portion 41. Thus, the diagnosis is ended.

[0212] As a consequence, in the condition monitoring method in the present embodiment, the total evaluation in which the presence or absence of the abnormality and its location are diagnosed by using plural compared/collated results is employed. Therefore, the influence of the impulsive noise, etc. upon the diagnosis can be lessened and thus the monitoring can be executed effectively with good precision.

[0213] In the present embodiment, since the frequency component is compared/collated every first time period t_1, the timing in the total evaluation may be evaluated by employing any second time period t_2 longer than the first time period t_1 instead of the predetermined number of times N.

[0214] Also, the amplifying process and the filtering process in the condition monitoring method in the present embodiment may be executed arbitrarily, and thus carried out as the case may be.

[0215] In addition, in step S114 in FIG.40, the total evaluation in which the presence or absence of the abnormality and its location are decided by comparing the number of times the bearing is provisionally diagnosed as the abnormal state with the threshold value is employed. Alternately, as a variation of the present embodiment, the condition monitoring can be executed by using the total evaluation in which an extent of the damage is decided based on the number of times the bearing is provisionally diagnosed as the abnormal state. As a result, the maintenance can be applied on schedule to the machinery facility an operation of which is not immediately stopped, or the like.

[0216] In the present embodiment, the condition monitoring is applied to the double row tapered roller bearing in the railway vehicle facility. But the condition monitoring may also be applied to other machinery facilities such as a machine tool, the windmill, and others.

[0217] Also, the double row tapered roller bearing as the rolling bearing is employed as the rotating body or the sliding member. But the condition monitoring method and system can also be applied to the ball screw, the linear guide, the linear ball bearing, or the like in addition to the rolling bearing. In this case, as the operation signal of the machinery facility used to calculate the reference value in the comparison/ collation, the rotation speed signal is used in the case of the rolling bearing, the ball screw, or the like as the rotating body whereas the moving speed is used in the case of the linear guide, the linear ball bearing, or the like as the sliding member.

[0218] Further, if the sensor including at least one sensing-element selected from at least sound, temperature, vibration, rotation speed, distortion, AE, and moving speed is provided, the presence or absence of the abnormality can be analyzed by the condition monitoring method and system. But it is preferable that the presence or absence of the abnormality should be analyzed by using at least one of the sensing elements of sound, vibration, and AE. Also, from an aspect of capable of utilizing the past abnormality database, it is desired to analyze the presence or absence of the abnormality by using the vibration information. However, in case the abnormality should be sensed in an initial stage of occurrence of the minute crack or in case the internal defect should be sensed, it is appropriate to employ the AE information in place of the vibration information. If the temperature information is employed in combination with the vibration information or the AE information, such information can have the larger effect than the case where such information is employed solely.

<Twelfth Embodiment>

[0219] Next, a machinery facility abnormality diagnosis system according to a twelfth embodiment of the present

invention will be explained hereunder. In this event, the same reference symbols are affixed to the portions similar to those in the first embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0220] FIG.41 is a view showing a bearing housing 301 of the railway vehicle bearing unit serving as the machinery facility to which an abnormality diagnosis system 310 according to the twelfth embodiment of the present invention is applied. The bearing housing 301 is fitted to cover an end portion of the axle of the railway vehicle, and holds rotatably the axle of the railway vehicle via a bearing (not shown in FIG.41) incorporated into the inside. Also, a cover 302 for covering the end portion of the axle of the railway vehicle is fitted to a housing 303 in the bearing housing 301.

[0221] The bearing housing 301 is fixed by four bolts 304 provided to four corners via the housing 303. Also, a hole used to measure the temperature of the bearing is provided to a side surface of the housing 303 and is stopped with a bolt 305. In the present embodiment, the sensor unit 22 of the above sensing/processing portion 20 is fitted to an end surface of the bolt 304 or the bolt 305, and the signals generated from the bearing in the bearing housing are sensed by respective sensors in the sensor unit 22.

[0222] FIG.42 is a view showing an overall configuration of the abnormality diagnosis system 310 using the sensor unit 22 in the present embodiment. As shown in FIG.42, a rolling bearing 306 is put into the bearing housing 301. The rolling bearing 306 is constructed by arranging rolling elements 309 made of a plurality of balls or rollers between an outer ring 307 fitted into the housing 303 and an inner ring 308 fitted onto the axle of the railway vehicle. Thus, the bearing housing 301 bears rotatably the axle of the railway vehicle via the rolling bearing 306.

[0223] As shown in FIG.42, the sensor unit 22 is fitted to the end surface of the bolt 304 or 305 secured to the surface of the housing 303. The sensor unit 22 can be fitted to the end surface of the bolt 304 used to fix the bearing housing, but the sensor unit may be fitted to the end surface of the bolt 305 used to stop the temperature sensing hole, as described above. Normally this bolt 305 is given to every rolling bearing 6 fitted to the inside. For example, in the case of the double row bearing, the fitting location can be selected on the row located on the wheel side, the row located on the motor side, the middle location, or the like according to the purpose. But it is preferable that, for convenience of the fitting operation, the bolt 305 should be fitted to the wheel side and the sensor unit 22 should be provided to the end surface of the bolt 305. Also, the sensor unit 22 can be fitted to not the end surface of the bolt 305 but the side surface or the inside of the hole that is stopped with this bolt 305.

[0224] It is preferable that the sensor unit 22 and the bolts 304, 305 should be tightly fitted/fixed without unsteadiness, looseness, or the like. More particularly, in view of the running conditions, the fitting conditions, characteristics of the sensor, and so on, the suitable fitting approach can be selected appropriately among various approaches such as screwing, bonding, magnet, inserting, molding integrally with the bolt, etc.

[0225] Also, in case the fitting location of the sensor unit 22 is chosen in the noisy area, preferably the sensor unit 22 should be fitted to be isolated from the circumference. If the sensor can be isolated from the circumference, the noise can be reduced and also the SN ratio can be improved.

[0226] In addition, in order to execute the sensing at the high SN ratio, it is preferable that the sensor unit 22 should be fitted in the loading range of the rolling bearing 306, as indicated by A1 in FIG.5, like the first embodiment. If the sensor unit 22 is fitted to the portion to which the load is applied (loading range), the signal can be sensed with good sensitivity and thus the higher-precision measurement can be done.

[0227] Also, in case the sensor is fitted inevitably in the non-loading range, e.g., when no space is found in the loading range to fit the sensor, when the high-tension cable that emits the noise is provided in the loading range, or the like, it is preferable that the sensing sensitivity of the signal can be enhanced by executing the filtering process.

[0228] Here, the sensor unit 22 has the similar structure/ functions to those of the sensor unit used in the first embodiment. Also, the calculating/processing portion 30 and the controlling/processing portion 40 shown in FIG.42 have the similar structure/functions to those of the sensor unit used in the first embodiment.

[0229] According to the abnormality diagnosis system 310 of the present embodiment, the sensing/processing portion 20 consisting of the sensor unit 22 that is fixed to the end surface of the bolt 304 or 305, which is screwed into the housing 303 of the bearing housing 301 that supports the rolling bearing 306 as the rotating body in the railway vehicle, and has the sensing element to output the signal generated from the rolling bearing 306 as the electric signal, the calculating/processing portion 30 for conducting the abnormality diagnosis of the bearing unit based on the output of the sensor unit 22, and the controlling/processing portion 40 for feeding back the control signal to the control system of the railway vehicle based on the decision result of the calculating/processing portion 30 are provided.

[0230] More specifically, like the first embodiment, the calculating/processing portion 30 includes the data accumulating/distributing portion 31 for accumulating the electric signal fed from the sensing/processing portion 20 and distributing the signal to the suitable distributing route according to the type of the signal, the analyzing portions 32, 33, 35 for calculating the predetermined physical quantity in regarding to the railway vehicle as the machinery facility based on the electric signal distributed from the data accumulating/ distributing portion 31, the internal data saving portion 37 as the first data saving portion in which machine equipment data concerning to the machine equipment are saved, the comparing/ deciding portion 36 for conducting the abnormality diagnosis of the machine equipment by comparing the physical quantity calculated by the analyzing portion with the machine equipment data saved in the internal data

saving portion, and the data accumulating/outputting portion 38 as the second data saving portion for saving the analyzed result by the analyzing portion and the abnormality diagnosis result by the comparing/deciding portion.

[0231] According to the abnormality diagnosis system 310, since the physical information about the rolling bearing 306 are collected by using the sensor unit 22 and the abnormality of the rolling bearing 306 is diagnosed based on the physical information to execute the control, the defect of the rolling bearing 306 can be sensed without decomposition of the bearing housing 301. Therefore, the time and labor required for the decomposition and the assembling of the bearing housing 301 can be reduced and also the damage of the rolling bearing 306 and the bearing housing 301 attendant upon the assembling after the decomposition can be prevented. Also, in the present embodiment, since the diagnosis is made by the abnormality diagnosis system 310 based on the predetermined references, it is possible to find the defect that the visual inspection may overlook.

[0232] Also, according to the present embodiment, since the sensor unit 22 is fixed onto the bolt 304 or 305, there is no need to provide particularly the flat surface, onto which the sensor unit 22 is fitted, on the bearing housing 301. Therefore, the sensor unit 22 can be fitted without reform of the bearing housing 301. As a result, the abnormality diagnosis can be conducted by installing the sensor unit 22 of the abnormality diagnosis system 310 into the bearing housing 301 without extra time/labor and cost.

[0233] In the present embodiment, explanation is made of the rolling bearing in the bearing housing of the railway vehicle as an example, but the present invention is not limited to this. The present invention can also be applied to other rotating parts (gear, wheel itself) of the railway vehicle, the windmill, the reduction gear, the electric motor, the ball screw, the linear guide, and others.

[0234] Also, the calculating/processing portion 30 may have the functions of the calculating/processing portion achieved by the microcomputer 250 in the eleventh embodiment.

[0235] Also, as shown in FIG.43, the calculating/processing portion 30 of the abnormality diagnosis system 310 in the present embodiment may be constructed by the one-chip or one-board microcomputer 81 shown in the fifth to tenth embodiments, or may be constructed by the IC chip. In addition, the controlling/processing portion 40 may also be constructed by the one-chip or one-board microcomputer or the IC chip. Also the microcomputer in which the calculating/processing portion 30 and the controlling/processing portion 40 are integrally provided may be loaded on the machine equipment such as the vehicle, or the like.

[0236] Also, as shown in FIG.44, the controlling/processing portion 40 may be removed from the vehicle and installed on the ground, and then the radio communication may be established between a transmitter/receiver 370 provided on the vehicle and a transmitter/receiver 380 provided adjacent to the railway. In this case, the functions corresponding to the controlling/ processing portion 40 can be provided to the information processing center provided on the ground, for example. This information center may be constructed to receive the information from the microcomputers 81 provided to a plurality of vehicles respectively and to collectively control a plurality of vehicles intensively, for example. In this case, the ID number, or the like may be added to the data sent out from the vehicles respectively to identify the information of respective vehicles. Similarly the sensor unit 22 and the microcomputer 81 may be connected via radio communication.

[0237] As a result, the signal transmission between the sensing/processing portion 20 and the calculating/processing portion 30 or the calculating/processing portion 30 and the controlling/processing portion 40 can be made without a wire connection.

<Thirteenth Embodiment>

[0238] Next, a bearing unit according to a thirteenth embodiment of the present invention will be explained hereunder. As shown in FIG.45, a bearing unit 410 according to a thirteenth embodiment of the present invention is constructed by a double row tapered roller bearing 411, a bearing housing 412 constituting a part of the carriage for the railway vehicle, and an abnormality sensing means 413.

[0239] The double row tapered roller bearing 411 has a pair of inner rings 414, 414 having inner ring raceway surfaces 415, 415 inclined like a tapered outer surface on their outer peripheral surfaces, a single outer ring 416 having a pair of outer ring raceway surfaces 417, 417 inclined like a tapered outer surface on their inner peripheral surfaces, tapered rollers 418 as the rolling elements that are arranged in plural between the inner ring raceway surfaces 415, 415 of the inner rings 414, 414 and the outer ring raceway surfaces 417, 417 of the outer ring 416 in double row, annular pressed retainers 419, 419 for holding reliably the tapered rollers 418, and a pair of sealing members 420, 420.

[0240] A radial load applied by weights of various members, etc. and any axial load are imposed onto the double row tapered roller bearing 411. An upper portion of the outer ring 416 is the loading range of the bearing.

[0241] The bearing housing 412 consists of an axle end member 421, a housing 422, a cover 423, and a shroud 424.

[0242] An inner ring spacer 425 is arranged between the inner rings 414, 414. Also, inner ring spacers 426, 426 are arranged on both outer sides of the inner rings 414, 414 in the axial direction. An axle 401 is fitted into the inner rings 414, 414 and the inner ring spacers 425, 426, 426. The inner ring raceway surfaces 415, 415 of the inner rings 414,

414 restrict the movement of the tapered rollers 418 in the axial direction.

[0243] The outer ring raceway surfaces 417, 417 of the outer ring 416, the inner ring raceway surfaces 415, 415 of the inner rings 414, 414, and the tapered rollers 418 are positioned such that vertexes located on prolonged lines of respective tapered surfaces are converged on one point on the axis line.

[0244] Out of the sealing members 420, 420, one sealing member 420 arranged on the top end portion side of the axle 401 is fitted between the outer end portion of the outer ring 416 and the axle end member 421.

[0245] The other sealing member 420 arranged on the counter top end portion side of the axle 401 is fitted between the outer end portion of the outer ring 416 and the shroud 424.

[0246] The axle end member 421 is fixed by screwing bolts 401a into the top end portion of the axle 401 to cover the inner ring spacer 426 arranged at the top end portion of the axle 401.

[0247] The housing 422 constitutes a side frame of the railway vehicle carriage, and is formed like the annular ring to cover the outer peripheral surface of the outer ring 416. A pair of projected walls 422a, 422a being projected into the inner peripheral surface are mounted on both side end portions of the outer ring 416. Then, a recess portion 422b in which the abnormality sensing means are housed is formed on the outer peripheral surface of the housing 422 corresponding to the center portion of the double row tapered roller bearing 411 in the axial direction. A flat surface 422c is formed on a bottom portion of the recess portion 422b.

[0248] The cover 423 is put on the top end portion of the housing 422. The shroud 424 is positioned between the end portion of the housing 422 and the axle 401 to cover the other sealing member 420 on the counter top end portion side of the axle 401.

[0249] The abnormality sensing means 413 is a composite sensor in which a temperature sensor 427 and a vibration sensor 428 are integrally provided. The temperature sensor 427 is a non-contact type temperature measuring element such as a thermistor temperature measuring element, a platinum resistance temperature sensor, a thermocouple, or the like. The vibration sensor 428 is a vibration measuring element such as a piezoelectric element, or the like.

[0250] Also, since the temperature sensor 427 and the vibration sensor 428 are aligned in the axial direction of the bearing and resin-molded in the recess portion 422b of the housing 422, such temperature sensor 427 and such vibration sensor 428 are integrally molded in a case 429. Thus, the abnormality sensing means 413 is fitted in the loading range of the housing 422 and the double row tapered roller bearing 411 in the center portion in a bearing width. The molding material used in the resin molding is the material that is rich in the waterproof property, the heat resisting property, and the insulating property.

[0251] The temperature sensor 427 senses the temperature of the double row tapered roller bearing 411 via the housing 422 to generate the temperature data signal (voltage signal). The temperature data signal generated by the temperature sensor 427 is transferred to the external controlling portion via a signal carrying means 430 provided in the case 429, and is used to sense the seizure abnormality of the double row tapered roller bearing 411. Here, as the temperature sensor 427, a temperature fuse that does not conduct by causing either a contact of a bimetal to disconnect or a contact to fuse when the atmospheric temperature exceeds a specified value may be employed. In such case, when the temperature of the device exceeds a specified value, conduction of the temperature fuse is cut off and thus the temperature abnormality is sensed.

[0252] The vibration sensor 428 senses the vibration of the double row tapered roller bearing 411 via the housing 422 to generate the vibration data signal (voltage signal). The vibration data signal generated by the vibration sensor 428 is transferred to the external controlling portion via the signal carrying means 430 provided in the case 429, and is used to sense the flaking of the inner ring raceway surfaces 415, 415 and the outer ring raceway surfaces 417, 417 of the double row tapered roller bearing 411, the fracture of the gear, and the flat wear of the wheel. Here, as the vibration sensor 428, any sensor capable of transforming the vibration such as acceleration, speed, displacement, or the like into the electric signal may be employed. When the vibration sensor is fitted to the device that is often exposed to the disturbance such as the noise, and the like, it is desired that the sensor does not suffer the noise by using the insulation type.

[0253] Since the temperature sensor 427 and the vibration sensor 428 are arranged in the case 429 formed by the molding, the entering of the rainwater can be prevented without fail. Also, since the temperature and the vibration can be sensed during the rotation, the defect of a plurality of parts can be inspected concurrently without overhaul of the system into which the rotating parts are incorporated. Since the vibration-proof property against the vibration applied from the outside can be improved rather than the case where the sensor is fixed to the outside of the housing 422, the reliability of the sensing performance can be improved tremendously. Also, since the sensor is never subjected to the surrounding circumstances such as fitting condition, rainwater, wind pressure, and the like in contrast to the case where respective sensors are fixed with the screws separately, the high-precision signal can be generated at the high SN ratio (signal-to-noise ratio).

[0254] As shown in FIG.46, in the first signal processing method in the abnormality sensing means 413, the temperature data signal generated by the temperature sensor 427 and the vibration data signal generated by the vibration sensor 428 are input into a comparator 431 via the signal carrying means 430. Then, the temperature data signal value

given from the temperature sensor 427 is compared with a predetermined temperature threshold value saved in a threshold setting portion 432 in the comparator 431. Similarly, the vibration data signal value given from the vibration sensor 428 is compared with a predetermined vibration threshold value saved in the threshold setting portion 432. That is, at least one abnormality selected from the temperature sensor 427 and the vibration sensor 428 is sensed by the abnormality sensing means 413. At this time, when the temperature data signal value exceeds the temperature threshold value, a temperature abnormality decision signal is output from an abnormality deciding portion 433 and also a temperature abnormality alarm is output from a decision result outputting portion 434.

[0255] Also, when the vibration data signal value exceeds the vibration threshold value, a vibration abnormality decision signal is output from the abnormality deciding portion 433 and also a vibration abnormality alarm is output from the decision result outputting portion 434. The alarm is transferred via cable or radio and then operated. At this time, as the temperature threshold value and the vibration threshold value saved in the threshold setting portion 432 and the temperature/ vibration abnormality decision signals output from the abnormality deciding portion 433, the root-mean-square value and the peak value in any time period may be employed.

[0256] As shown in FIG.47, in the second signal processing method in the abnormality sensing means 413, the vibration data signal generated by the vibration sensor 428 is amplified, then only a predetermined frequency band is extracted from the vibration data signal by a filtering portion 435 to remove the unnecessary frequency band, and then the resultant signal is input into an envelope processing portion 436. The absolute-value detecting process of detecting the absolute value of the waveform is executed in the envelope processing portion 436, then the frequency analyzing process is executed in a frequency analyzing portion 437, and then the actually measured data are transferred to a comparing/collating portion 438.

[0257] Meanwhile, the calculated value data of the frequency components, which are set as those generated due to the abnormality such as one-sided wear, or the like of the bearing, the gear, and the wheel in a theoretical frequency calculating portion 440 based on rotation speed information 439, are transferred to the comparing/collating portion 438. Then, the actually measured data are compared/collated with the calculated value data in the comparing/collating portion 438 to specify the presence or absence of the vibration abnormality and the abnormal location. Then, the presence or absence of the vibration abnormality and the identified location are output from a result outputting portion 441. The information are transferred to the result outputting portion 441 via cable or radio.

[0258] In the second signal processing method, for example, the calculation of the frequency components and the comparison/ collation can be easily made based on the rotation speed information sensed from the electric motor, or the like and design specifications of the rotating elements parts. Also, various data processes and calculation are applied as the processing of the vibration data signal after the amplification. For example, such processing may be executed by the computer, the dedicated microchip, or the like. In addition, the calculation process may be applied to the sensed data signal after such signal is stored in the saving means such as the memory, or the like.

[0259] Also, because it takes much time and labor to exchange the bearing in some machine, such machine cannot be immediately stopped. In this case, in some cases the exchange of the bearing is applied according to a degree of the damage. As the criterion in such case, the root-mean-square value, the maximum value, and the peak factor of the vibration, for example, may be employed with respect to the previously decided reference values.

[0260] Also, as the abnormality diagnosis processing method on the basis of the vibration information in the comparing/ collating portion 438 shown in FIG.46, the above approaches (1) to (6) may be employed.

[0261] According to the bearing unit 410 in the thirteenth embodiment, since the sensors are molded with the resin in the loading range of the bearing housing 412, particularly in the recess portion 422b formed on the housing 422 of the bearing housing 412 that covers the outer peripheral surface of the outer ring 416, the temperature sensor 427 and the vibration sensor 428 can be integrally formed in a single case 429. Thus, the vibration or temperature information accompanying the rotating condition of the rotating parts can be sensed at the same time by sensing at least one abnormality selected from the temperature sensor 427 and the vibration sensor 428 by means of the abnormality sensing means 413. As a result, the defect of a plurality of parts can be inspected simultaneously still in the actual operating state without overhaul of the system into which the rotating parts are incorporated.

[0262] In other words, the abnormality sensing means may be provided in the loading range of the bearing housing. Also, it is preferable that the abnormality sensing means should be secured onto the flat portion provided to a part of the outer peripheral surface of the bearing housing on the loading range side. Like the present embodiment, when the abnormality sensing means is embedded/fixed in the recess portion formed on the bearing housing, preferably such means should be fitted to mold a clearance between the abnormality sensing means and the recess portion. Also, the abnormality sensing means may be arranged on the outer diameter portion of the bearing housing in the loading range and in the center portion of the bearing width.

[0263] In addition, in the present embodiment, the case of the abnormality sensing means has a signal carrying means for sending out the sensed signal, and a decision result outputting portion for deciding/outputting the presence or absence of the abnormality based on the signal sent out via the signal carrying means.

[0264] Further, the inspection executed based on the vibration information is attained by providing the filtering

processing portion for removing the unnecessary frequency band from the vibration waveform from the vibration sensor, the envelope processing portion for detecting the absolute value of the filtered waveform transferred from the filtering processing portion, the frequency analyzing portion for analyzing the frequency of the waveform transferred from the envelope processing portion, the comparing/collating portion for comparing the frequency generated due to the damage calculated based on the rotation speed with the frequency derived based on the actually measured data, and the result outputting portion for identifying the presence or absence of the abnormality and the abnormal location based on the compared result in the comparing/collating portion.

[0265] Therefore, the abnormal decision can be made still in the normal state of use without overhaul of the bearing unit 410. As a result, a frequency of the overhauling/assembling operations that require a lot of time and labor can be reduced and thus the maintenance/administrative costs can be reduced largely. Also, the variation of the decision due to a degree of expertise or the individual differences of the person in charge of inspection is in no way generated rather than the visual inspection in the prior art, and thus the reliability of the abnormality diagnosis can be improved dramatically.

<Fourteenth Embodiment>

[0266] Next, a bearing unit according to a fourteenth embodiment of the present invention will be explained with reference to FIG.48 hereunder. In this event, the same reference symbols are affixed to the portions similar to those in the thirteenth embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0267] As shown in FIG.48, in a bearing unit 450 in the present embodiment, the abnormality sensing means 413 constructed by molding integrally the temperature sensor 427 and the vibration sensor 428 in the case 429 is fixed to the recess portion 422b formed on the outer peripheral surface of the housing 422 via a spacer 451.

[0268] The spacer 451 is made of a metal that has the temperature characteristic and the natural vibration characteristic equivalent to the housing 422. The spacer 451 is fixed by tightening screws 453, 453, which are inserted into a flange 452 arranged on the outer peripheral portion of the housing 422, into the housing 422.

[0269] In this case, the abnormality sensing means 413 as well as the spacer 451 can be detachably attached to the housing 422. Therefore, when the temperature sensor 427 and the vibration sensor 428 are to be exchanged, the exchanging operation can be executed only by taking out the screws 453, 453 not to consume much time. In the bearing unit 450 in the fourteenth embodiment, the same signal processing as that in the first embodiment is applied.

<Fifteenth Embodiment>

[0270] Next, a bearing unit according to a fifteenth embodiment of the present invention will be explained with reference to FIG. 5 hereunder. In this case, the same reference symbols are affixed to the portions similar to those in the thirteenth embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0271] As shown in FIG.49, in a bearing unit 460 of the present embodiment, a pair of recess portions 422d, 422d into which the abnormality sensing means is installed are formed on the outer peripheral surface of the housing 422 in the position that corresponds to the center portion in the width area of the inner ring raceway surfaces 415, 415 of the double row tapered roller bearing 411. First and second abnormality sensing means 461, 462 in which the temperature sensor 427 and the vibration sensor 428 are molded integrally in the case 429 are molded in the recess portions 422d, 422d with the resin.

[0272] The recess portions 422d, 422d are also arranged corresponding to the center portion in the width area of the outer ring raceway surfaces 417, 417.

[0273] In this case, the first and second abnormality sensing means 461, 462 are arranged in close vicinity to the position in which the tapered rollers 418 come into contact with the inner and outer ring raceway surfaces 415, 415, 417, 417 while rolling down. Therefore, the sensing sensitivity can be improved further, and a time required until the abnormal signal is generated when the abnormality occurs can be shortened. In the bearing unit 460 of the fifteenth embodiment, the same signal processing as that in the first embodiment is applied.

[0274] Also, the abnormality sensing means in which the temperature sensor and the vibration sensor are molded integrally may be fitted directly to the outer peripheral surface of the housing in the loading range. In such case, the abnormality sensing means should be fitted to the flat portion that is formed on a part of the outer peripheral surface of the housing. Then, the signal processing should be applied in the similar manner to respective embodiments. Also, like the present embodiment, the abnormality sensing means may be arranged on the outer diameter portion of the bearing housing in the loading range and in the width area of the inner ring raceway surfaces or the outer ring raceway surfaces.

[0275] Also, as the bearing used in the bearing unit, a combination of the cylindrical roller bearing and the single row radial ball bearing, or the cylindrical roller bearing or the tapered roller bearing or the self-aligning roller bearing may be applied.

[0276] Here, the machinery facility condition monitoring method and system and the abnormality diagnosis system according to the present invention are not limited to the foregoing embodiments, and appropriate variations, improvements, etc. can be applied. Also, in the present invention, respective embodiments can be employed in combination in the practicable range. Also, the machinery facility of the present invention includes the railway vehicle, the machine tool, the windmill, the reduction gear, the electric motor, and others, and any facility may be employed if the machinery facility includes at least one of the rotating body and the sliding member. Also, the rotating body or the sliding member of the present invention includes the rolling bearing, the sliding bearing, the ball screw, the linear guide, the linear ball bearing, other rotating parts (gear, wheel itself), and others.

[0277] The present invention is explained in detail with reference to particular embodiments, but it is apparent for the person skilled in the art that various variations and modifications can be applied without departing from a spirit and a scope of the present invention.

[0278] This application is filed based on

Japanese Patent Application (Patent Application No.2002-252877) filed on August 30, 2002,
Japanese Patent Application (Patent Application No.2002-338423) filed on November 21, 2002,
Japanese Patent Application (Patent Application No.2002-370800) filed on December 20, 2002,
Japanese Patent Application (Patent Application No.2003-010131) filed on January 17, 2003,
Japanese Patent Application (Patent Application No.2003-048309) filed on February 25, 2003,
Japanese Patent Application (Patent Application No.2003-182996) filed on July 26, 2003,
Japanese Patent Application (Patent Application No.2003-304700) filed on August 28, 2003,

and the contents thereof are incorporated by the reference hereinto.

<Industrial Applicability>

[0279] There is provided the high-precision machinery facility abnormality monitoring system that is capable of deciding the presence or absence of the abnormality in the state of normal use without decomposition of the facility like the machinery facility such as a railway vehicle facility, a machine tool, a windmill, or the like, which requires much time and labor to decompose, and thus capable of reducing the maintenance/ administrative costs and being hardly affected by the noise, and the like.

FIGS.1, 42:

(1) data accumulating/distributing portion 31
(2) temperature analyzing portion 32
(3) rotation analyzing portion 33
(4) filtering processing portion 34
(5) vibration analyzing portion 35
(6) comparing/deciding portion 36
(7) internal data saving portion 37
(8) data accumulating/outputting portion 38
(9) controlling portion 41
(10) result outputting portion 42
(11) amplifier 50
(12) (temperature information)
(13) (rotation information)
(14) (vibration information)
(15) signals
(16) sound information J1
(17) temperature information J2
(18) vibration information J3
(19) rotation speed information J4
(20) distortion information J5

FIG.2(a):

(1) temperature sensing element 22b
(2) rotation sensing element 22c

(3) vibration sensing element 22d
(4) To a calculating/processing portion 30

FIG.2(b):

(1) temperature sensing element 22b
(2) rotation sensing element 22c
(3) vibration sensing element 22d
(4) amplifier 22e
(5) amplifier 22f
(6) amplifier 22g
(7) To a calculating/processing portion 30

FIG.3:

(1) data accumulating portion 31a
(2) sampling reference setting portion 31b
(3) sampling portion 31 c
(4) inputting portion 100
(5) To a temperature analyzing portion 32
(6) To a rotation analyzing portion 33
(7) To a filtering processing portion 34

FIG.4:

(1) flaw of a rolling bearing
(2) frequency after an enveloping process
(3) inner ring (Si)
(4) outer ring (So)
(5) rolling element (Sb)
(6) retainer (Sc)
(7) fr: inner ring rotation speed [Hz]
(8) fc: retainer rotation speed [Hz]
(9) fb: rolling element rotation speed [Hz]
(10) dm: pitch circle diameter [mm]
(11) Z: number of rolling elements
(12) Da: rolling element diameter [mm]
(13) α: contact angle [degree]

FIG.5:

(1) loading range A1
(2) non-loading range A2

FIG.6:

(1) time-variant waveform

FIG.7:

(1) FFT spectrum

FIG.8:

(1) envelope FFT spectrum
(2) frequency component due to damage of the outer ring of the bearing

FIG.9:

(1) sense sound/vibration signals (S101)
(2) A/D conversion (S102)
(3) save in a predetermined format (S103)
(4) frequency analysis (S104)
(5) select a filter bandwidth (S105)
(6) filtering process (S106)
(7) enveloping process (S107)
(8) frequency analysis (S108)
(9) calculate a RMS value (S109)
(10) calculate a frequency due to abnormality of the bearing (S110)
(11) extract an inner ring flaw component Si (Zfi), an outer ring flaw component So (Zfc), a rolling element flaw component Sb (2fb), and a retainer component Sc (fc) (S111)
(12) calculate a reference value (S112)
(13) Si, So, Sb, Sc > reference value (S113)
(14) No abnormality is generated in the bearing (S114)
(15) identify the abnormal position Si(inner ring flaw), So (outer ring flaw), Sb (rolling element flaw), Sc (retainer flaw) (S115)

FIGS.10, 11, 12:

(1) reference value

FIG.13:

(1) sense sound/vibration signals (S101)
(2) A/D conversion (S102)
(3) forming into a digital file (S103)
(4) frequency analysis (S104)
(5) select a filter bandwidth (S105)
(6) filtering process (S106)
(7) enveloping process (S107)
(8) frequency analysis (S108)
(9) calculate a peak value (S201)
(10) calculate a frequency due to abnormality of the bearing (S202)
(11) extract an inner ring flaw component Si (Zfi), an outer ring flaw component So (Zfc), a rolling element flaw component Sb (2fb), and a retainer component Sc (fc) (S203)
(12) Do Si, So, Sb, Sc have a peak value ? (S204)
(13) No abnormality is generated in the bearing (S205)
(14) identify the abnormal position Si(inner ring flaw), So (outer ring flaw), Sb (rolling element flaw), Sc (retainer flaw) (S206)

FIG.14:

(1) $\delta_1(=Y_1-Y_0)>0$ ·①
$\delta_2(=Y_2-Y_1)<0$ ·②
where A (X_0,Y_0), B (X_1,Y_1), C (X_2,Y_2).
When ① , ② are satisfied and
$dy/dx=(Y_1-Y_0)/(X_1-X_0)>1$
or
$dy/dx=(Y_2-Y_1)/(X_2-X_1)<-1$
is satisfied, Y_1 is decided as a peak.

FIG. 15:

(1) Do the primary components coincide with each other ? (S201)
(2) Do the secondary components coincide with each other ? (S202)
(3) Do the secondary components coincide with each other ? (S211)
(4) Do the quaternary components coincide with each other ? (S212)

(5) No abnormality is generated (S321)
(6) The abnormality is generated (S321)

FIG. 16:

(1) collate only the primary, secondary, quaternary components (flaw of the outer ring)
(2) (secondary)
(3) (quaternary)

FIG.17:

(1) reference level L_0 (RMS value f1)
(2) level difference

FIG.18:

(1) a relationship between a size of flaking and a level difference
(2) reference level dB
(3) size of flaking mm

FIG.19:

(1) calculate the abnormal frequency due to the abnormality in the bearing (S401)
(2) extract a primary component due to the inner ring flaw, a primary component due to the outer ring flaw, a primary component due to the rolling element flaw, and a primary component due to the retainer (S402)
(3) extract a natural-number multiple component due to the inner ring flaw, a natural-number multiple component due to the outer ring flaw, a natural-number multiple component due to the rolling element flaw, and a natural-number multiple component due to the retainer (S403)
(4) comparing the primary component with respective natural- number multiple components by referring to reference value (S404)
(5) Is the abnormality generated ? (S405)
(6) The abnormality is generated. Identify the abnormal position (S406)
(7) No abnormality is generated (S407)

FIG.20:

(1) degree
(2) level (dB)
(3) criterion line
(4) roller missing sound
(5) The case where the flaw is generated

FIG.21:

(1) calculate the abnormal frequency due to the abnormality in the bearing (S501)
(2) calculate V_i and V_{RMS} (S502)
(3) calculate a difference between V_i, V_{RMS} or a quotient (S503)
(4) Does the difference or the quotient exceed a reference value ? (S504)
(5) The abnormality is generated. Identify the abnormality occurring location (S505)
(6) No abnormality is generated (S506)

FIGS.22, 23, 24, 25:

(1) frequency Hz
(2) intensity

FIG.26:

(1) temperature sensing element 52b
(2) rotation sensing clement 52c
(3) vibration sensing element 52d
(4) transmitting portion 52h
(5) To the calculating/processing portion 30

FIG.27:

(1) data accumulating portion 31
(2) temperature analyzing portion
(3) rotation analyzing portion
(4) filtering processing portion 34
(5) vibration analyzing portion
(6) comparing/deciding portion 36
(7) internal data saving portion 37
(8) data accumulating/outputting portion 38
(9) controlling portion 41
(10) result outputting portion 42
(11) receiving portion 60
(12) (temperature information)
(13) (rotation information)
(14) (vibration information)
(15) radio communication
(16) signals
(17) sound information J1
(18) temperature information J2
(19) vibration information J3
(20) rotation speed information J4
(21) distortion information J5

FIG.28:

(1) (sensor built-in bearing) 21
(2) <calculating/processing portion> 30
(3) data accumulating/distributing portion 31
(4) temperature analyzing portion 32
(5) rotation analyzing portion 33
(6) filtering processing portion 34
(7) vibration analyzing portion 35
(8) comparing/deciding portion 36
(9) internal data saving portion 37
(10) data accumulating/outputting portion 38
(11) <controlling/processing portion> 40
(12) controller 41
(13) result outputting portion 42
(14) signal transmitting/receiving device 63
(15) information processing center
(16) (temperature information)
(17) (rotation information)
(18) (vibration information)
(19) signals
(20) sound information J1
(21) temperature information J2
(22) vibration information J3
(23) rotation speed information J4
(24) distortion information J5
(25) feedback

FIG.29:

(1) (sensor built-in bearing) 21
(2) data accumulating/distributing portion 31
(3) temperature analyzing portion 32
(4) rotation analyzing portion 33
(5) filtering processing portion 34
(6) vibration analyzing portion 35
(7) comparing/deciding portion 36
(8) internal data saving portion 37
(9) data accumulating/outputting portion 38
(10) result outputting portion 42
(11) calculating/processing portion> 73
(12) controlling/processing portion> 75
(13) (temperature information)
(14) (rotation information)
(15) (vibration information)
(16) signals
(17) sound information J1
(18) temperature information J2
(19) vibration information J3
(20) rotation speed information J4
(21) distortion information J5
(22) remove and bring it to the calculating/processing portion

FIG.30:

(1) <controlling/processing portion> 40
(2) controller 41
(3) result outputting portion 42
(4) <microcomputer> IC chip memory 81
(5) machinery facility 90
(6) <sensing processing portion>
(7) signals
(8) sound information J1
(9) temperature information J2
(10) vibration information J3
(11) rotation speed information J4
(12) distortion information J5

FIG.31:

(1) data accumulating/distributing portion 31
(2) temperature analyzing portion 32
(3) rotation analyzing portion 33
(4) filtering processing portion 34
(5) vibration analyzing portion 35
(6) comparing/deciding portion 36
(7) internal data saving portion 37
(8) <microcomputer> 81
(9) (temperature information)
(10) (rotation information)
(11) (vibration information)

FIGS.32, 33:

(1) <controlling/processing portion> 40
(2) controller 41

(3) result outputting portion 42
(4) <microcomputer> IC chip memory 81
(5) machinery facility 90
(6) signals
(7) sound information J1
(8) temperature information J2
(9) vibration information J3
(10) rotation speed information J4
(11) distortion information J5

FIG.34(a):

(1) piezoelectric sensor signal
(2) temperature data input
(3) rotating pulse input

FIG.35(a):

(1) temperature sensor 163
(2) sensing circuit
(3) impact sensor 183
(4) amplifier filter 184
(5) rotating pulse input

FIG.36:

(1) machinery facility monitoring system 191
(2) peripheral function
(3) sensor signal output
(4) diagnosed feature parameter output diagnosis result output

FIG.38:

(1) <controlling/processing portion> 40
(2) controller 41
(3) result outputting portion 42
(4) <sensing processing portion>
(5) <microcomputer> IC chip memory 250
(6) signals
(7) sound information J 1
(8) temperature information J2
(9) vibration information J3
(10) rotation speed information J4
(11) distortion information J5

FIG.39:

(1) data accumulating/distributing portion 31
(2) temperature analyzing portion 32
(3) rotation analyzing portion 33
(4) filtering processing portion 34
(5) vibration analyzing portion 35
(6) internal data saving portion 37
(7) -calculating/processing portion> 250
(8) comparing/deciding portion 252
(9) (temperature information)
(10) (rotation information)
(11) (vibration information)

FIG.40:

(1) input sound/vibration signals (S602)
(2) A/D conversion (S603)
(3) amplifying process (S604)
(4) filtering process (S606)
(5) enveloping process (S607)
(6) frequency analysis (S608)
(7) rotation speed information (S609)
(8) calculate a theoretical frequency (S610)
(9) compare/collate (S611)
(10) save the result (S612)
(11) decide based on N results whether or not the abnormal is present (S614)
(12) display the result (S615)

FIG.43:

(1) <controlling/processing portion> 40
(2) controller 41
(3) result outputting portion 42
(4) microcomputer 81
(5) signals
(6) sound information J1
(7) temperature information J2
(8) vibration information J3
(9) rotation speed information J4
(10) distortion information J5

FIG.44:

(1) controlling/processing portion 40
(2) microcomputer 81
(3) transmitter/receiver 370

FIG.46:

(1) temperature sensor 427
(2) vibration sensor 428
(3) comparator 431
(4) threshold setting portion 432
(5) abnormality deciding portion 433
(6) decision result outputting portion 434

FIG.47:

(1) vibration sensor 428
(2) filter portion 435
(3) envelope processing portion 436
(4) frequency analyzing portion 437
(5) comparing/collating portion 438
(6) rotation speed 439
(7) theoretical frequency calculating portion 440
(8) result outputting portion 441

FIG.53:

(1) bearing 1131
(2) pickup 1132

(3) AGC amplifier 1133
(4) band-pass filter 1134
(5) RMS calculator 1135
(6) envelope circuit 1136
(7) RMS calculator 1137
(8) alarm circuit 1138
(9) means for deciding whether or not the abnormality is present
(10) amplitude

FIG.54:

(1) abnormality diagnosis system 1140
(2) rolling bearing 1141
(3) microphone 1142
(4) amplifier 1143
(5) electronic device 1144
(6) transducer 1147
(7) abnormality diagnosing portion 1149
(8) filtering processing portion
(9) abnormality deciding portion
(10) analog outputting portion 1150

FIG.55:

(1) A/D conversion 1162
(2) waveform processing portion (enveloping process) 1163
(3) calculating portion 1164
(4) deciding portion 1165
(5) outputting portion 1166
(6) system driving portion

Claims

1. An abnormality diagnosis system for diagnosing a presence or absence of an abnormality of a bearing unit for a railway vehicle axle, comprising:

a sensing/processing portion for outputting a signal generated from the bearing unit as an electric signal;
a calculating/processing portion for making an abnormality diagnosis of the bearing unit based on an output of the sensing/processing portion;
a result outputting portion for outputting a decision result of the calculating/processing portion; and
a controlling/processing portion for feeding back a control signal to a control system of the railway vehicle based on the decision result.

2. An abnormality diagnosis system according to claim 1, wherein the calculating/processing portion includes
a data accumulating/distributing portion for accumulating the electric signal fed from the sensing/ processing portion and distributing the signal to an appropriate distributing route according to a type of the electric signal,
an analyzing portion for calculating a predetermined physical quantity in regarding to the bearing unit based on the electric signal distributed from the data accumulating/ distributing portion,
a first data saving portion for saving bearing unit data in regarding to the bearing unit,
a comparing/deciding portion for making the abnormality diagnosis of the bearing unit by comparing/referring an analyzed result of the analyzing portion with the bearing unit data saved in the first data saving portion, and
a second data saving portion for saving the analyzed result of the analyzing portion and a decision result of the comparing/deciding portion.

3. An abnormality diagnosis system according to claim 2, wherein the analyzing portion includes
a filtering processing portion for removing a noise component of the electric signal fed from the calculating/ processing portion or extracting a particular frequency component to output, and

a frequency analyzing portion for executing a frequency analysis of a signal output from the filtering processing portion, and

the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on a result of the frequency analysis of the frequency analyzing portion.

4. An abnormality diagnosis system according to claim 2 or 3, wherein the analyzing portion has a temperature analyzing portion that calculates a temperature of the bearing unit based on the signal output from the data accumulating portion, and

the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on the temperature calculated by the temperature analyzing portion.

5. An abnormality diagnosis system according to any one of claims 2 to 4, wherein the analyzing portion has a rotation analyzing portion that calculates a rotation speed of the bearing unit based on the signal output from the data accumulating portion, and

the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on the rotation speed calculated by the rotation analyzing portion.

6. An abnormality diagnosis system according to any one of claims 1 to 5, wherein the calculating/processing portion outputs data saved in the second data saving portion to the controlling/processing portion in response to the abnormality diagnosis result.

7. An abnormality diagnosis system according to any one of claims 1 to 6, wherein the filtering processing portion extracts only a frequency component of 1 kHz or less.

8. An abnormality diagnosis system according to any one of claims 1 to 7, wherein a sensing element of the sensing/processing portion is arranged on a stationary portion of the bearing unit in a loading range.

9. An abnormality diagnosis system according to any one of claims 1 to 8, wherein the data accumulating/distributing portion does not output the electric signal containing a noise component, which exceeds a predetermined level, to the analyzing portion.

10. An abnormality diagnosis system according to any one of claims 1 to 9, wherein the comparing/deciding portion makes the abnormality diagnosis of the bearing unit by comparing levels of a frequency due to the abnormality and its higher harmonics with a reference value.

11. An abnormality diagnosis system according to any one of claims 1 to 10, wherein the comparing/deciding portion decides that the abnormality is generated when at least one of peak values of the frequency due to the abnormal and its higher harmonics is larger than a predetermined reference value.

12. An abnormality diagnosis system according to any one of claims 1 to 11, wherein the comparing/deciding portion estimates a degree of damage of the bearing unit based on the peak values of the frequency due to the abnormal and its higher harmonics.

13. An abnormality diagnosis system according to any one of claims 1 to 12, wherein the comparing/deciding portion makes the abnormality diagnosis by comparing the levels of the frequency due to the abnormal and its higher harmonics.

14. An abnormality diagnosis system according to any one of claims 1 to 13, wherein the comparing/deciding portion makes the abnormality diagnosis based on a square mean or a partial overall of a frequency band containing the frequency due to the abnormal.

15. An abnormality diagnosis system according to any one of claims 1 to 14, wherein the comparing/deciding portion makes the abnormality diagnosis by applying a cepstrum analysis to a frequency spectrum.

16. An abnormality diagnosis system according to any one of claims 1 to 15, wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion and the calculating/processing portion and the controlling/processing portion via a cable that has waterproof, oil-resistant, dustproof, rust-preventive, and moisture-proof functions, and heat-resistant, voltage-proof, and electromagnetic noise-resistant properties respec-

tively.

17. An abnormality diagnosis system according to any one of claims 1 to 15, wherein a radio communicating device is provided to the sensing/processing portion and the calculating/ processing portion and the calculating/processing portion and the controlling/processing portion respectively, and the signal is transmitted therebetween by using the radio communicating device via radio.

18. An abnormality diagnosis system according to any one of claims 1 to 15, wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion and the calculating/processing portion and the controlling/processing portion via the cable that has waterproof, oil-resistant, dustproof, rust-preventive, and moisture-proof functions, and heat-resistant, and electromagnetic noise-resistant properties respectively, or the signal is transmitted therebetween by using the radio communicating device.

19. An abnormality diagnosis system according to any one of claims 1 to 18, wherein the abnormality diagnosis is made in real time.

20. An abnormality diagnosis system according to any one of claims 1 to 18, wherein the abnormality diagnosis is made at a time different from a vehicle traveling time, based on data accumulated in the accumulating portion.

21. An abnormality diagnosis system according to any one of claims 1 to 20, wherein the presence or absence of the abnormality of a bearing in the bearing unit and an abnormality occurring location are diagnosed.

22. An abnormality diagnosis system according to any one of claims 1 to 20, wherein a flat portion of a wheel is diagnosed.

23. An abnormality diagnosis system according to any one of claims 1 to 20, wherein the presence or absence of the abnormality of a gear in the bearing unit and an abnormality occurring location are diagnosed.

24. An abnormality diagnosis system for a machinery facility having a rotating body, comprising:

a sensor unit having a sensor fitted to a constituent parts of the rotating body to sense a physical quantity of the rotating body in a rotating operation;
a calculating/processing portion for deciding a presence or absence of an abnormality of the rotating body by analyzing an output signal of the sensor unit and then comparing an analyzed result with predetermined reference data; and
a controlling/processing portion for displaying the analyzed result of the calculating/processing portion and a decision result of the calculating/processing portion, and controlling an operation of the machinery facility in response to the decision result.

25. An abnormality diagnosis system according to claim 24, wherein the sensor unit has an output amplifying means for amplifying the output signal of the sensor.

26. An abnormality diagnosis system according to claim 24 or 25, wherein the sensor unit has a radio communicating means for transmitting the output signal to the calculating/ processing portion via radio.

27. An abnormality diagnosis system according to claim 26, wherein the calculating/processing portion and the controlling/processing portion are provided to a monitoring base station that is remote from the rotating body.

28. An abnormality diagnosis system according to claim 27, wherein the sensor unit is fitted to a bearing of a railway vehicle, and
the sensor unit diagnoses the abnormality of the bearing.

29. A machinery facility abnormality diagnosis system for sensing a presence or absence of an abnormality of a sliding member or a rotating body in a machinery facility, comprising:

a sensor unit having one of plural sensing elements for sensing a signal emitted from the machinery facility; and
a calculating/processing portion for executing a calculating process to decide the presence or absence of the abnormality in the machinery facility based on an output of the sensing element;

wherein the calculating/processing portion is composed of a microcomputer.

30. A machinery facility abnormality diagnosis system according to claim 29, wherein the sensor unit is incorporated into the sliding member or the rotating body.

31. A machinery facility abnormality diagnosis system according to claim 30, wherein the microcomputer is fitted to the sliding member or the rotating body or a mechanism parts that supports the sliding member or the rotating body.

32. A machinery facility abnormality diagnosis system according to claim 29, wherein the microcomputer and the sensor unit are mounted on a single device board, and are fitted to the sliding member or the rotating body or a mechanism parts that supports the sliding member or the rotating body as a single processing unit.

33. A machinery facility abnormality diagnosis system according to any one of claims 29 to 32, wherein the calculating/processing portion is installed in a single casing.

34. A machinery facility abnormality diagnosis system according to claim 33, wherein the sensor unit is arranged integrally in the casing.

35. A machinery facility abnormality diagnosis system according to any one of claims 29 to 34, wherein the sensing element senses at least one of temperature, vibration displacement, vibration speed, vibration acceleration, force, distortion, acoustic, acoustic emission, ultrasonic waves, and rotation speed.

36. A machinery facility abnormality diagnosis system according to any one of claims 29 to 35, wherein the calculating/processing portion includes central processing unit, amplifier, analog/digital converter, filter, comparator, pulse counter, timer, interruption controller, ROM, RRAM, digital/analog converter, communication module, and external interface.

37. A machinery facility abnormality diagnosis system according to any one of claims 29 to 36, wherein the calculating/processing portion executes at least one process or more of calculation of feature parameters of a standard deviation and a peak factor, envelope detection, FFT, filtering, wavelet transform, short-time FFT, calculation of a feature frequency due to a defect of the rotating body and comparison/decision.

38. A condition monitoring method for a machinery facility having at least one of a rotating body and a sliding member, comprising the steps of:

analyzing a predetermined physical quantity of the machinery facility based on a signal generated from the machinery facility;
provisionally diagnosing a presence or absence of an abnormality of the machinery facility by comparing/allocating an analyzed result with information serving as references to decide whether or not the abnormality is present in the machinery facility, every first time period; and
diagnosing the presence or absence of the abnormality of the machinery facility and an abnormal location, by executing a total evaluation, which decides the abnormality when a number of times the abnormality is provisionally diagnosed exceeds a threshold value, after a comparison/allocation is executed predetermined number of times or based on a compared/allocated result obtained every second time period.

39. A condition monitoring method for a machinery facility having at least one of a rotating body and a sliding member, comprising the steps of:

analyzing a predetermined physical quantity of the machinery facility based on a signal generated from the machinery facility;
provisionally diagnosing a presence or absence of an abnormality of the machinery facility by comparing/allocating an analyzed result with information serving as references to decide whether or not the abnormality is present in the machinery facility, every first time period; and
diagnosing the presence or absence of the abnormality of the machinery facility and an abnormal location, by executing a total evaluation, which decides a degree of the abnormality according to a number of times the abnormality is provisionally diagnosed, after a comparison/allocation is executed predetermined number of times or based on a compared/allocated result obtained every second time period.

40. A machinery facility condition monitoring method according to claim 38 to 39, wherein the signal is A/D-converted into a digital signal, then a process of analyzing a frequency of the digital signal is executed, and then a frequency component generated due to a damage of the machinery facility and calculated based on an operating signal of the machinery facility is compared/allocated with a frequency component derived based on actually measured data every first time period.

41. A machinery facility condition monitoring method according to claim 40, wherein the signal is subjected to an amplifying process and a filtering process.

42. A machinery facility condition monitoring method according to claim 40 or 41, wherein at least one of the rotating body and the sliding member of the machinery facility is any one of rolling bearing, ball screw, linear guide, and linear ball bearing, and the operating signal of the machinery facility is either a rotation speed signal in the rolling bearing and the ball screw or a moving speed signal in the linear guide and linear ball bearing.

43. A machinery facility condition monitoring system for a machinery facility having at least one of a rotating body and a sliding member and using the condition monitoring method set forth in claim 38 or 39, comprising:

at least one sensing/processing portion for sensing a signal generated from the machinery facility;
a calculating/processing portion having a microcomputer that executes a calculating process to decide a condition of the machinery facility based on the signal output from the sensing/processing portion; and
a controlling/processing portion having at least one of a result outputting portion that outputs a decision result of the calculating/processing portion and a controller that feeds back a control signal to a control system of the machinery facility based on the decision result.

44. A machinery facility condition monitoring system according to claim 43, wherein at least one of the sensing/ processing portion and the microcomputer is installed into the rotating body and the sliding member.

45. A machinery facility condition monitoring system according to claim 43 or 44, wherein at least one of the rotating body and the sliding member is a bearing to which a radial load is applied, and
the sensing/processing portion is fixed in a radial load loading range of a bearing housing that is fitted onto a raceway ring of the bearing.

46. An abnormality diagnosis system for a railway vehicle bearing unit using the machinery facility condition monitoring system set forth in any one of claims 43 to 45.

47. An abnormality diagnosis system for a windmill bearing unit using the machinery facility condition monitoring system set forth in any one of claims 43 to 45.

48. An abnormality diagnosis system for a machine tool spindle bearing unit using the machinery facility condition monitoring system set forth in any one of claims 43 to 45.

49. A machine equipment abnormality diagnosis system comprising:

a sensing/processing portion having a sensor unit that is fixed to a bolt screwed into a housing of the machine equipment and outputs a signal generated from the machine equipment as an electric signal;
a calculating/processing portion for making an abnormality diagnosis of the machine equipment based on an output of the sensing/processing portion; and
a controlling/processing portion for feeding back a control signal to a control system of the machine equipment based on a result of the abnormality diagnosis.

50. A machine equipment abnormality diagnosis system according to claim 49, wherein the calculating/processing portion includes
the calculating/processing portion includes
a data accumulating/distributing portion for accumulating the electric signal fed from the sensing/ processing portion and distributing the signal to an appropriate distributing route according to a type of the electric signal,
an analyzing portion for calculating a predetermined physical quantity in regarding to the machine equipment based on the electric signal distributed from the data accumulating/ distributing portion,
a first data saving portion for saving machine equipment data in regarding to the machine equipment,

a comparing/deciding portion for making the abnormality diagnosis of the machine equipment by comparing the physical quantity calculated by the analyzing portion with the machine equipment data saved in the inside data saving portion,

a second data saving portion for saving the analyzed result of the analyzing portion and a result of the abnormality diagnosis of the comparing/deciding portion.

51. A machine equipment abnormality diagnosis system according to claim 49 or 50, wherein the calculating/processing portion and the controlling/processing portion are composed of a microcomputer or an IC chip.

52. A machine equipment abnormality diagnosis system according to any one of claims 49 to 51, wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion or the calculating/processing portion and the controlling/processing portion without a wire connection.

53. A bearing unit including an inner ring having an inner ring raceway surface, an outer ring having an outer ring raceway surface, a plurality of rolling elements arranged relatively rotatably between the inner ring raceway surface and the outer ring raceway surface, and a retainer for holding reliably the rolling elements, whereby a bearing to which a radial load is applied is arranged in a bearing housing,

the bearing unit comprising:

an abnormality sensing means provided in a loading range of the bearing housing, for sensing an abnormality from at least one selected from a vibration sensor and a temperature sensor installed/fixed in a single case.

54. A bearing unit according to claim 53, wherein a flat portion is provided to a part of an outer peripheral surface of the bearing housing on a loading range side, and the abnormality sensing means is fixed to the flat portion.

55. A bearing unit according to claim 54, wherein the abnormality sensing means is arranged on an outer diameter portion of the bearing housing on the loading range side in a center portion of a bearing width.

56. A bearing unit according to claim 53, wherein the abnormality sensing means is arranged on an outer diameter portion of the bearing housing on the loading range side in a width area of the inner ring raceway surface or the outer ring raceway surface.

57. A bearing unit according to any one of claims 53 to 56, wherein a case of the abnormality sensing means has a signal carrying means that sends out a sensed signal, and a decision result outputting portion that decides a presence or absence of the abnormality based on the signal sent out via the signal carrying means and output a decision result.

58. A bearing unit according to any one of claims 53 to 57, wherein the abnormality sensing means is embedded/fixed on a recess portion formed on the bearing housing, and then secured by molding a clearance between the abnormality sensing means and the recess portion.

59. A bearing unit according to claim 58, wherein the abnormality sensing means is fixed to the recess portion via a spacer.

60. A bearing unit according to any one of claims 53 to 59, wherein a filtering processing portion for removing an unnecessary frequency band from a vibration waveform from the vibration sensor, an envelope processing portion for detecting an absolute value of a filtered waveform transferred from the filtering processing portion, a frequency analyzing portion for analyzing a frequency of a waveform transferred from the envelope processing portion, a comparing/collating portion for comparing a frequency generated due to a damage calculated based on a rotation speed with a frequency derived based on actually measured data, and a result outputting portion for identifying a presence or absence of the abnormality and an abnormal location based on a compared result in the comparing/collating portion are provided.

FIG. 1

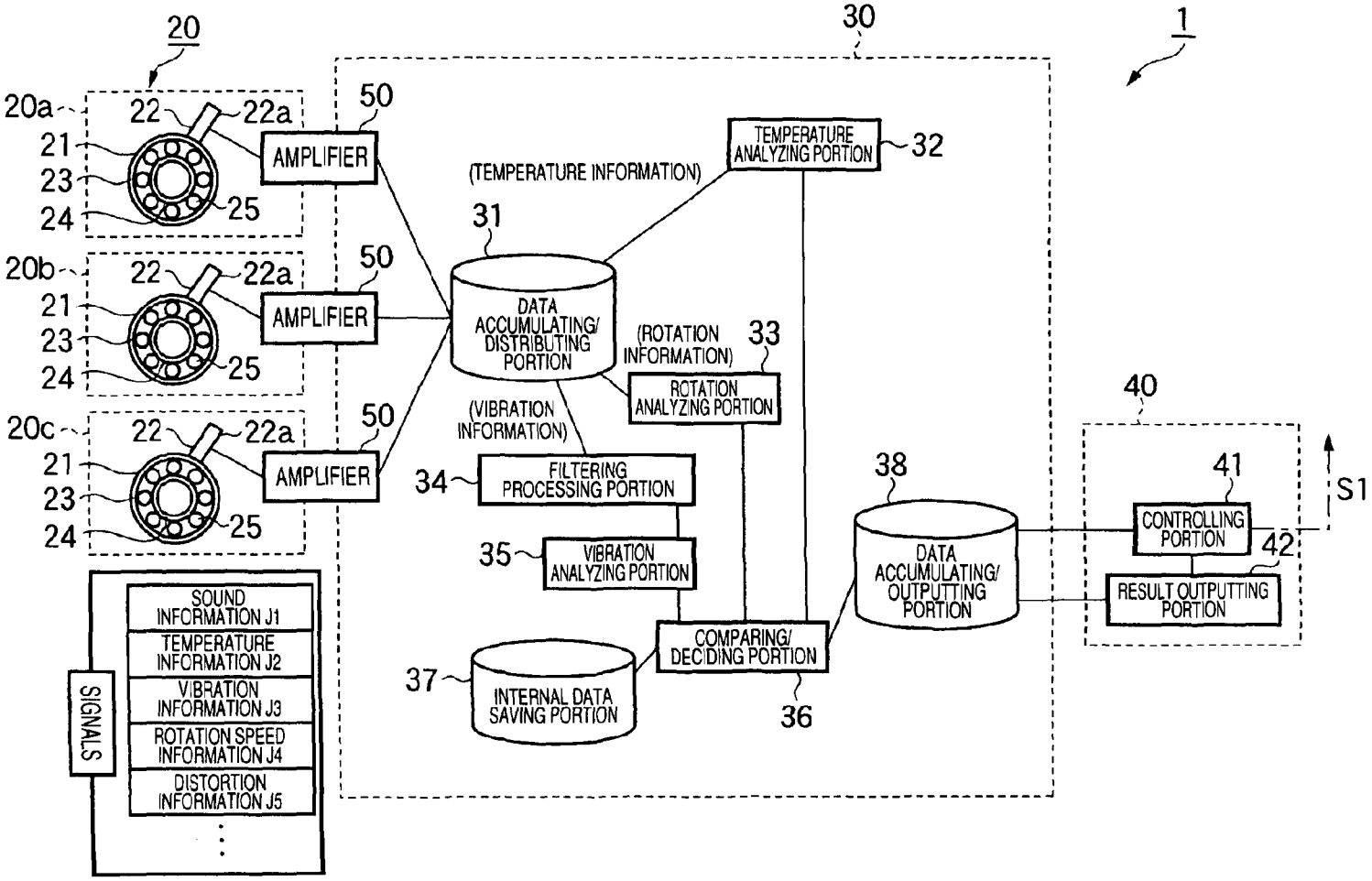

20
30
1
20a
22
22a
21
23
24
25
AMPLIFIER
50
20b
20c
(TEMPERATURE INFORMATION)
TEMPERATURE ANALYZING PORTION
32
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
(ROTATION INFORMATION)
33
ROTATION ANALYZING PORTION
(VIBRATION INFORMATION)
34
FILTERING PROCESSING PORTION
35
VIBRATION ANALYZING PORTION
37
INTERNAL DATA SAVING PORTION
COMPARING/ DECIDING PORTION
36
38
DATA ACCUMULATING/ OUTPUTTING PORTION
40
41
CONTROLLING PORTION
42
RESULT OUTPUTTING PORTION
S1
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5

FIG. 2(a)

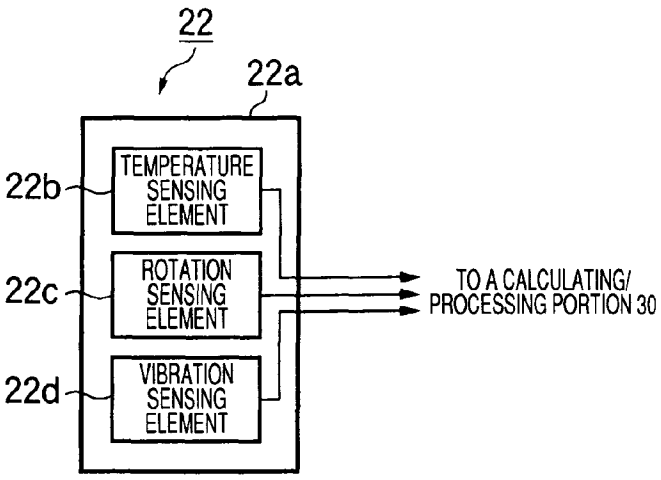

22
22a
22b
TEMPERATURE SENSING ELEMENT
22c
ROTATION SENSING ELEMENT
22d
VIBRATION SENSING ELEMENT
TO A CALCULATING/ PROCESSING PORTION 30

FIG. 2(b)

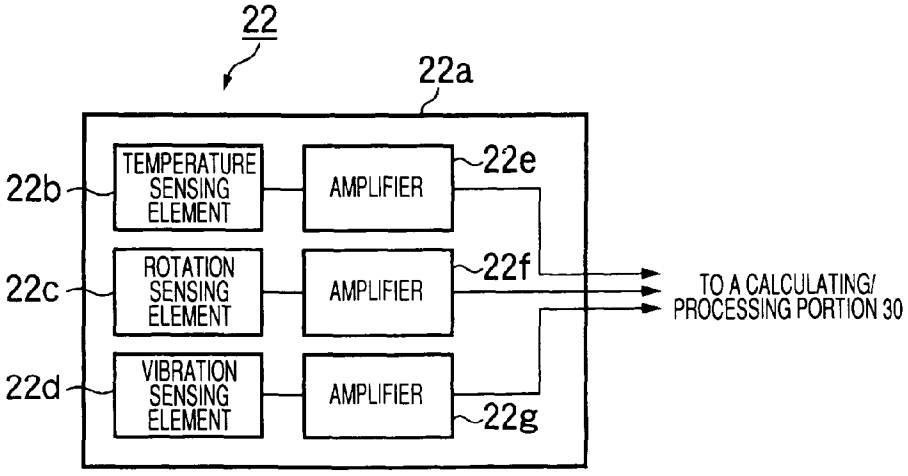

22
22a
22b
TEMPERATURE SENSING ELEMENT
AMPLIFIER
22e
22c
ROTATION SENSING ELEMENT
AMPLIFIER
22f
22d
VIBRATION SENSING ELEMENT
AMPLIFIER
22g
TO A CALCULATING/ PROCESSING PORTION 30

FIG. 3

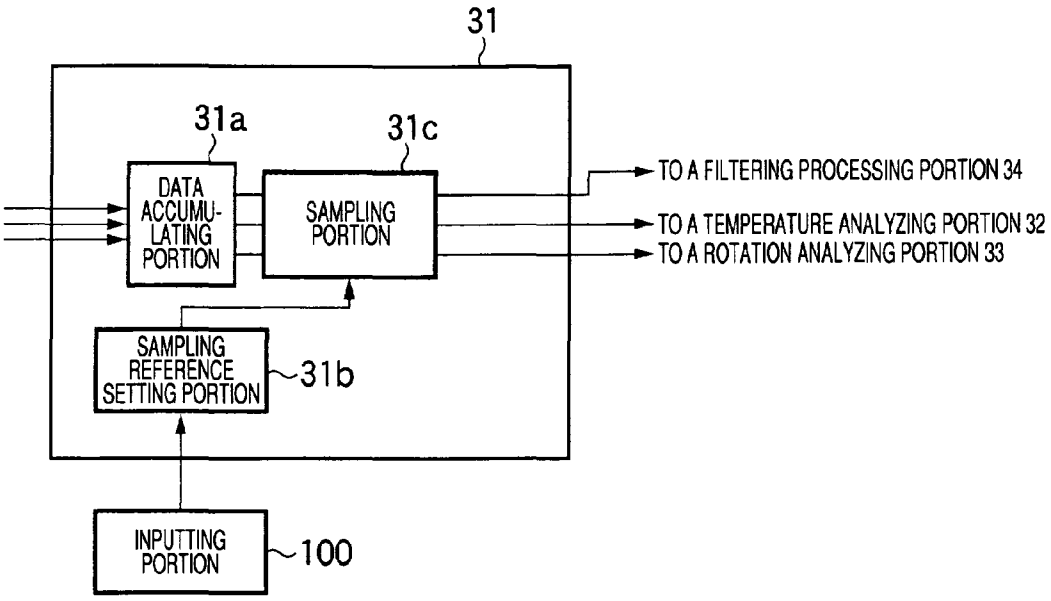

31
31a
31c
DATA ACCUMU-LATING PORTION
SAMPLING PORTION
TO A FILTERING PROCESSING PORTION 34
TO A TEMPERATURE ANALYZING PORTION 32
TO A ROTATION ANALYZING PORTION 33
SAMPLING REFERENCE SETTING PORTION
31b
INPUTTING PORTION
100

FIG. 4

FLAW OF A ROLLING BEARING	FREQUENCY AFTER AN ENVELOPING PROCESS
INNER RING (Si)	$Zfi=\frac{fr}{2}\left(1+\frac{Da}{dm}\cos\alpha\right)Z$ [Hz]
OUTER RING (So)	$Zfc=\frac{fr}{2}\left(1-\frac{Da}{dm}\cos\alpha\right)Z$ [Hz]
ROLLING ELEMENT (Sb)	$2fb=fr\left(1-\frac{Da^2}{dm^2}\cos^2\alpha\right)$ [Hz]
RETAINER (Sc)	$fc=\frac{fr}{2}\left(1-\frac{Da}{dm}\cos\alpha\right)$ [Hz]

fr: INNER RING ROTATION SPEED [Hz]
fc: RETAINER ROTATION SPEED [Hz]
fb: ROLLING ELEMENT ROTATION SPEED [Hz]
dm: PITCH CIRCLE DIAMETER [mm]
Z: NUMBER OF ROLLING ELEMENTS
fi: fr-fc
Da: ROLLING ELEMENT DIAMETER [mm]
α: CONTACT ANGLE [DEGREE]

FIG. 5

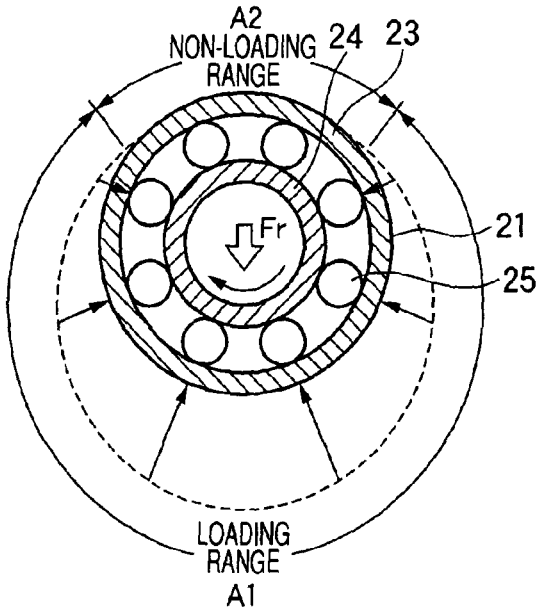


FIG. 6

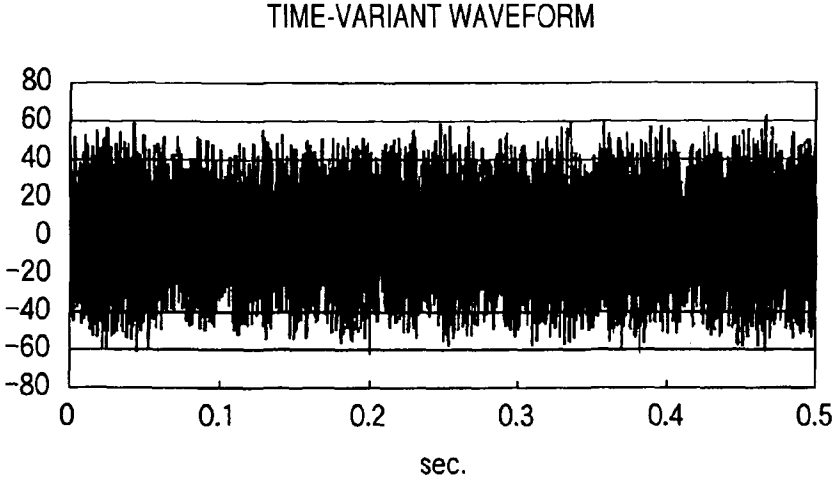

TIME-VARIANT WAVEFORM
80
60
40
20
0
-20
-40
-60
-80
0
0.1
0.2
0.3
0.4
0.5
sec.

FIG. 7

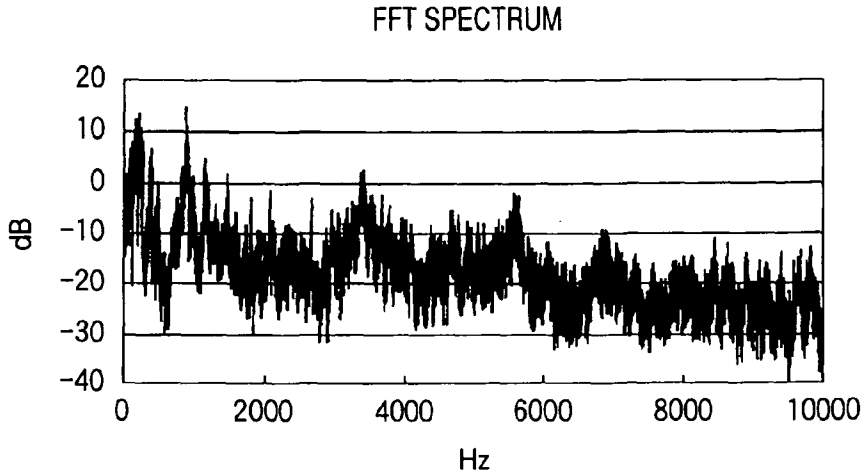

FFT SPECTRUM
20
10
0
-10
-20
-30
-40
dB
0
2000
4000
6000
8000
10000
Hz

FIG. 8

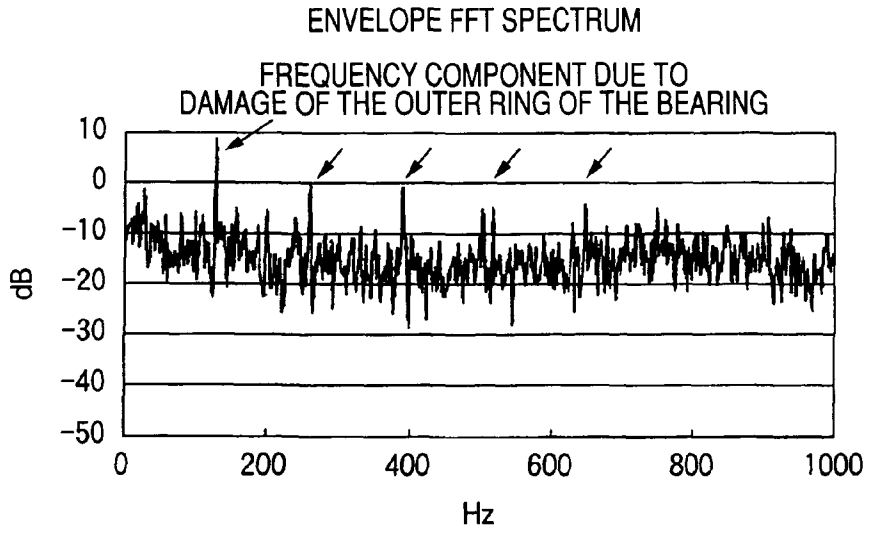

ENVELOPE FFT SPECTRUM
FREQUENCY COMPONENT DUE TO
DAMAGE OF THE OUTER RING OF THE BEARING
10
0
-10
-20
-30
-40
-50
dB
0
200
400
600
800
1000
Hz

FIG. 9

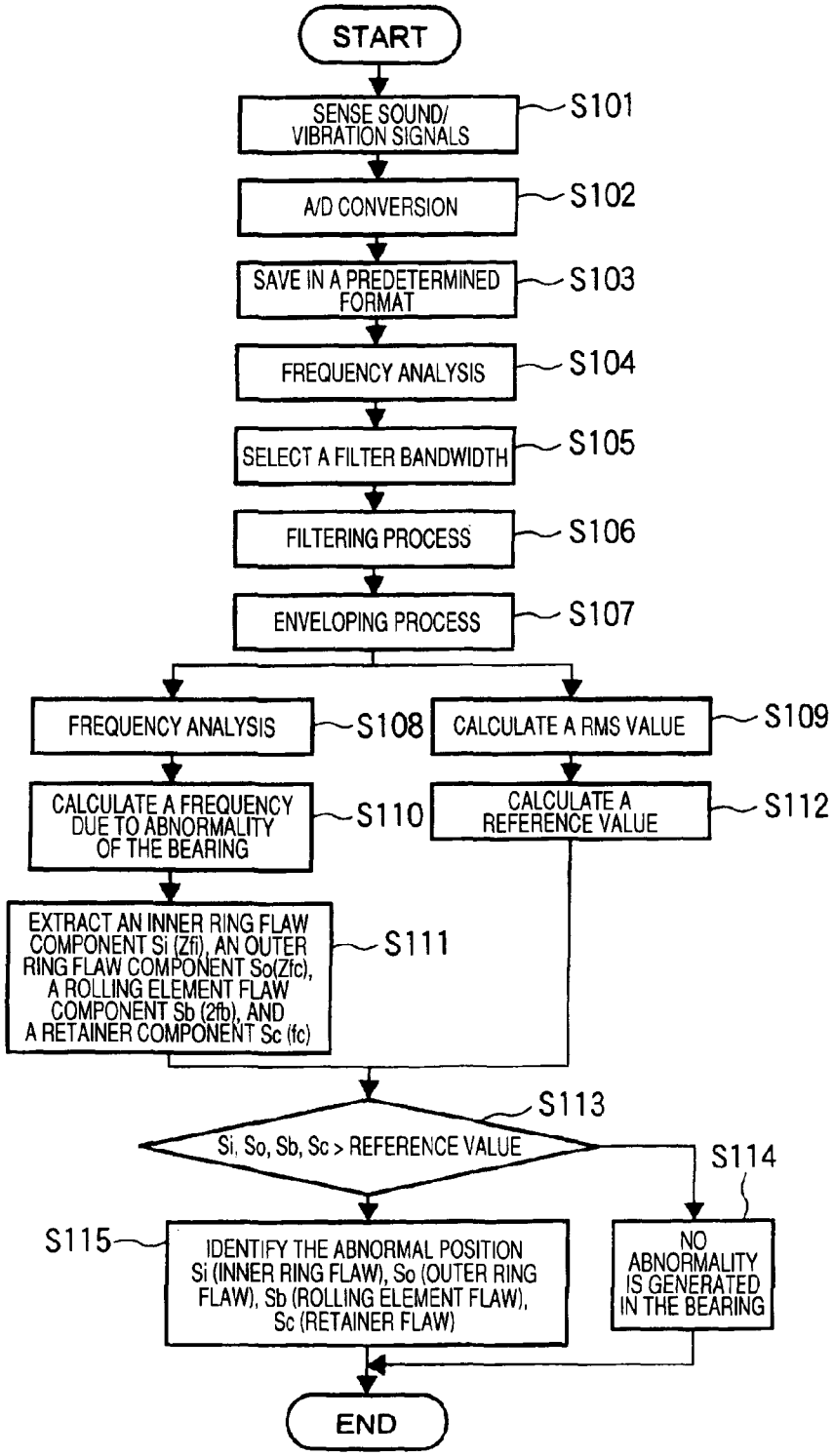

START
SENSE SOUND/ VIBRATION SIGNALS
S101
A/D CONVERSION
S102
SAVE IN A PREDETERMINED FORMAT
S103
FREQUENCY ANALYSIS
S104
SELECT A FILTER BANDWIDTH
S105
FILTERING PROCESS
S106
ENVELOPING PROCESS
S107
FREQUENCY ANALYSIS
S108
CALCULATE A RMS VALUE
S109
CALCULATE A FREQUENCY DUE TO ABNORMALITY OF THE BEARING
S110
CALCULATE A REFERENCE VALUE
S112
EXTRACT AN INNER RING FLAW COMPONENT Si (Zfi), AN OUTER RING FLAW COMPONENT So(Zfc), A ROLLING ELEMENT FLAW COMPONENT Sb (2fb), AND A RETAINER COMPONENT Sc (fc)
S111
S113
Si, So, Sb, Sc > REFERENCE VALUE
S114
S115
IDENTIFY THE ABNORMAL POSITION Si (INNER RING FLAW), So (OUTER RING FLAW), Sb (ROLLING ELEMENT FLAW), Sc (RETAINER FLAW)
NO ABNORMALITY IS GENERATED IN THE BEARING
END

FIG. 10

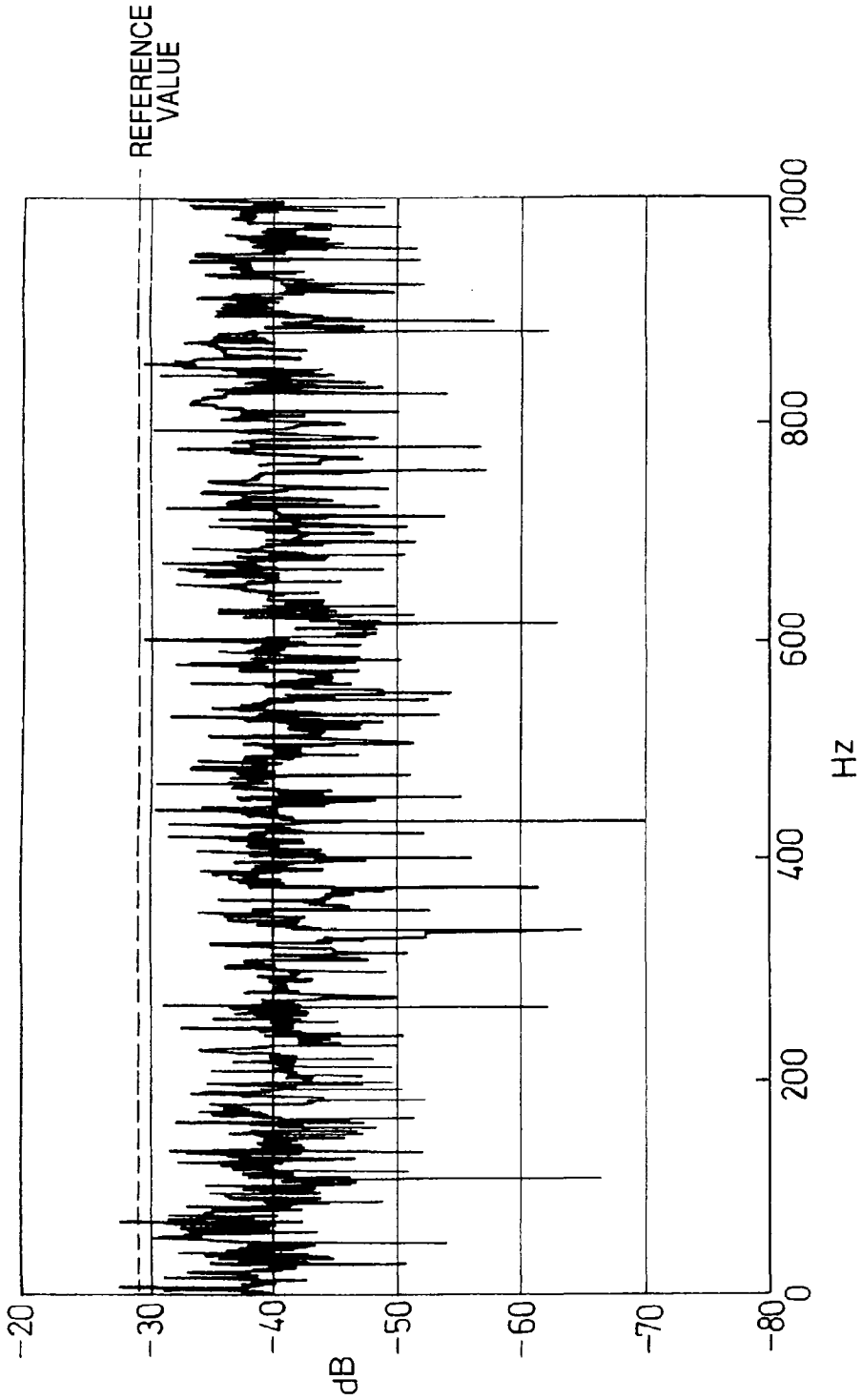


FIG. 11

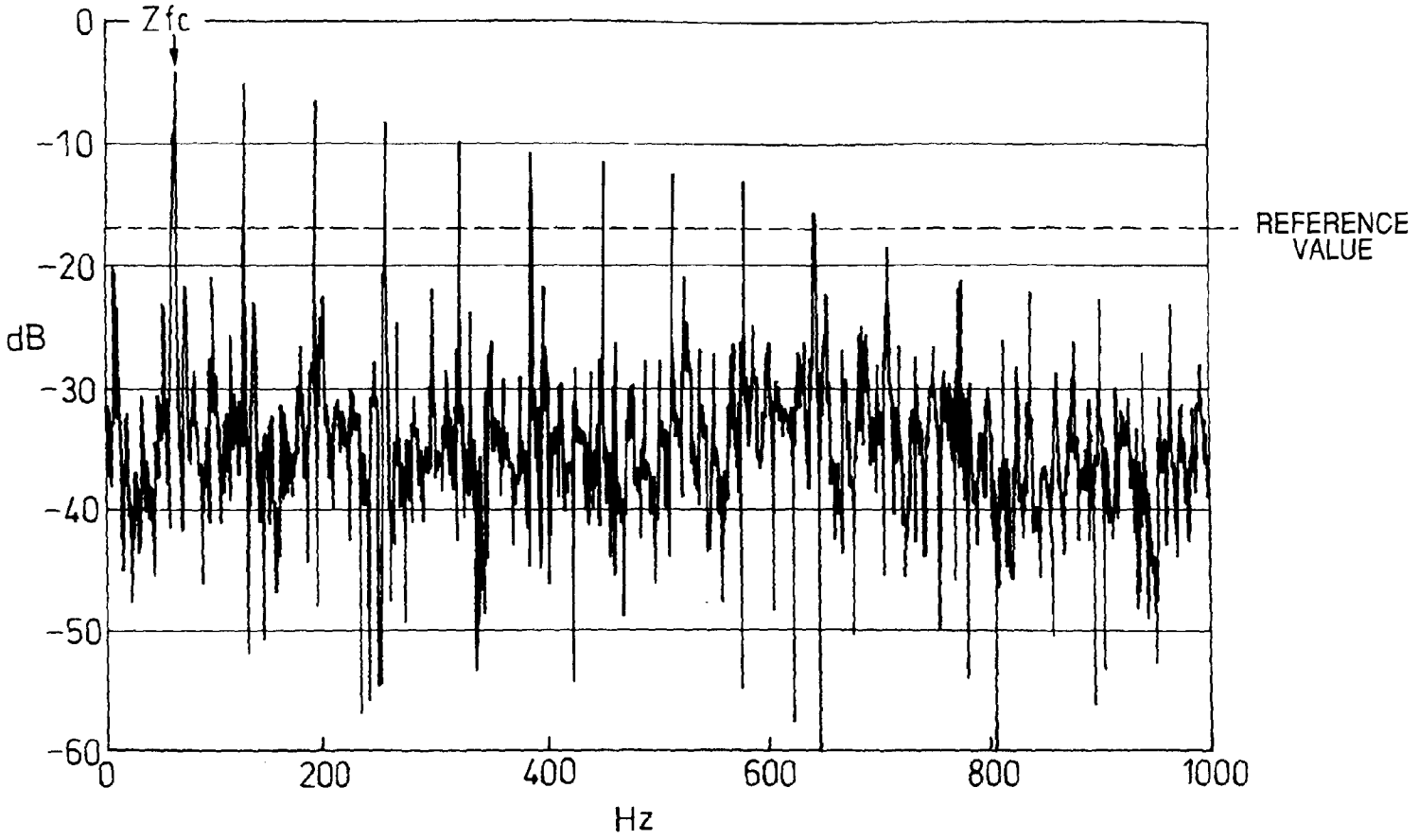

0
Zfc
-10
-20
dB
-30
-40
-50
-60
0
200
400
600
800
1000
Hz
REFERENCE VALUE

FIG. 12

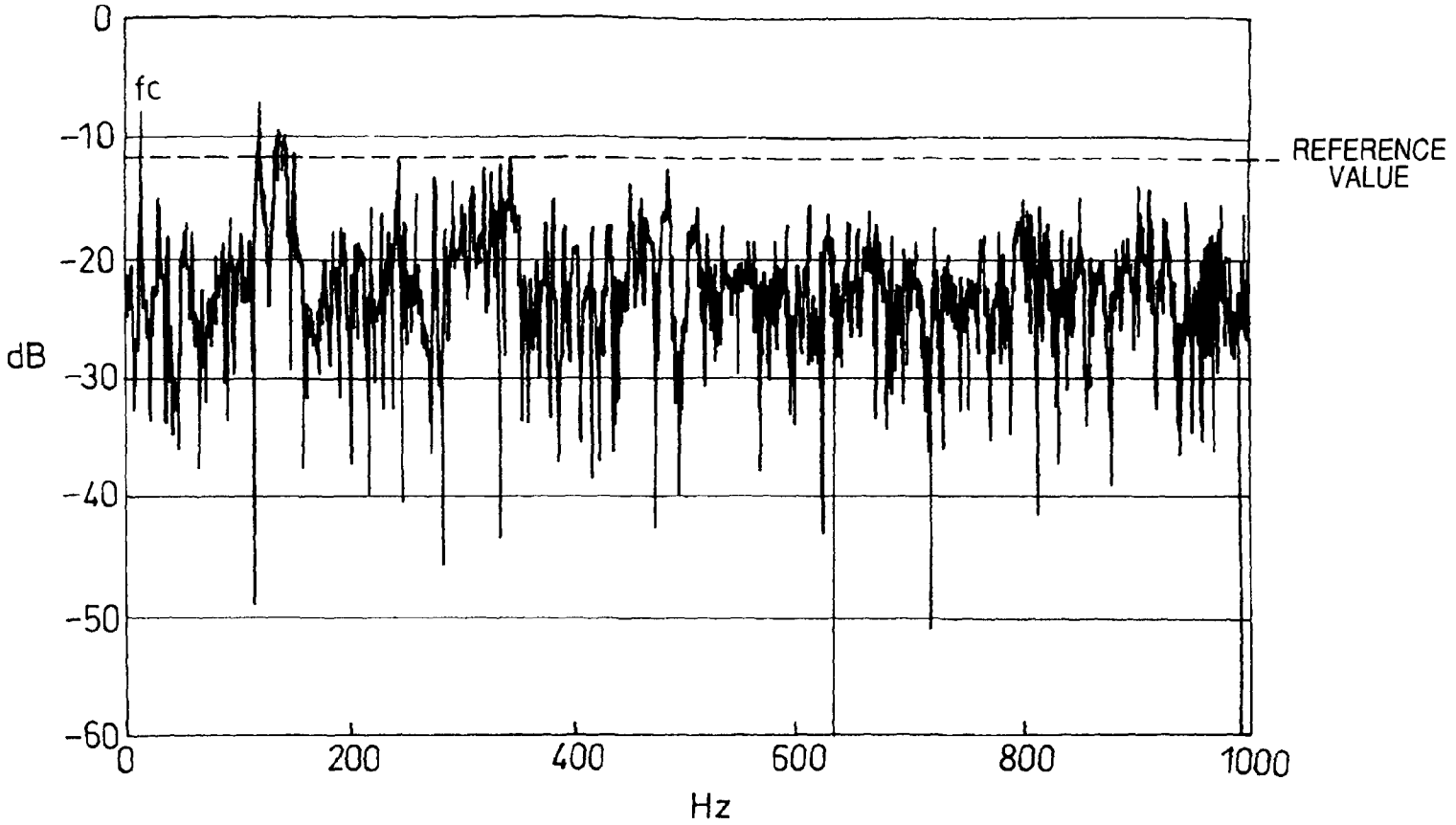

0
fc
-10
-20
-30
-40
-50
-60
dB
REFERENCE VALUE
0
200
400
600
800
1000
Hz

FIG. 13

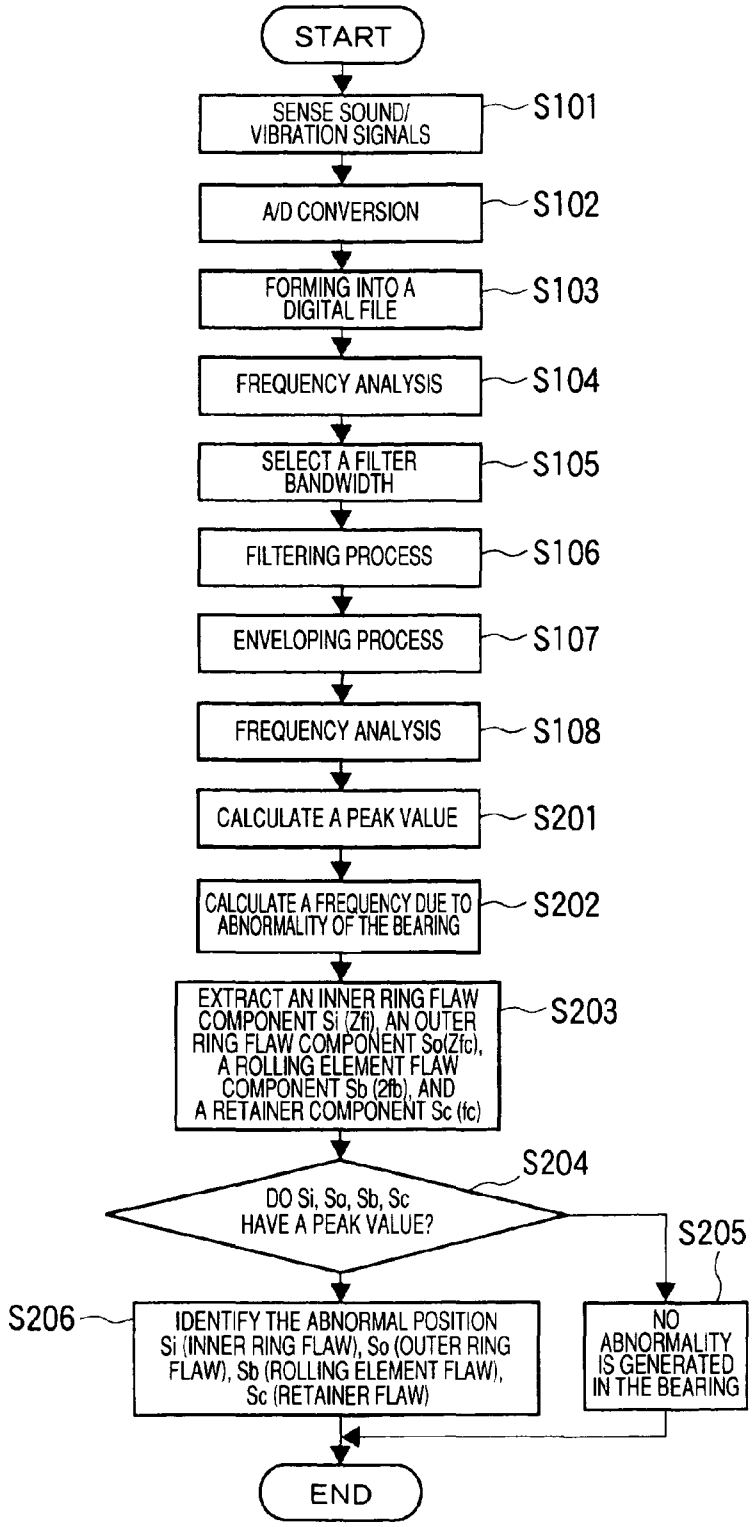
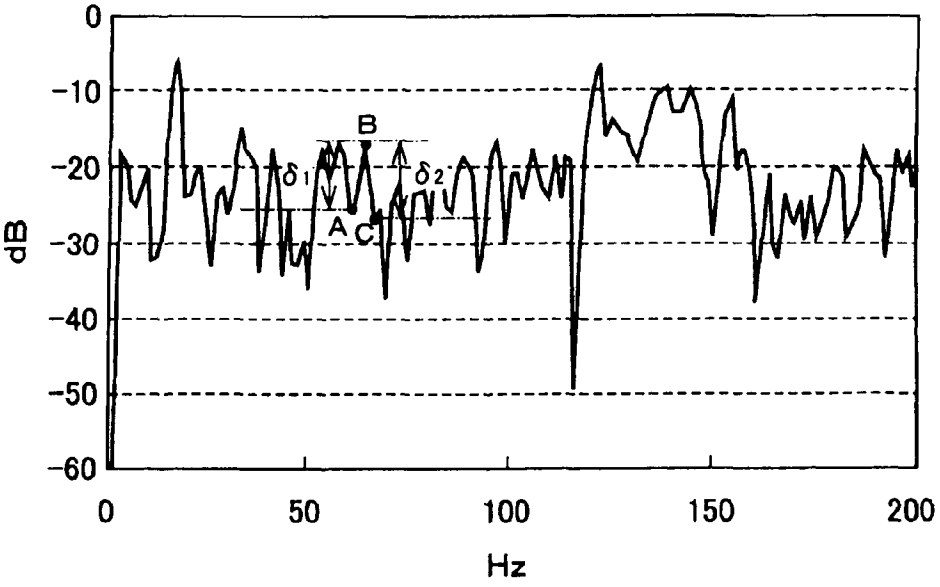

START
SENSE SOUND/ VIBRATION SIGNALS
S101
A/D CONVERSION
S102
FORMING INTO A DIGITAL FILE
S103
FREQUENCY ANALYSIS
S104
SELECT A FILTER BANDWIDTH
S105
FILTERING PROCESS
S106
ENVELOPING PROCESS
S107
FREQUENCY ANALYSIS
S108
CALCULATE A PEAK VALUE
S201
CALCULATE A FREQUENCY DUE TO ABNORMALITY OF THE BEARING
S202
EXTRACT AN INNER RING FLAW COMPONENT Si (Zfi), AN OUTER RING FLAW COMPONENT So(Zfc), A ROLLING ELEMENT FLAW COMPONENT Sb (2fb), AND A RETAINER COMPONENT Sc (fc)
S203
DO Si, So, Sb, Sc HAVE A PEAK VALUE?
S204
S205
S206
IDENTIFY THE ABNORMAL POSITION Si (INNER RING FLAW), So (OUTER RING FLAW), Sb (ROLLING ELEMENT FLAW), Sc (RETAINER FLAW)
NO ABNORMALITY IS GENERATED IN THE BEARING
END

FIG. 14



$\delta 1(=Y1-Y0)>0$ - (1)
$\delta 2(=Y2-Y1)<0$ - (2)
WHERE A $(X0,Y0)$, B $(X1,Y1)$, C $(X2,Y2)$.
WHEN (1), (2) ARE SATISFIED AND
$dy/dx=(Y1-Y0)/(X1-X0)>1$
OR
$dy/dx=(Y2-Y1)/(X2-X1)<-1$
IS SATISFIED, $Y1$ IS DECIDED AS A PEAK.

FIG. 15

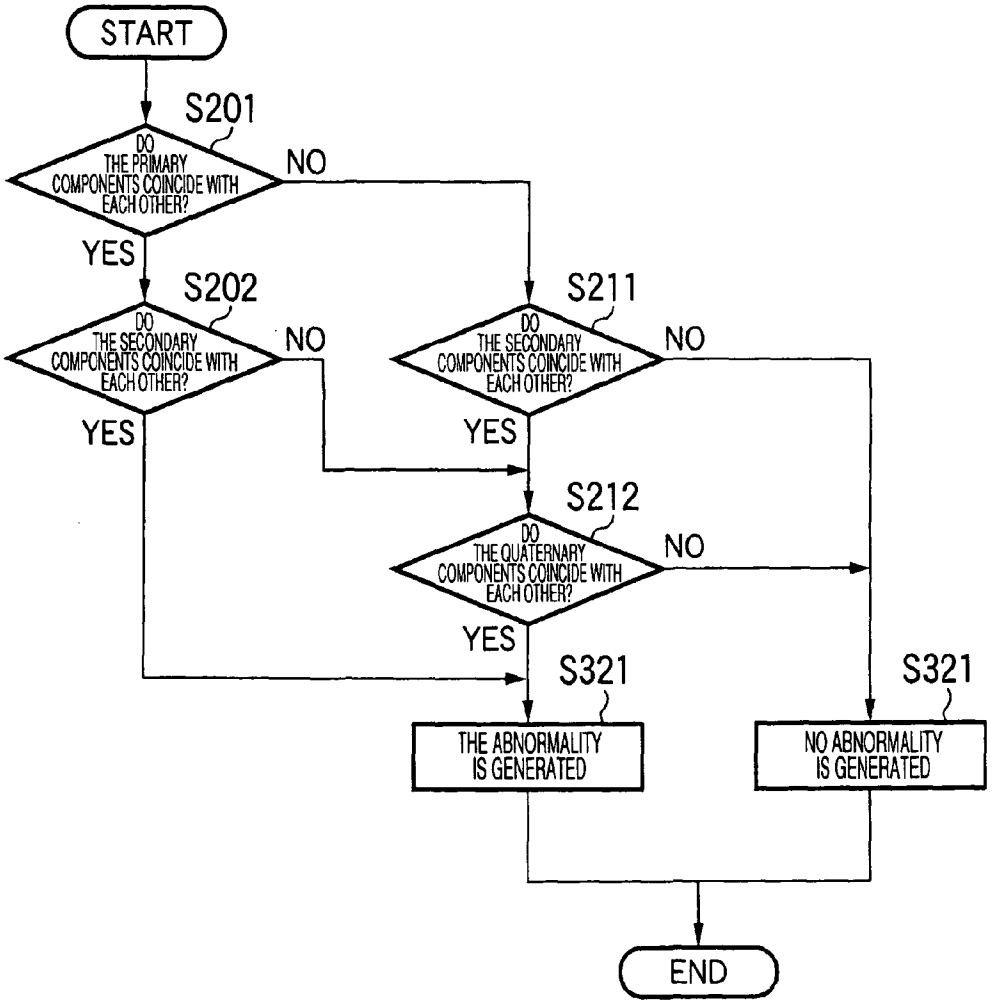
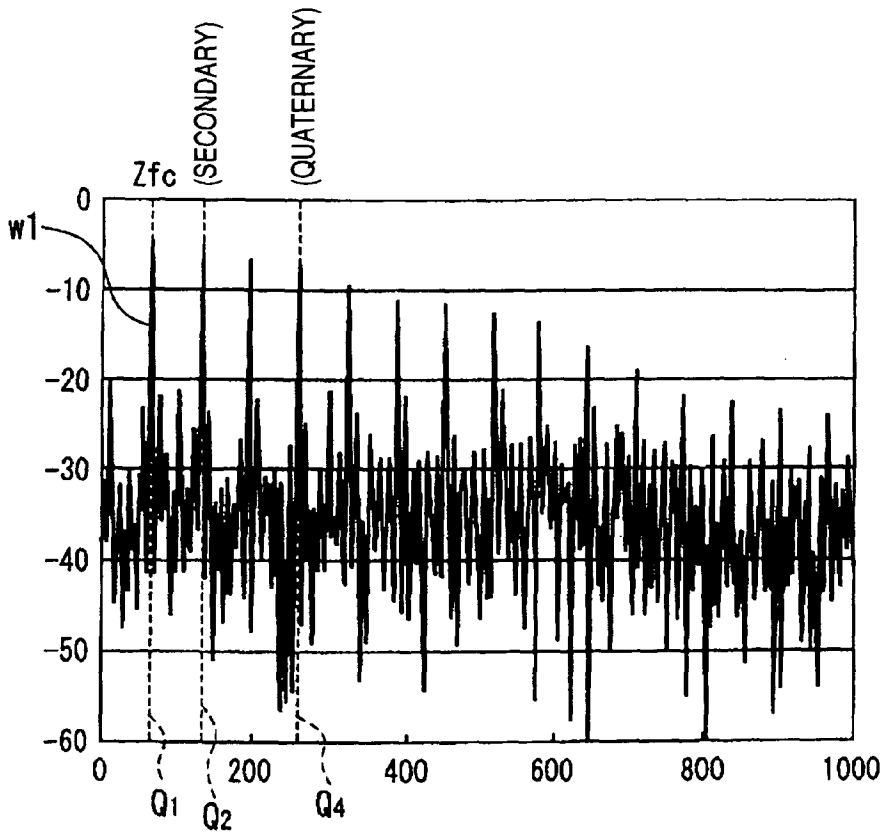

START
S201
DO THE PRIMARY COMPONENTS COINCIDE WITH EACH OTHER?
NO
YES
S202
DO THE SECONDARY COMPONENTS COINCIDE WITH EACH OTHER?
NO
YES
S211
DO THE SECONDARY COMPONENTS COINCIDE WITH EACH OTHER?
NO
YES
S212
DO THE QUATERNARY COMPONENTS COINCIDE WITH EACH OTHER?
NO
YES
S321
THE ABNORMALITY IS GENERATED
S321
NO ABNORMALITY IS GENERATED
END

FIG. 16



COLLATE ONLY THE PRIMARY, SECONDARY, QUATERNARY COMPONENTS (FLAW OF THE OUTER RING)

FIG. 17

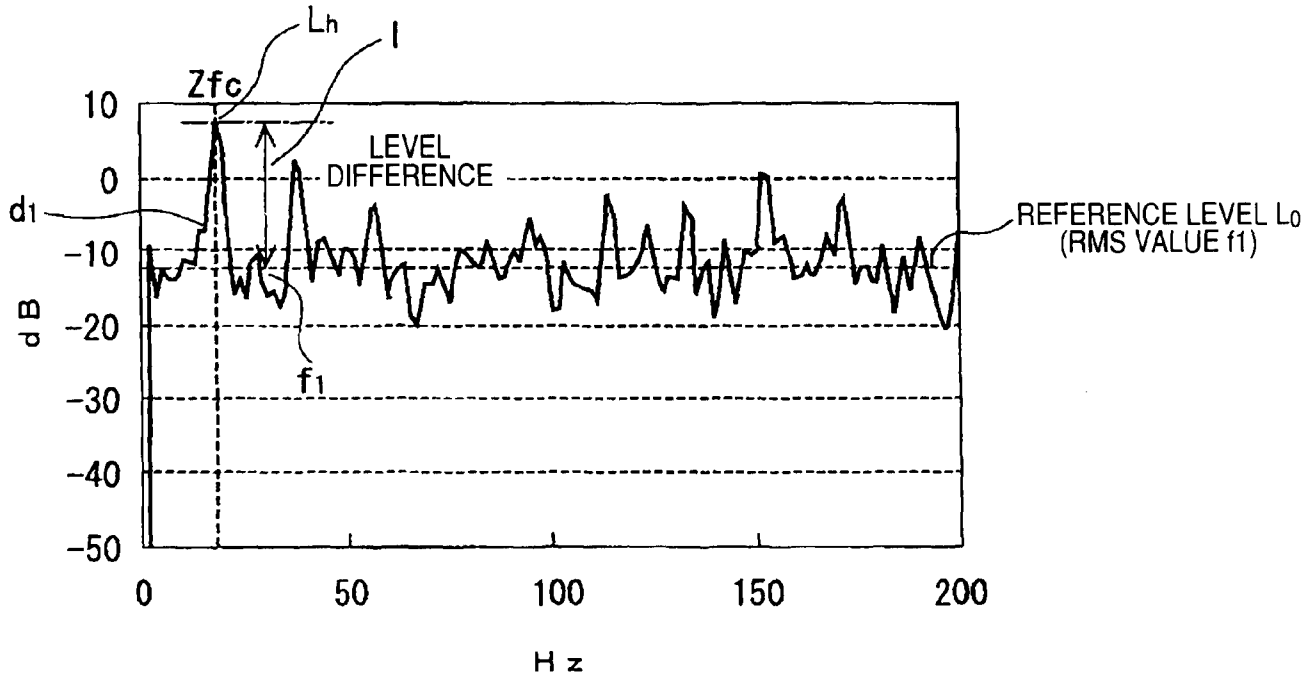
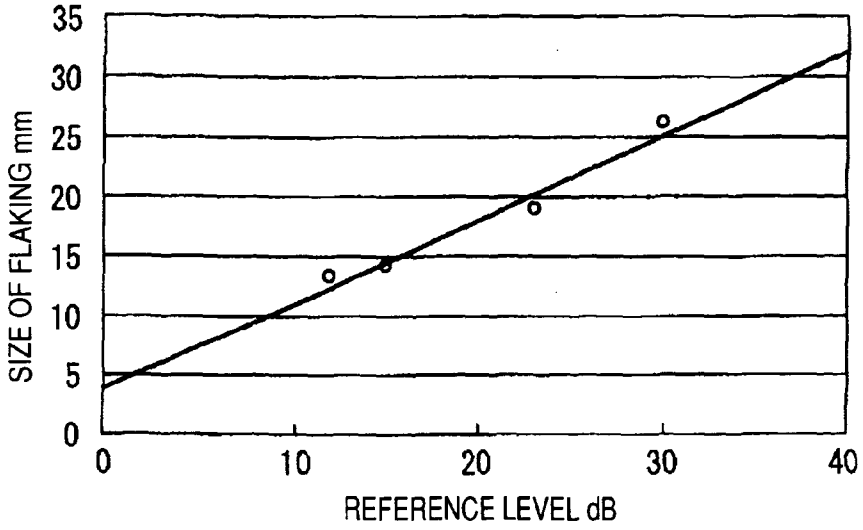

Lh
l
Zfc
10
0
LEVEL
DIFFERENCE
d1
REFERENCE LEVEL L0
(RMS VALUE f1)
-10
dB
-20
f1
-30
-40
-50
0
50
100
150
200
Hz

FIG. 18



A RELATIONSHIP BETWEEN A SIZE OF FLAKING AND A LEVEL DIFFERENCE

FIG. 19

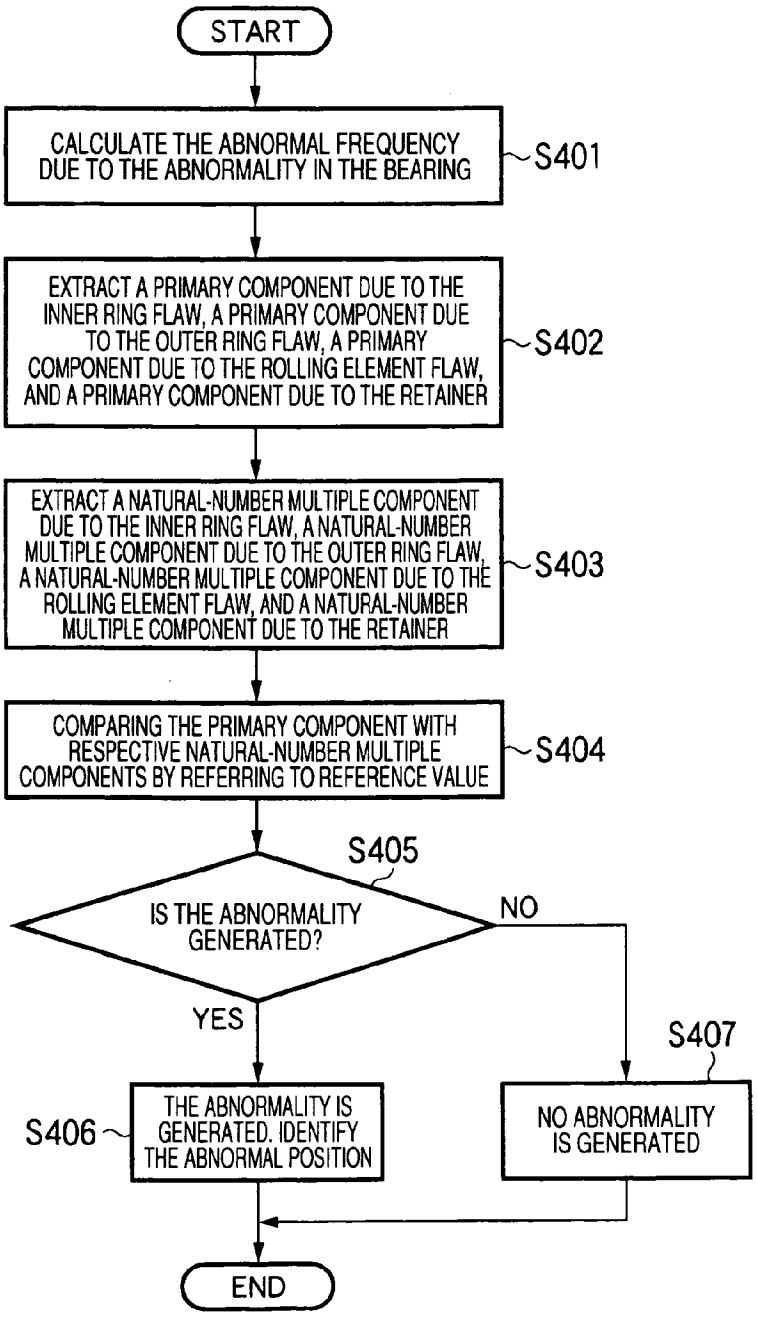

START
CALCULATE THE ABNORMAL FREQUENCY DUE TO THE ABNORMALITY IN THE BEARING
S401
EXTRACT A PRIMARY COMPONENT DUE TO THE INNER RING FLAW, A PRIMARY COMPONENT DUE TO THE OUTER RING FLAW, A PRIMARY COMPONENT DUE TO THE ROLLING ELEMENT FLAW, AND A PRIMARY COMPONENT DUE TO THE RETAINER
S402
EXTRACT A NATURAL-NUMBER MULTIPLE COMPONENT DUE TO THE INNER RING FLAW, A NATURAL-NUMBER MULTIPLE COMPONENT DUE TO THE OUTER RING FLAW, A NATURAL-NUMBER MULTIPLE COMPONENT DUE TO THE ROLLING ELEMENT FLAW, AND A NATURAL-NUMBER MULTIPLE COMPONENT DUE TO THE RETAINER
S403
COMPARING THE PRIMARY COMPONENT WITH RESPECTIVE NATURAL-NUMBER MULTIPLE COMPONENTS BY REFERRING TO REFERENCE VALUE
S404
S405
IS THE ABNORMALITY GENERATED?
NO
YES
S407
S406
THE ABNORMALITY IS GENERATED. IDENTIFY THE ABNORMAL POSITION
NO ABNORMALITY IS GENERATED
END

FIG. 20

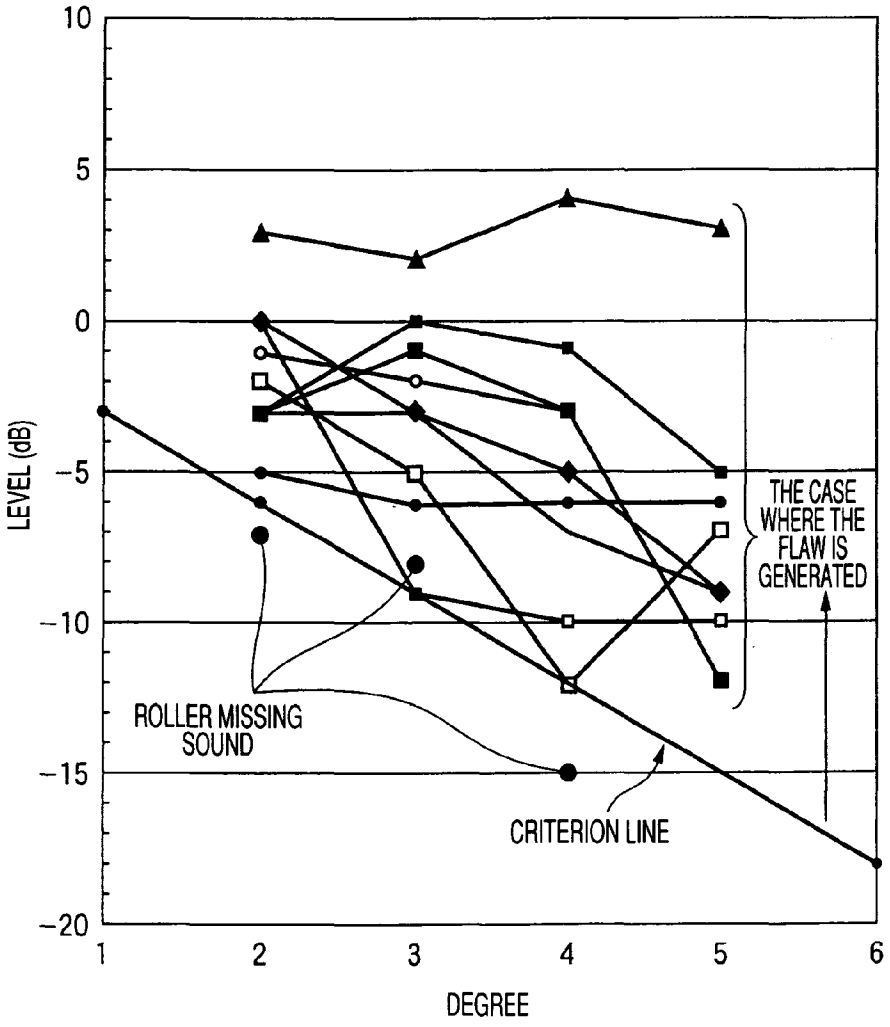

10
5
0
−5
−10
−15
−20
LEVEL (dB)
1
2
3
4
5
6
DEGREE
THE CASE WHERE THE FLAW IS GENERATED
ROLLER MISSING SOUND
CRITERION LINE

FIG. 21

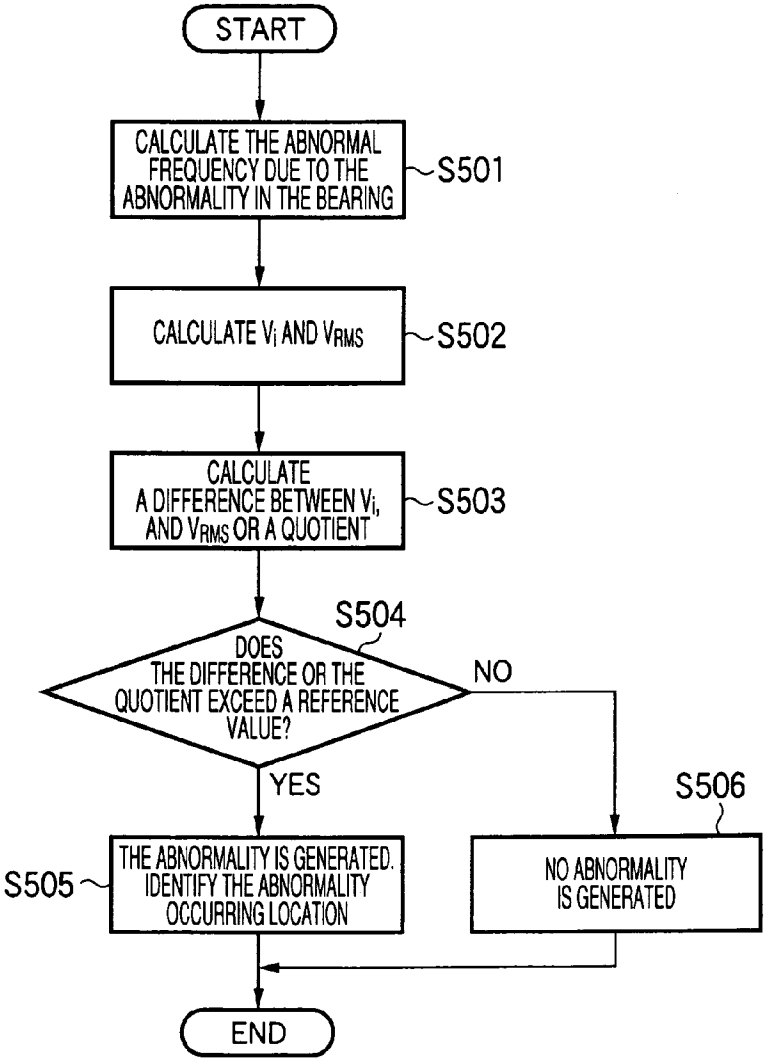

START
CALCULATE THE ABNORMAL FREQUENCY DUE TO THE ABNORMALITY IN THE BEARING
S501
CALCULATE Vi AND VRMS
S502
CALCULATE A DIFFERENCE BETWEEN Vi, AND VRMS OR A QUOTIENT
S503
S504
DOES THE DIFFERENCE OR THE QUOTIENT EXCEED A REFERENCE VALUE?
NO
YES
S506
S505
THE ABNORMALITY IS GENERATED. IDENTIFY THE ABNORMALITY OCCURRING LOCATION
NO ABNORMALITY IS GENERATED
END

FIG. 22

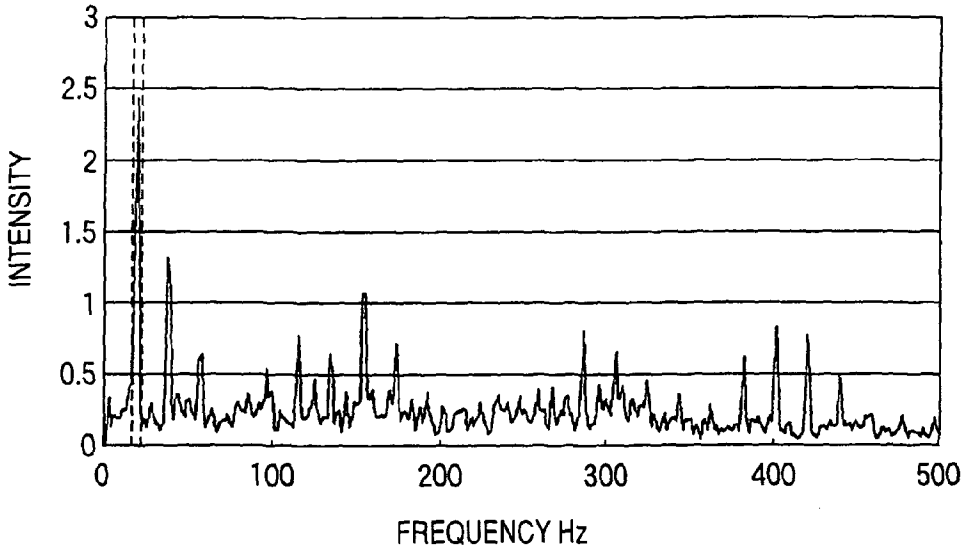

INTENSITY
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
FREQUENCY Hz

FIG. 23

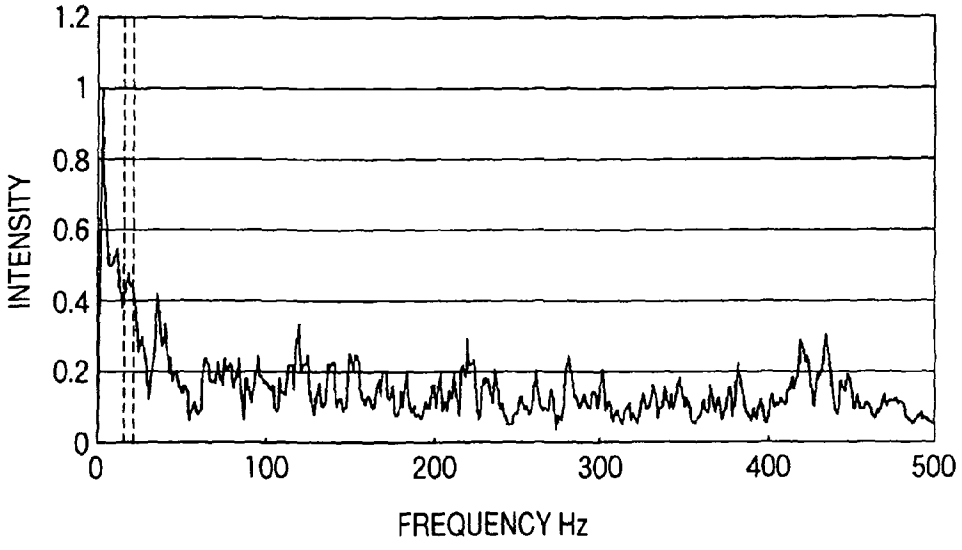

INTENSITY
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
FREQUENCY Hz

FIG. 24

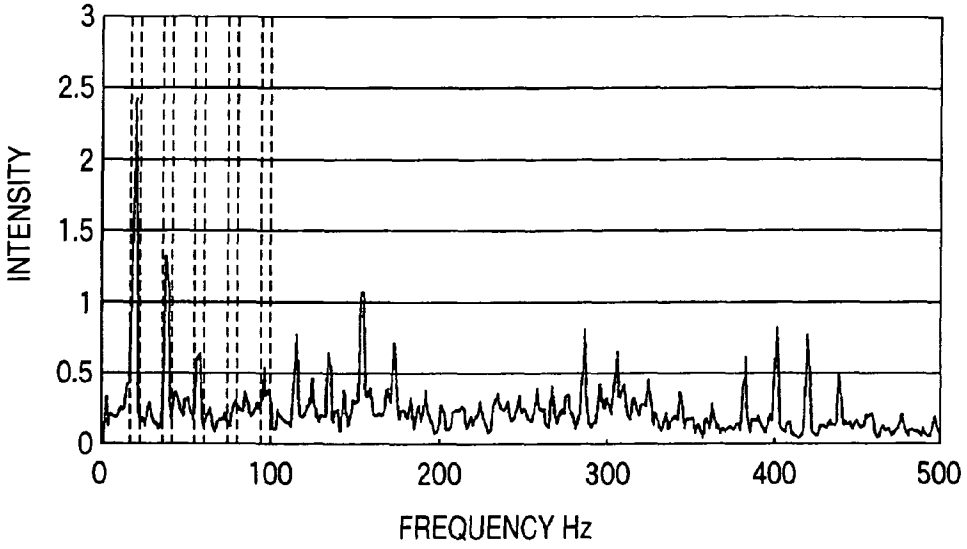

INTENSITY
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
FREQUENCY Hz

FIG. 25

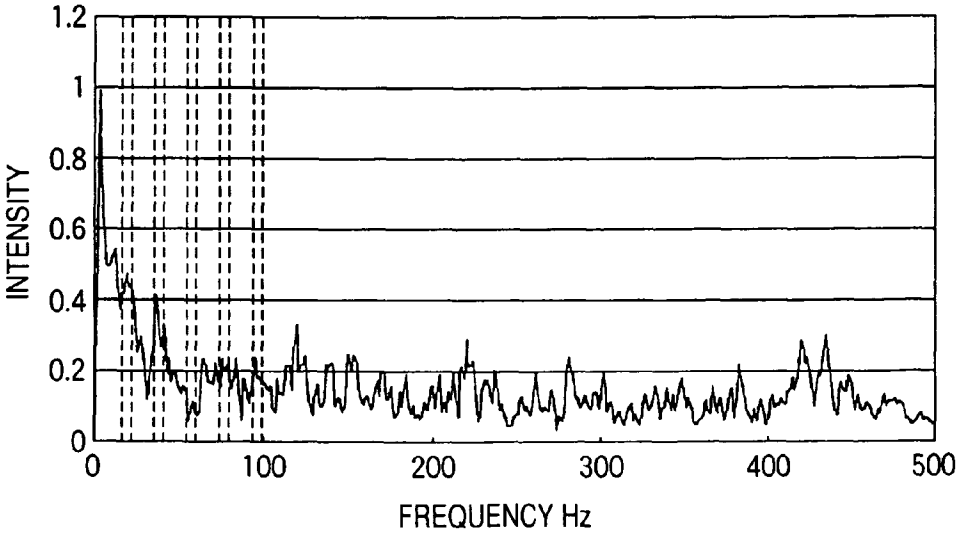

INTENSITY
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
FREQUENCY Hz

FIG. 26

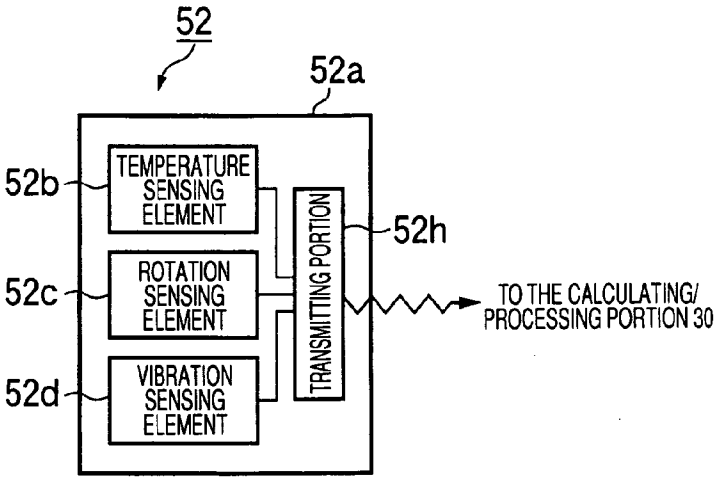

52
52a
52b
TEMPERATURE SENSING ELEMENT
52c
ROTATION SENSING ELEMENT
52d
VIBRATION SENSING ELEMENT
TRANSMITTING PORTION
52h
TO THE CALCULATING/ PROCESSING PORTION 30

FIG. 27

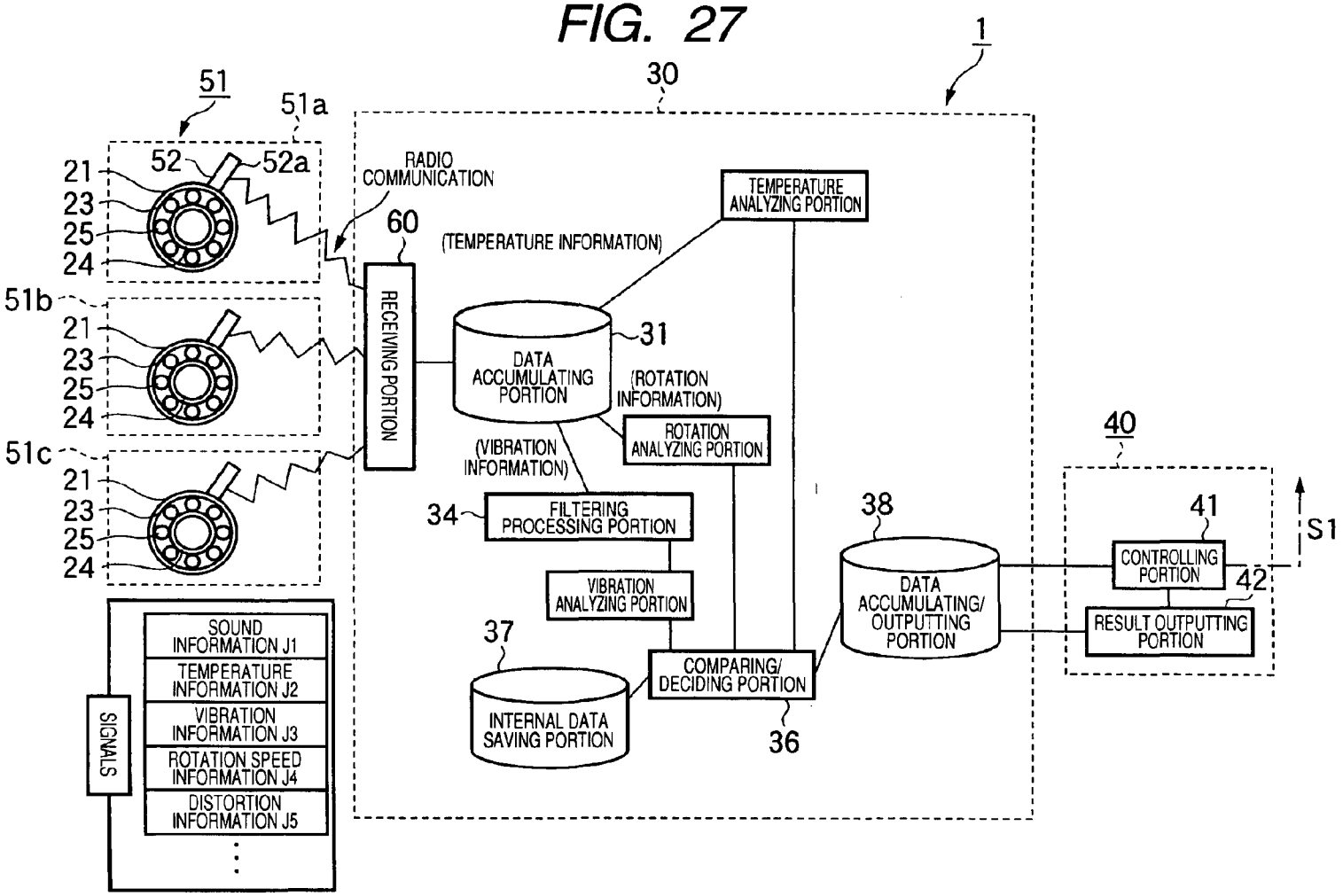

1
30
51
51a
52
52a
21
23
25
24
51b
51c
RADIO COMMUNICATION
60
RECEIVING PORTION
(TEMPERATURE INFORMATION)
TEMPERATURE ANALYZING PORTION
DATA ACCUMULATING PORTION
31
(ROTATION INFORMATION)
ROTATION ANALYZING PORTION
(VIBRATION INFORMATION)
34
FILTERING PROCESSING PORTION
VIBRATION ANALYZING PORTION
37
INTERNAL DATA SAVING PORTION
COMPARING/ DECIDING PORTION
36
38
DATA ACCUMULATING/ OUTPUTTING PORTION
40
41
CONTROLLING PORTION
42
RESULT OUTPUTTING PORTION
S1
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5

FIG. 28

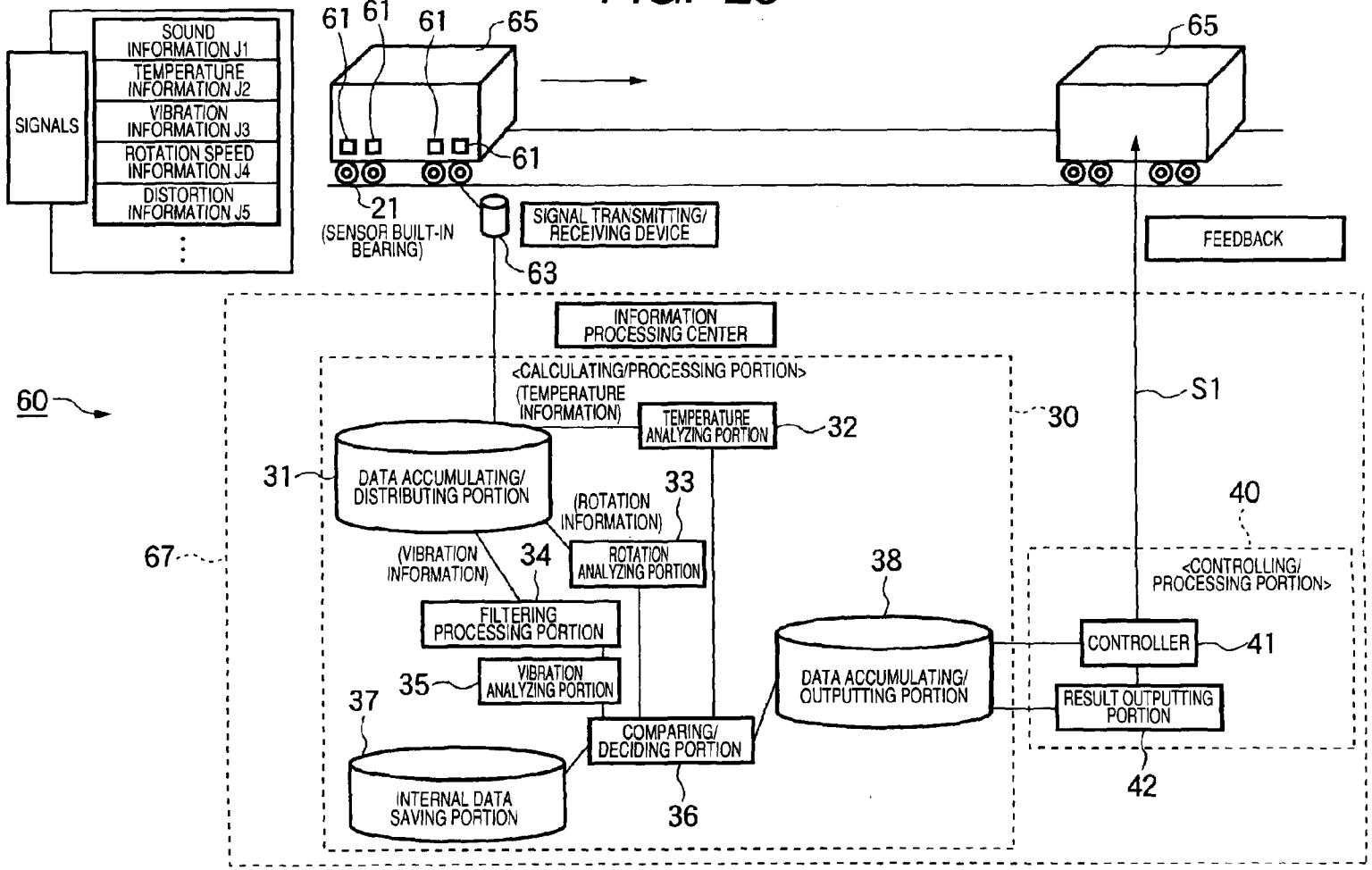

SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5
61
61
61
65
65
61
21
(SENSOR BUILT-IN BEARING)
SIGNAL TRANSMITTING/ RECEIVING DEVICE
63
FEEDBACK
INFORMATION PROCESSING CENTER
60
<CALCULATING/PROCESSING PORTION>
(TEMPERATURE INFORMATION)
TEMPERATURE ANALYZING PORTION
32
30
S1
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
33
(ROTATION INFORMATION)
ROTATION ANALYZING PORTION
40
67
(VIBRATION INFORMATION)
34
38
<CONTROLLING/ PROCESSING PORTION>
FILTERING PROCESSING PORTION
CONTROLLER
41
VIBRATION ANALYZING PORTION
35
DATA ACCUMULATING/ OUTPUTTING PORTION
37
RESULT OUTPUTTING PORTION
COMPARING/ DECIDING PORTION
INTERNAL DATA SAVING PORTION
36
42

FIG. 29

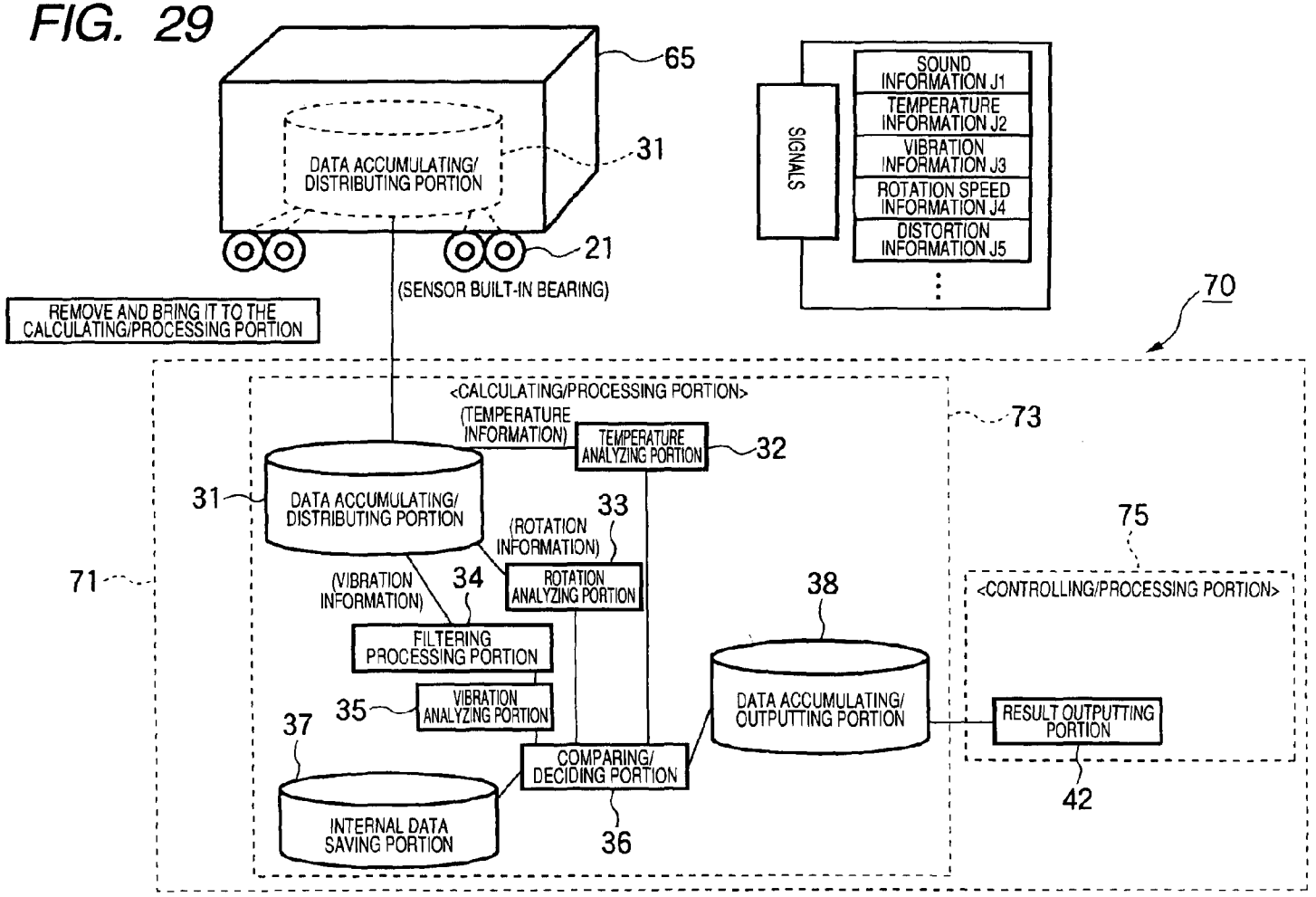

65
DATA ACCUMULATING/
DISTRIBUTING PORTION
31
21
(SENSOR BUILT-IN BEARING)
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5
REMOVE AND BRING IT TO THE CALCULATING/PROCESSING PORTION
70
<CALCULATING/PROCESSING PORTION>
73
(TEMPERATURE INFORMATION)
TEMPERATURE ANALYZING PORTION
32
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
33
(ROTATION INFORMATION)
ROTATION ANALYZING PORTION
71
(VIBRATION INFORMATION)
34
FILTERING PROCESSING PORTION
38
75
<CONTROLLING/PROCESSING PORTION>
35
VIBRATION ANALYZING PORTION
37
DATA ACCUMULATING/ OUTPUTTING PORTION
RESULT OUTPUTTING PORTION
COMPARING/ DECIDING PORTION
42
INTERNAL DATA SAVING PORTION
36

FIG. 30

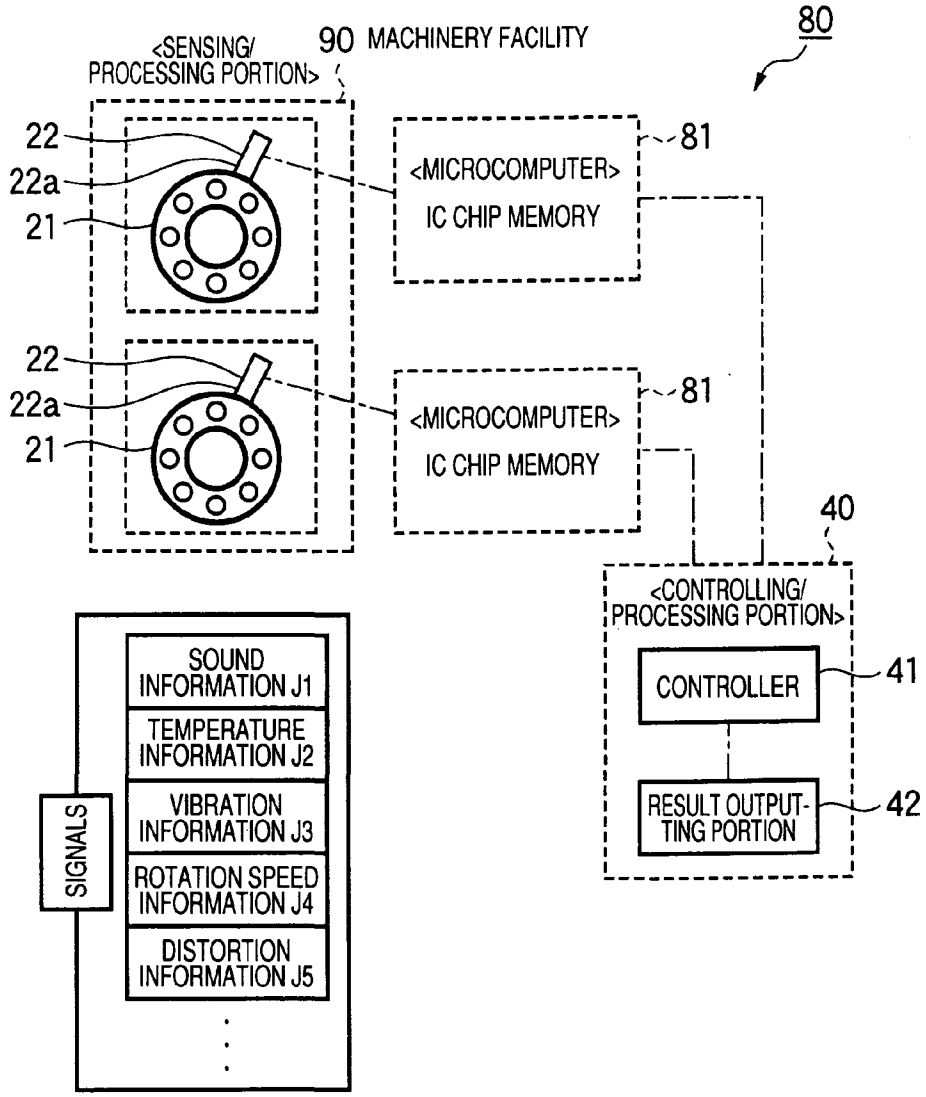

80
<SENSING/ PROCESSING PORTION>
90 MACHINERY FACILITY
22
22a
21
<MICROCOMPUTER>
IC CHIP MEMORY
81
22
22a
21
<MICROCOMPUTER>
IC CHIP MEMORY
81
40
<CONTROLLING/ PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUT-TING PORTION
42
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5

FIG. 31

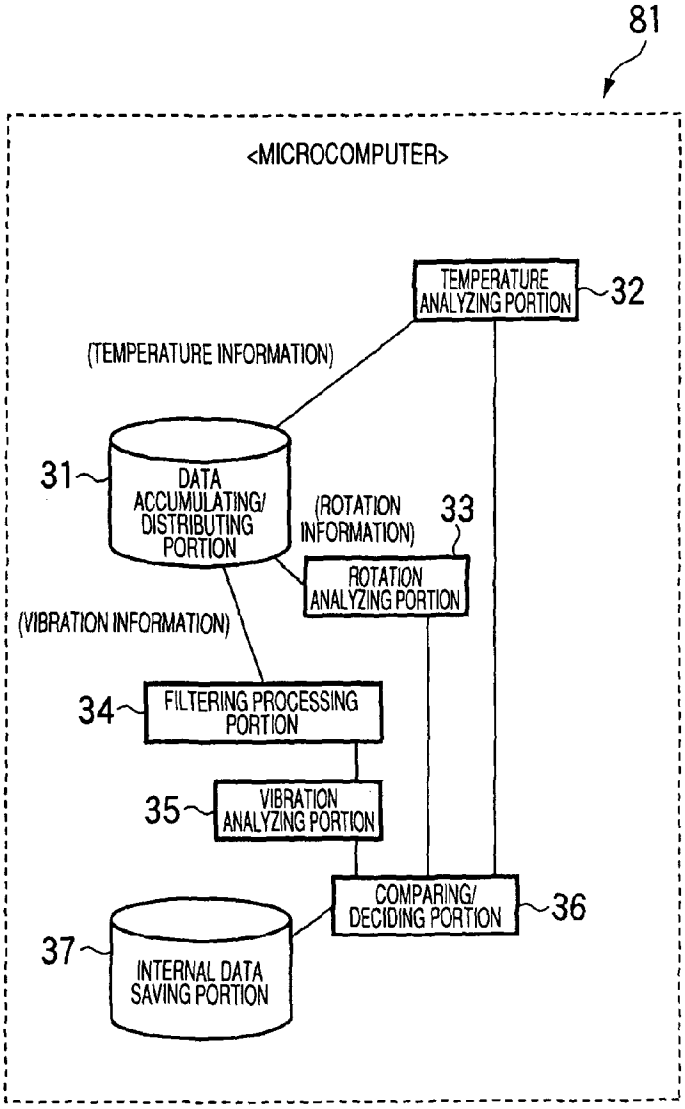

81
<MICROCOMPUTER>
TEMPERATURE ANALYZING PORTION
32
(TEMPERATURE INFORMATION)
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
(ROTATION INFORMATION)
33
ROTATION ANALYZING PORTION
(VIBRATION INFORMATION)
34
FILTERING PROCESSING PORTION
35
VIBRATION ANALYZING PORTION
COMPARING/ DECIDING PORTION
36
37
INTERNAL DATA SAVING PORTION

FIG. 32

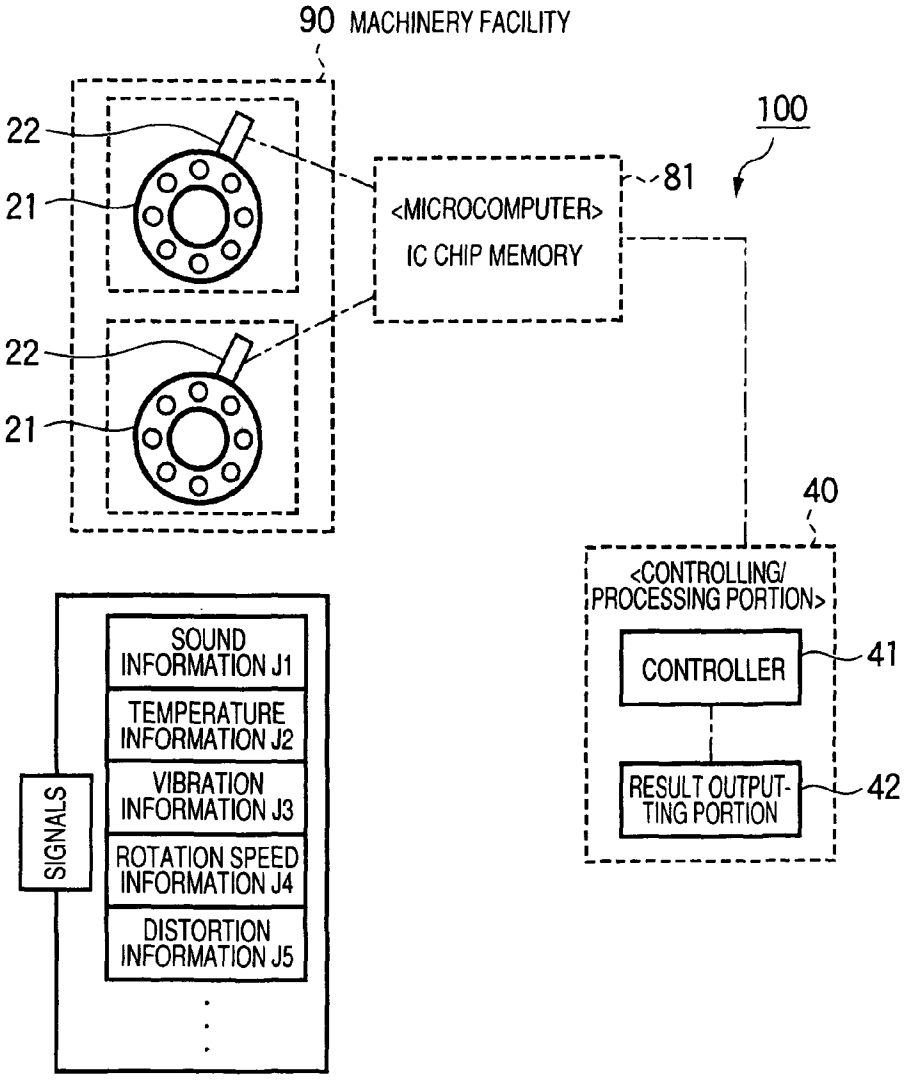

90 MACHINERY FACILITY
22
21
22
21
100
81
<MICROCOMPUTER>
IC CHIP MEMORY
40
<CONTROLLING/
PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUT-
TING PORTION
42
SIGNALS
SOUND
INFORMATION J1
TEMPERATURE
INFORMATION J2
VIBRATION
INFORMATION J3
ROTATION SPEED
INFORMATION J4
DISTORTION
INFORMATION J5

FIG. 33

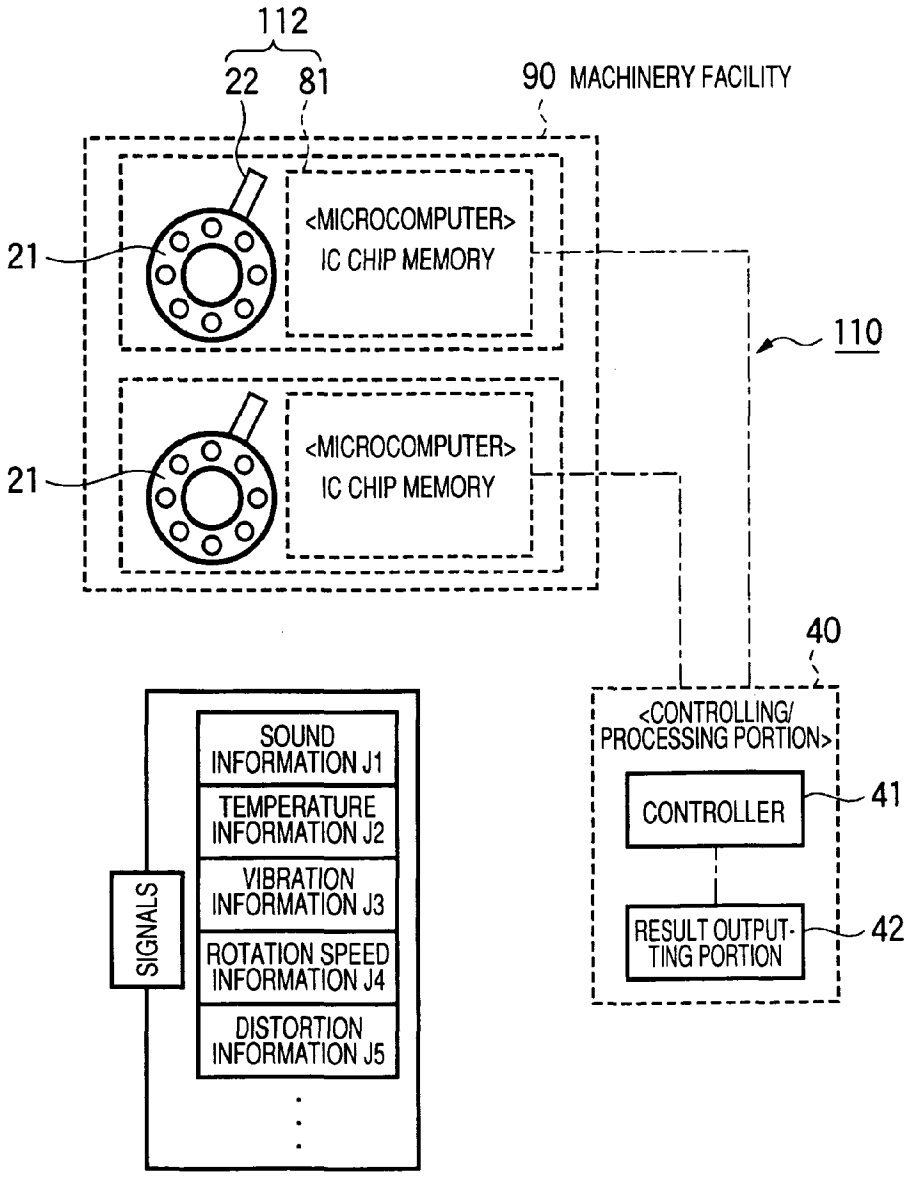

112
22
81
90 MACHINERY FACILITY
21
<MICROCOMPUTER>
IC CHIP MEMORY
21
<MICROCOMPUTER>
IC CHIP MEMORY
110
40
<CONTROLLING/
PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUT-
TING PORTION
42
SIGNALS
SOUND
INFORMATION J1
TEMPERATURE
INFORMATION J2
VIBRATION
INFORMATION J3
ROTATION SPEED
INFORMATION J4
DISTORTION
INFORMATION J5

FIG. 34(a)

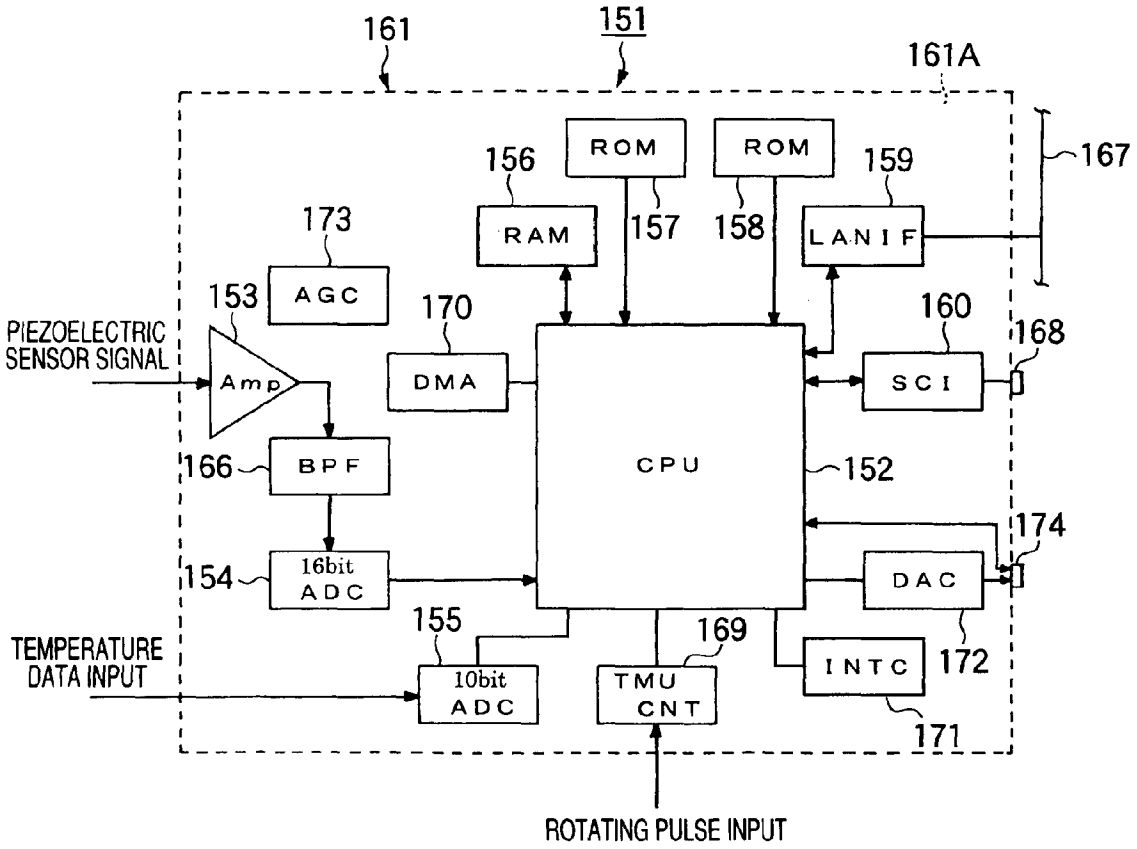
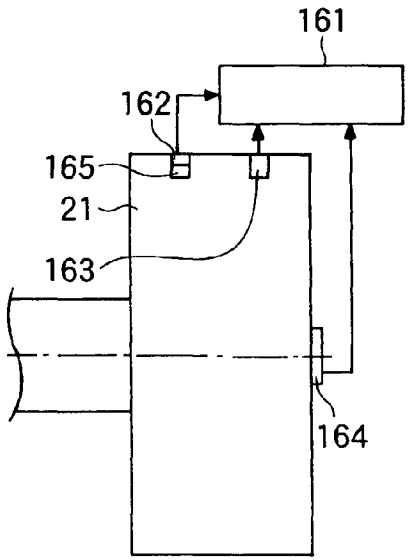


FIG. 34(b)



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FIG. 35(a)

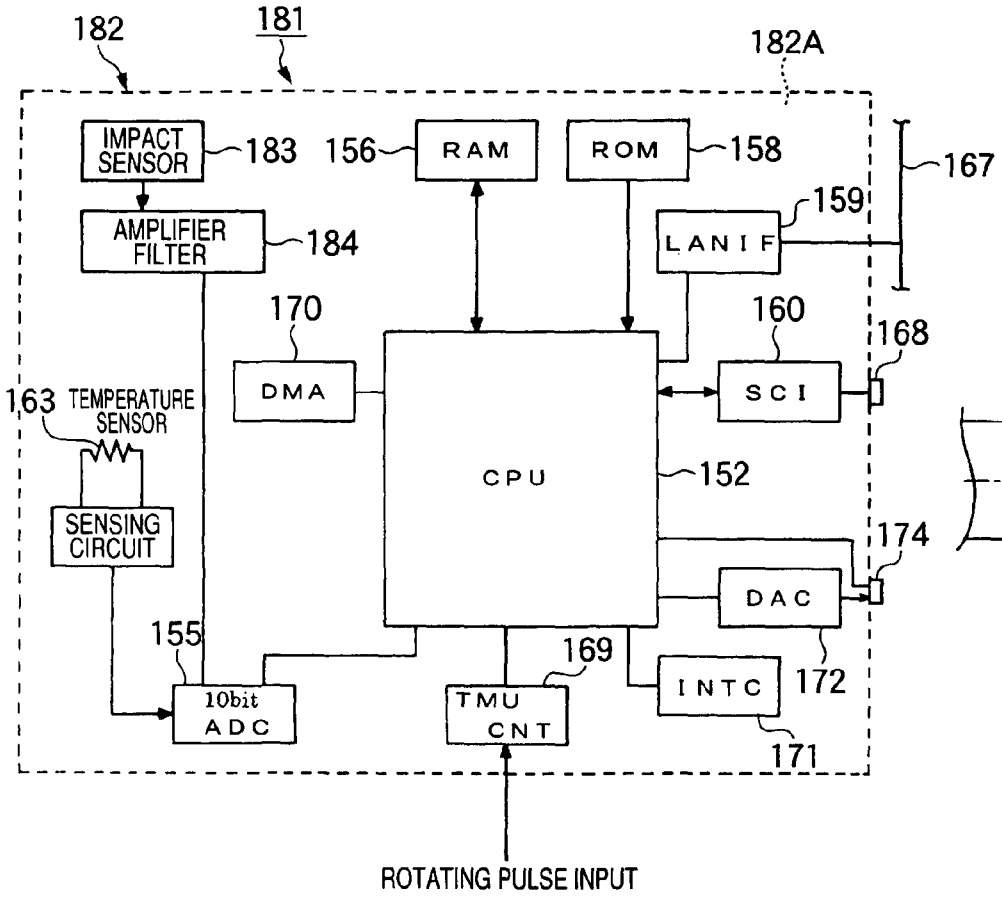


FIG. 35(b)

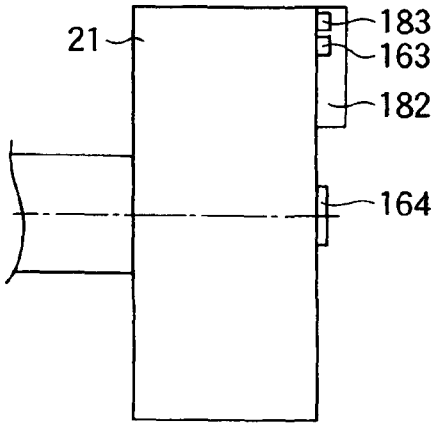


FIG. 36

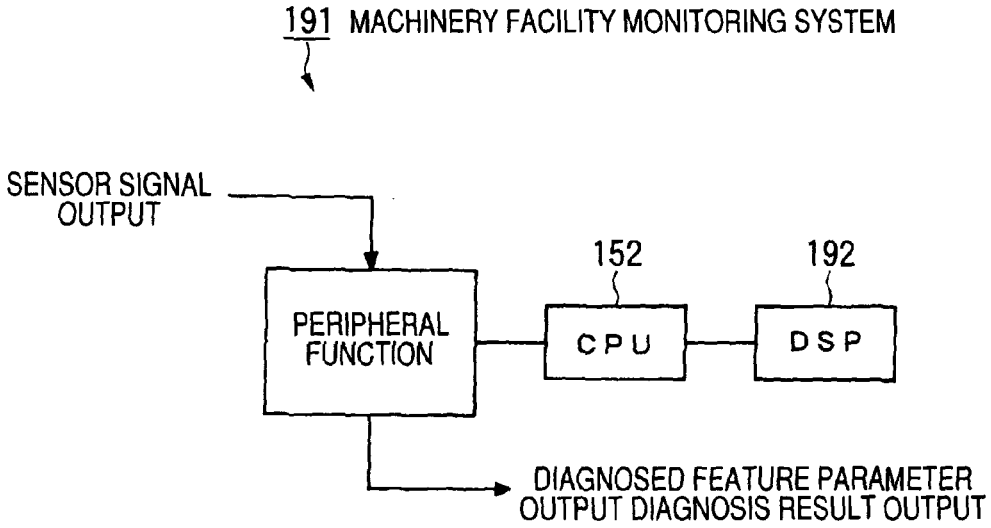

191 MACHINERY FACILITY MONITORING SYSTEM
SENSOR SIGNAL OUTPUT
PERIPHERAL FUNCTION
152
CPU
192
DSP
DIAGNOSED FEATURE PARAMETER OUTPUT DIAGNOSIS RESULT OUTPUT

FIG. 37

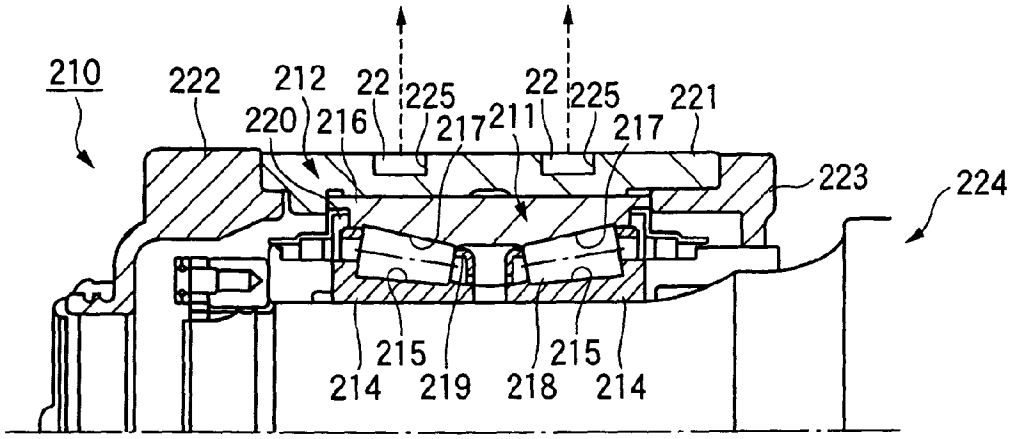

210
222
212
220
216
22
225
217
211
22
225
217
221
223
224
215
214
219
218
215
214

FIG. 38

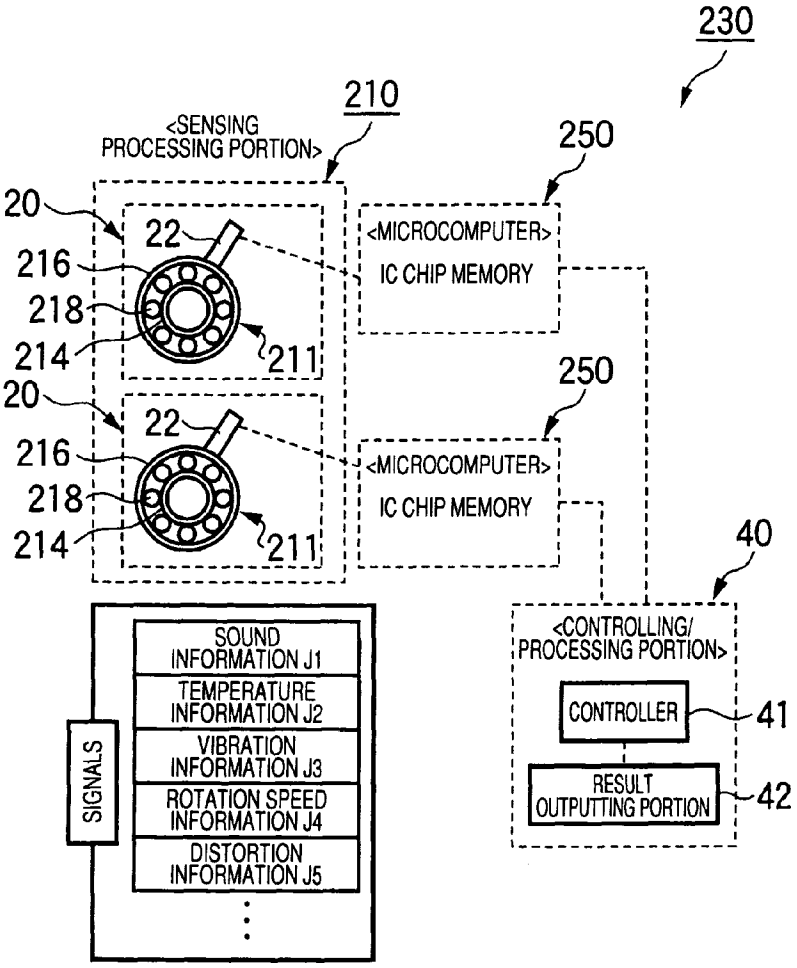

230
210
<SENSING PROCESSING PORTION>
250
20
22
216
218
214
211
<MICROCOMPUTER>
IC CHIP MEMORY
250
20
22
216
218
214
211
<MICROCOMPUTER>
IC CHIP MEMORY
40
<CONTROLLING/ PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUTTING PORTION
42
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5

FIG. 39

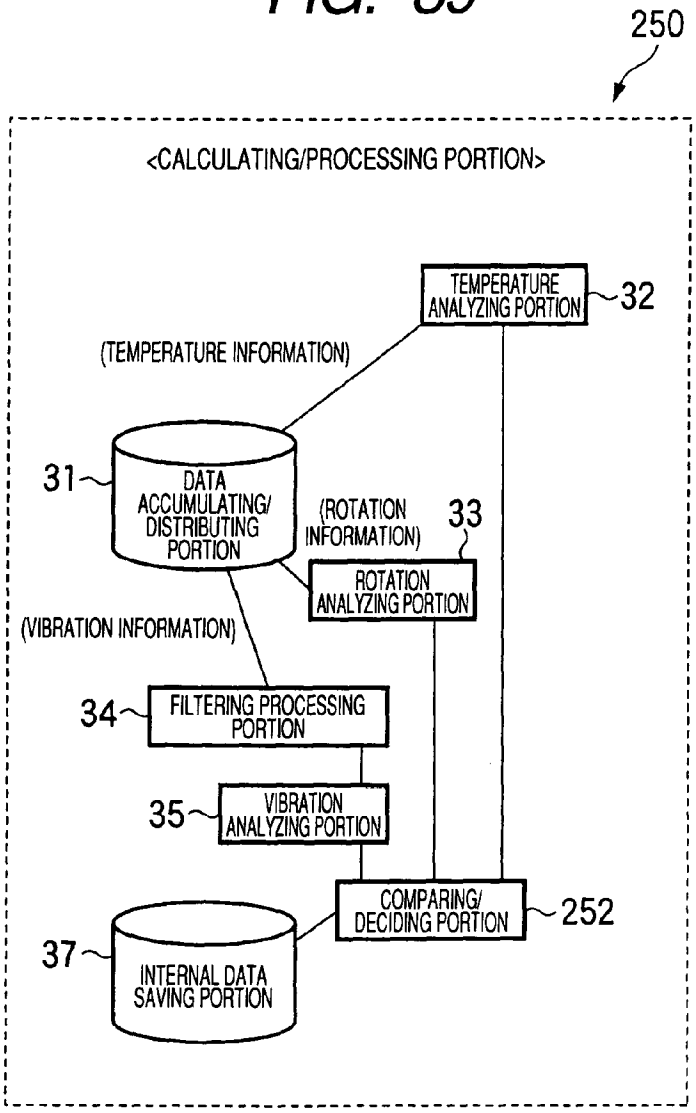

250
<CALCULATING/PROCESSING PORTION>
TEMPERATURE ANALYZING PORTION
32
(TEMPERATURE INFORMATION)
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
(ROTATION INFORMATION)
33
ROTATION ANALYZING PORTION
(VIBRATION INFORMATION)
34
FILTERING PROCESSING PORTION
35
VIBRATION ANALYZING PORTION
COMPARING/ DECIDING PORTION
252
37
INTERNAL DATA SAVING PORTION

FIG. 40

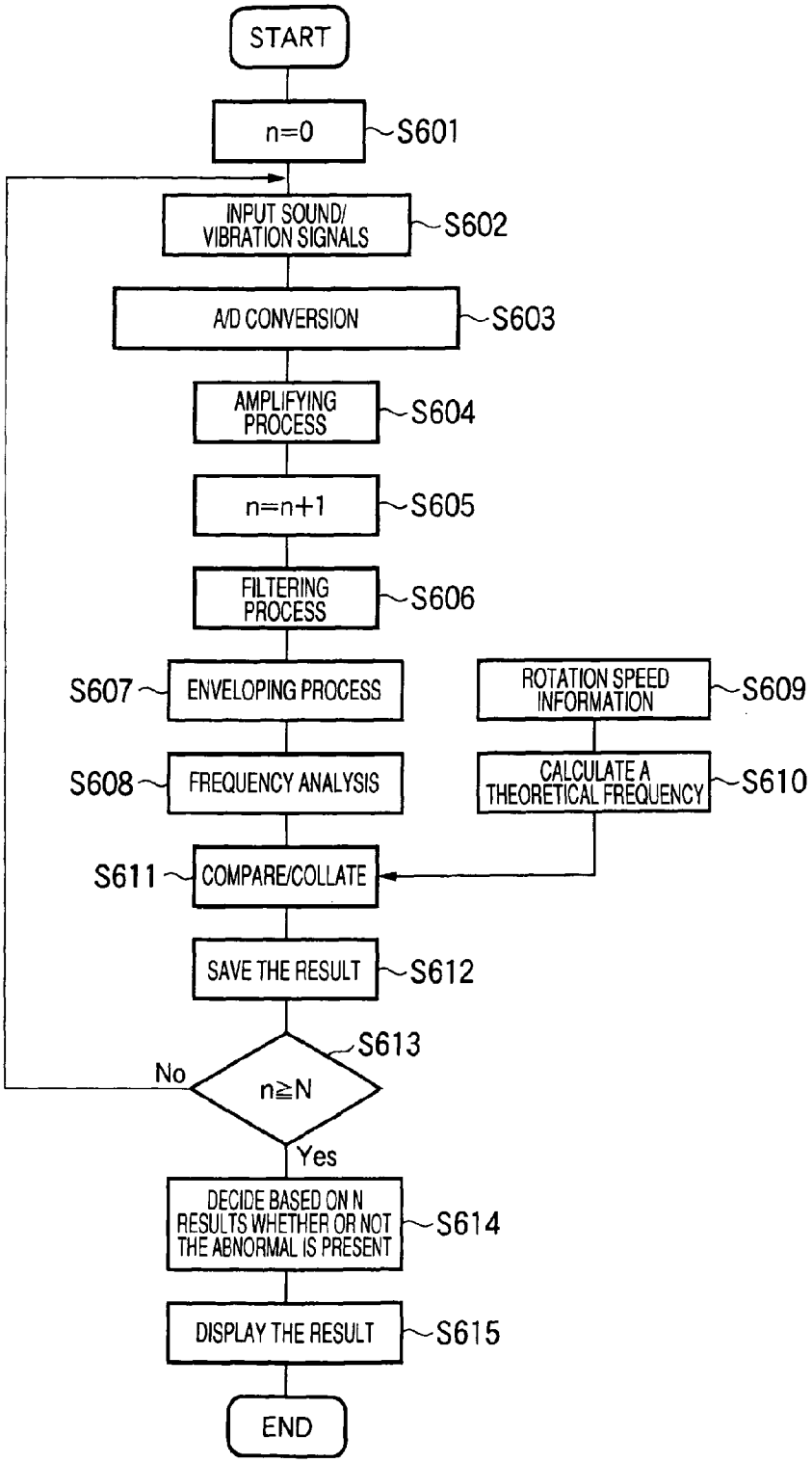

START
n=0
S601
INPUT SOUND/ VIBRATION SIGNALS
S602
A/D CONVERSION
S603
AMPLIFYING PROCESS
S604
n=n+1
S605
FILTERING PROCESS
S606
S607
ENVELOPING PROCESS
ROTATION SPEED INFORMATION
S609
S608
FREQUENCY ANALYSIS
CALCULATE A THEORETICAL FREQUENCY
S610
S611
COMPARE/COLLATE
SAVE THE RESULT
S612
S613
No
n≧N
Yes
DECIDE BASED ON N RESULTS WHETHER OR NOT THE ABNORMAL IS PRESENT
S614
DISPLAY THE RESULT
S615
END

FIG. 41

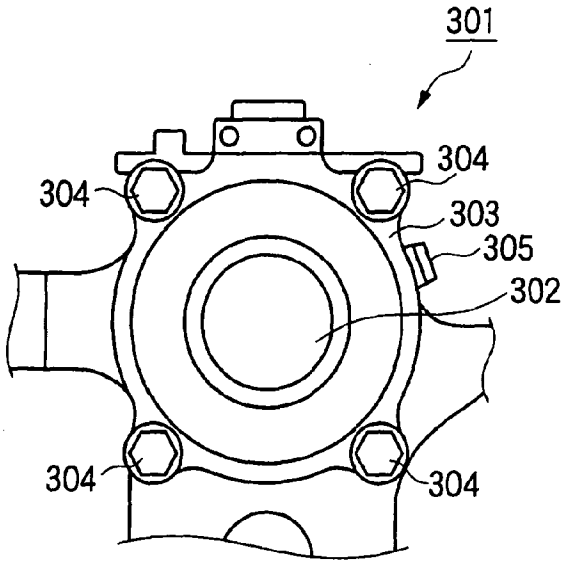
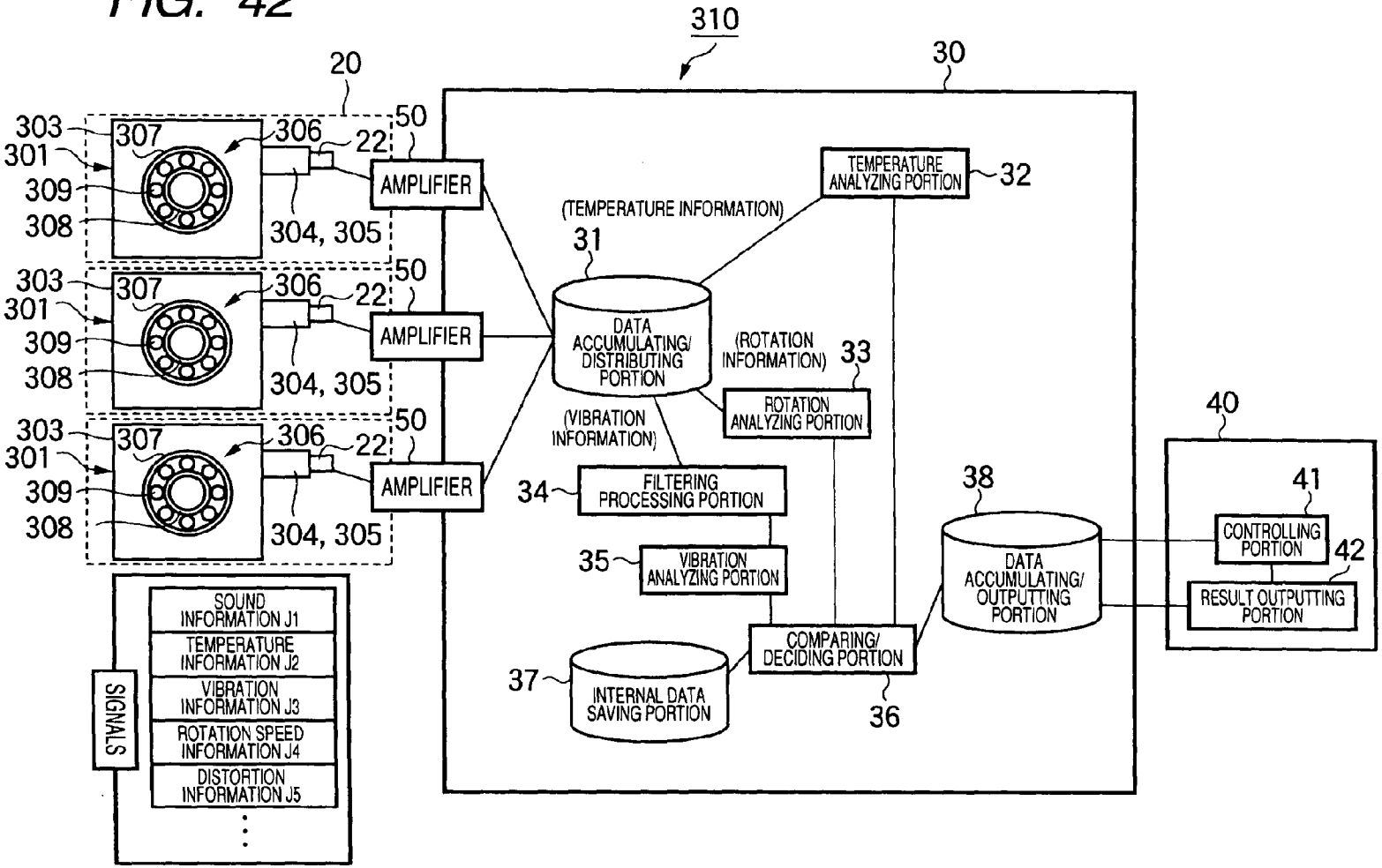


FIG. 42



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FIG. 43

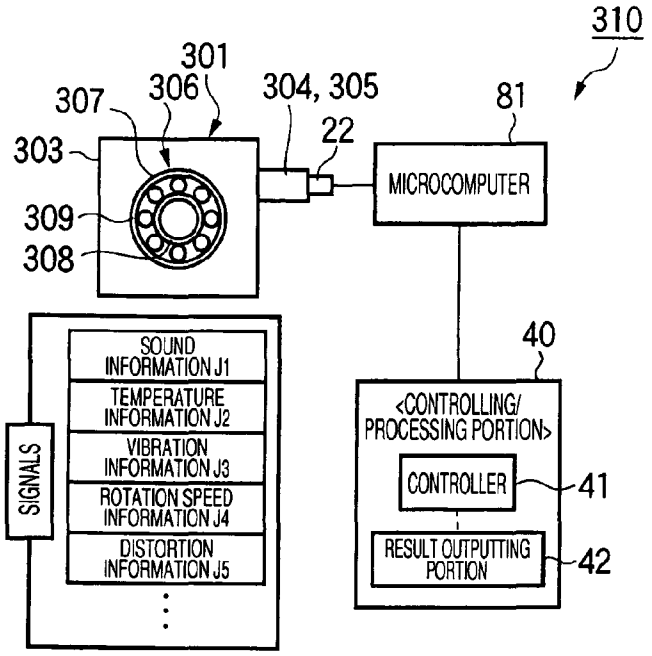

310
301
306
307
304, 305
22
81
303
MICROCOMPUTER
309
308
40
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5
SIGNALS
<CONTROLLING/ PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUTTING PORTION
42

FIG. 44

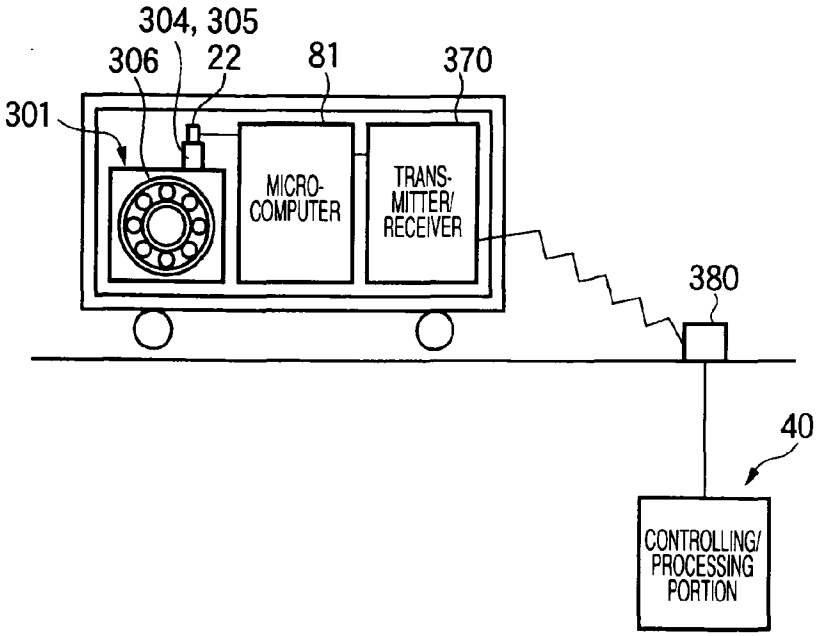

304, 305
306
22
81
370
301
MICRO-COMPUTER
TRANS-MITTER/ RECEIVER
380
40
CONTROLLING/ PROCESSING PORTION

FIG. 45

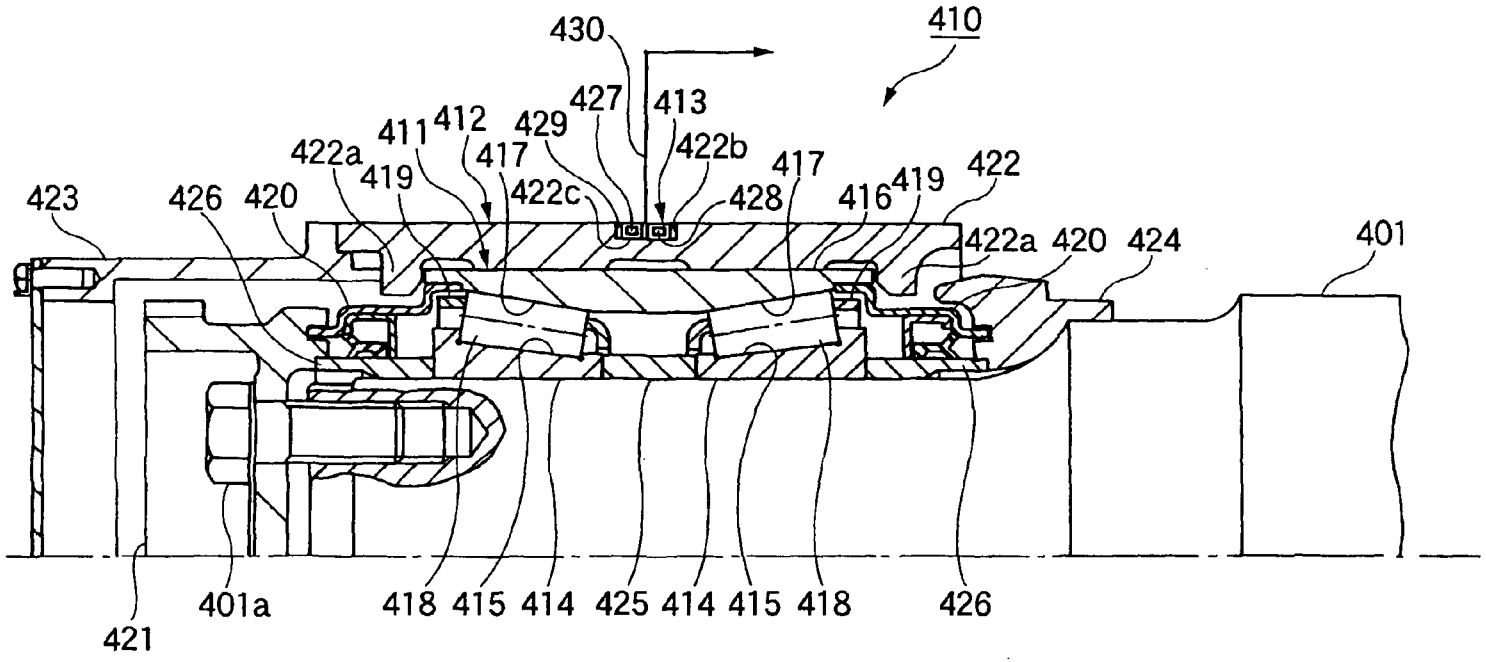

430
410
427
413
411
412
429
422a
417
422b
417
422
419
419
423
426
420
422c
428
416
422a
420
424
401
401a
418
415
414
425
414
415
418
426
421

FIG. 46

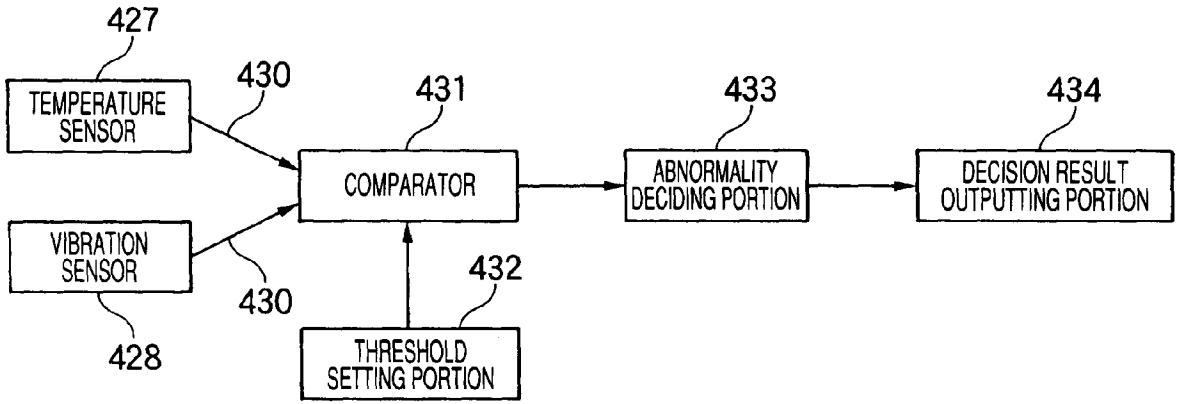

427
TEMPERATURE SENSOR
430
431
433
434
COMPARATOR
ABNORMALITY DECIDING PORTION
DECISION RESULT OUTPUTTING PORTION
VIBRATION SENSOR
430
432
428
THRESHOLD SETTING PORTION

FIG. 47

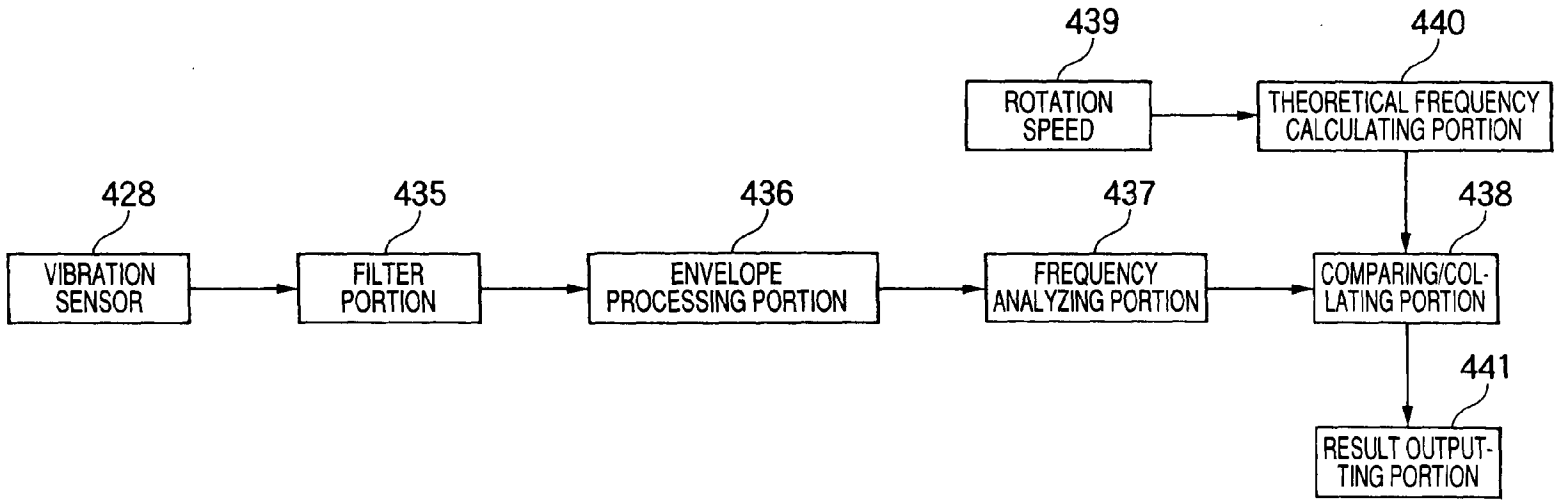

439
440
ROTATION SPEED
THEORETICAL FREQUENCY CALCULATING PORTION
428
435
436
437
438
VIBRATION SENSOR
FILTER PORTION
ENVELOPE PROCESSING PORTION
FREQUENCY ANALYZING PORTION
COMPARING/COL-LATING PORTION
441
RESULT OUTPUT-TING PORTION

FIG. 48

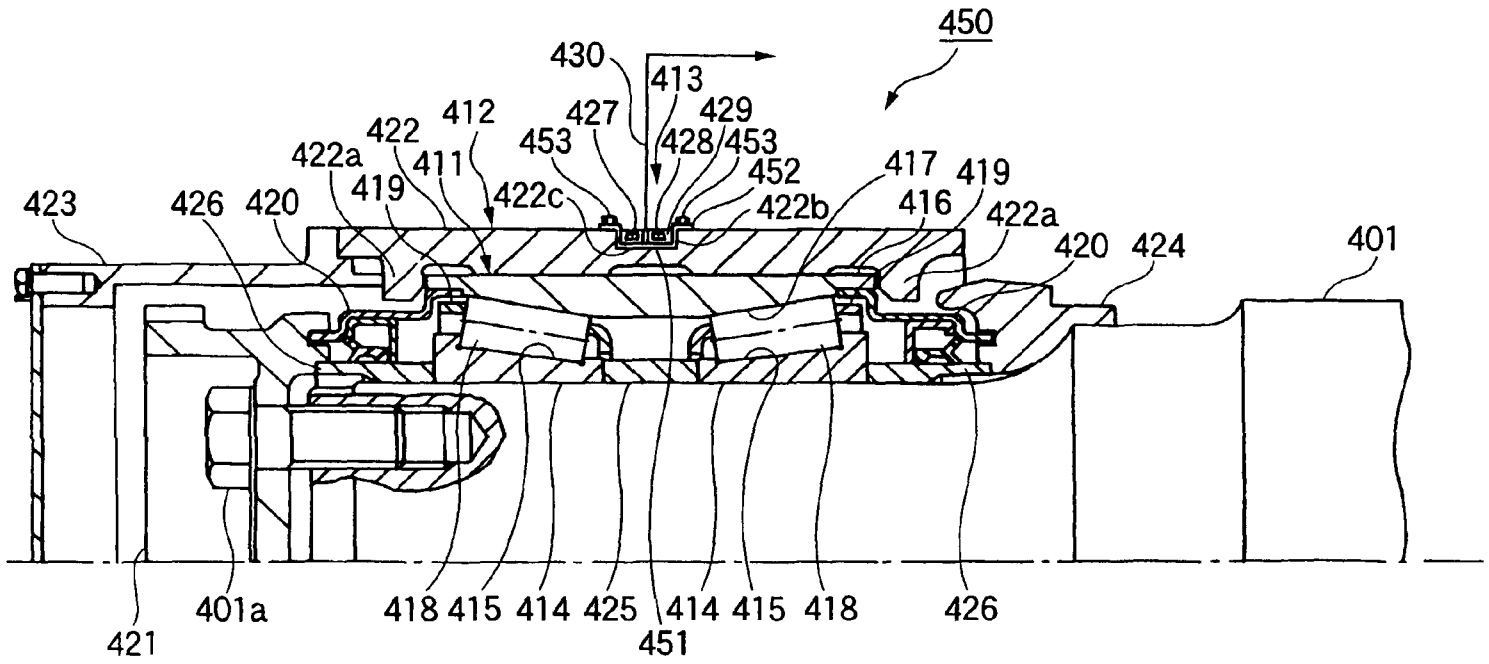

450
430
413
427
429
412
422
453
428
453
422a
411
452
417
419
423
426
420
419
422c
422b
416
422a
420
424
401
401a
418
415
414
425
414
415
418
426
421
451

FIG. 49

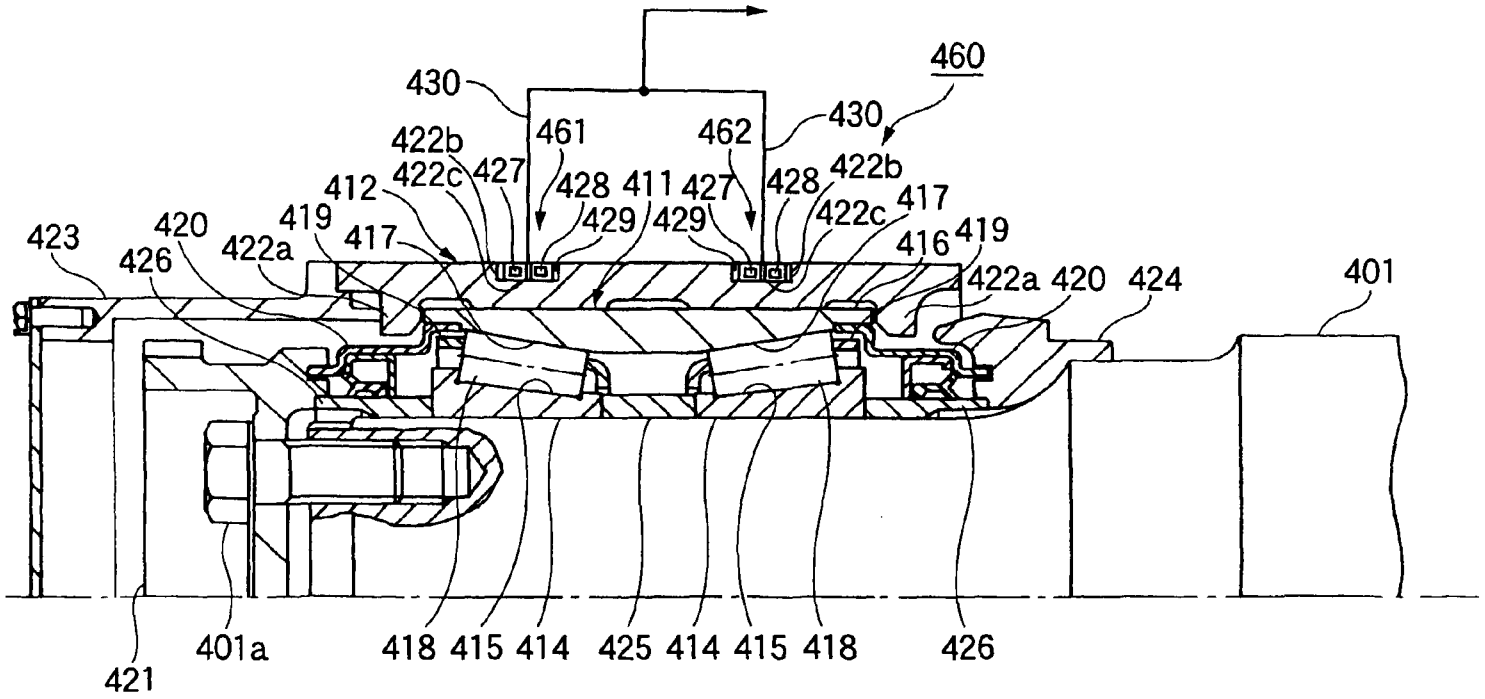

460
430
461
462
430
422b
422c
427
428
411
427
428
422b
412
417
429
429
422c
417
419
420
422a
416
419
423
426
422a
420
424
401
401a
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415
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425
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426
421

FIG. 50

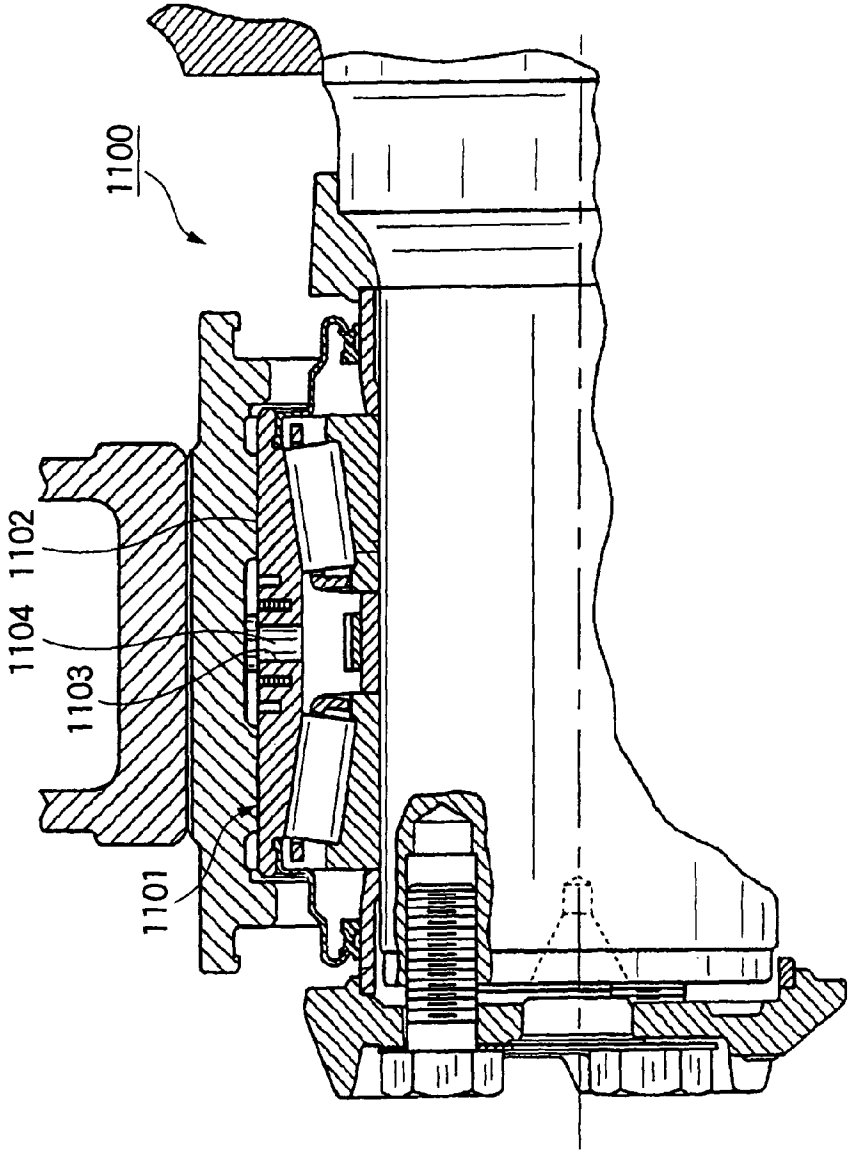


FIG. 51

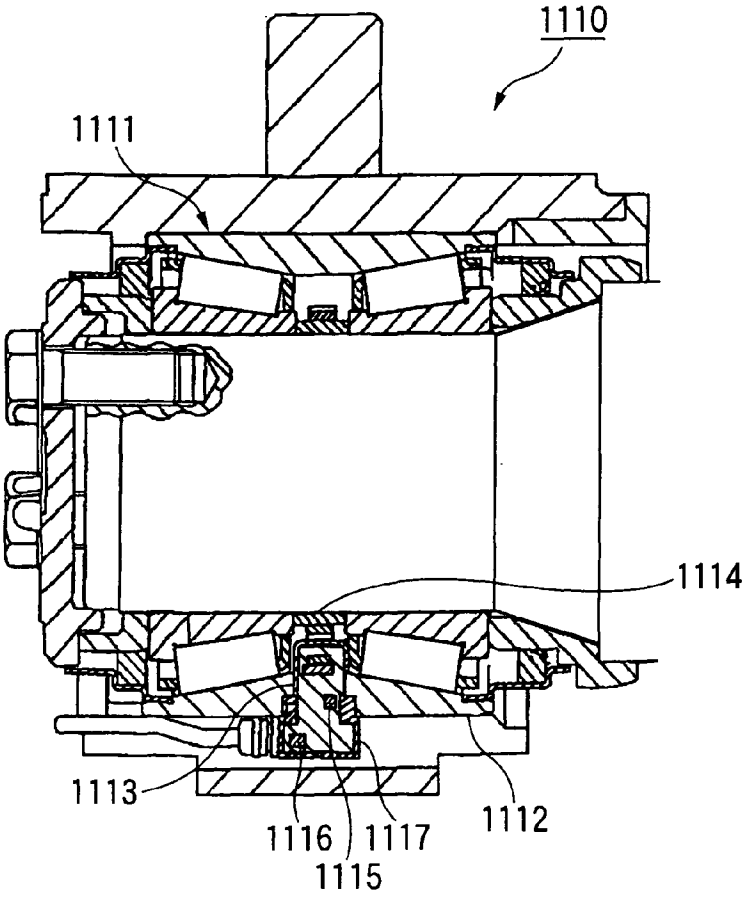


FIG. 52

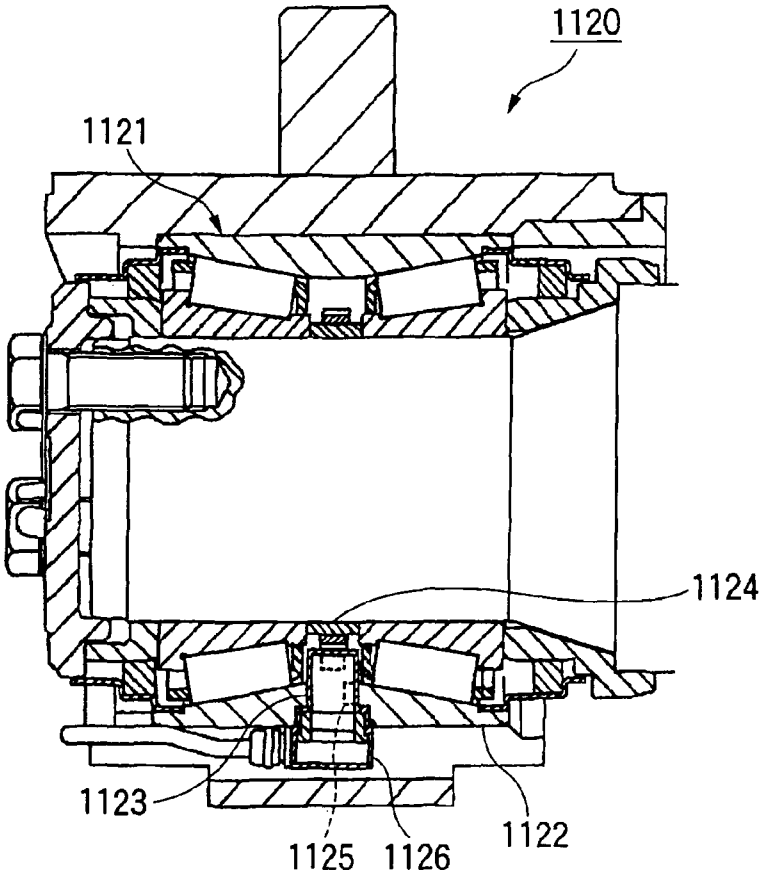


FIG. 53

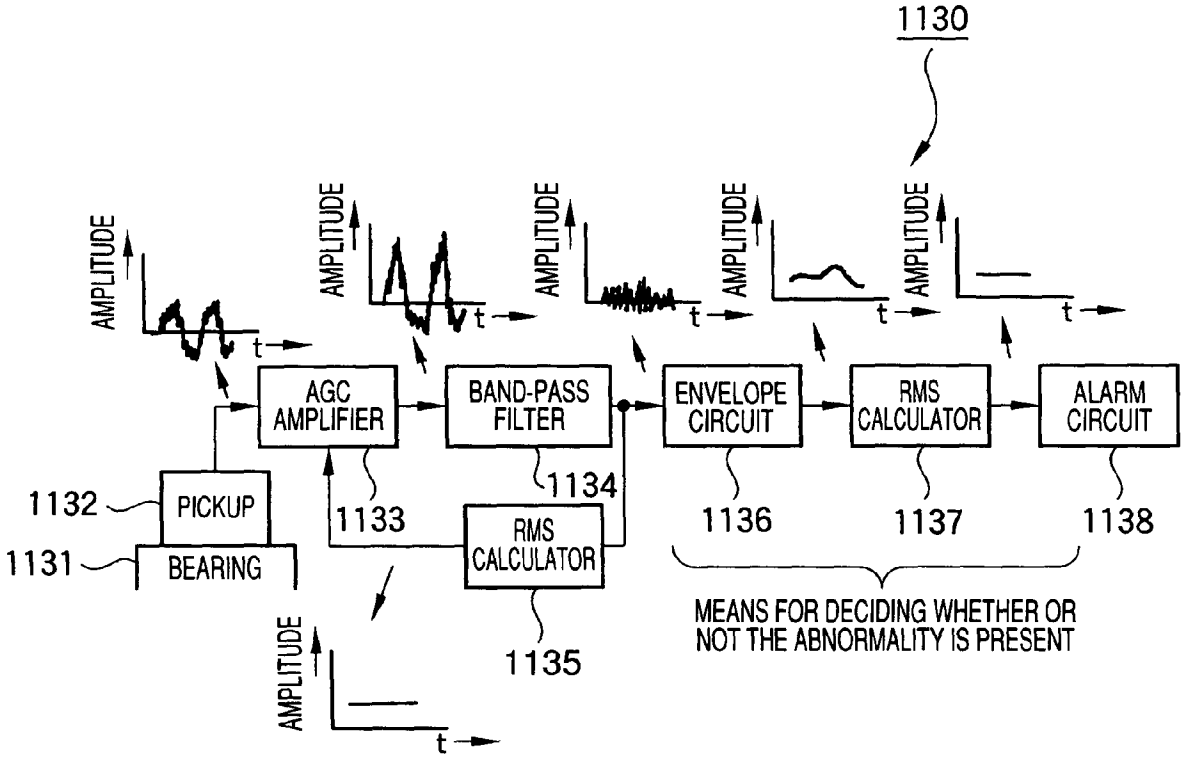

1130
AMPLITUDE
t
AGC AMPLIFIER
BAND-PASS FILTER
ENVELOPE CIRCUIT
RMS CALCULATOR
ALARM CIRCUIT
1132
PICKUP
1131
BEARING
1133
1134
RMS CALCULATOR
1135
1136
1137
1138
MEANS FOR DECIDING WHETHER OR NOT THE ABNORMALITY IS PRESENT

FIG. 54

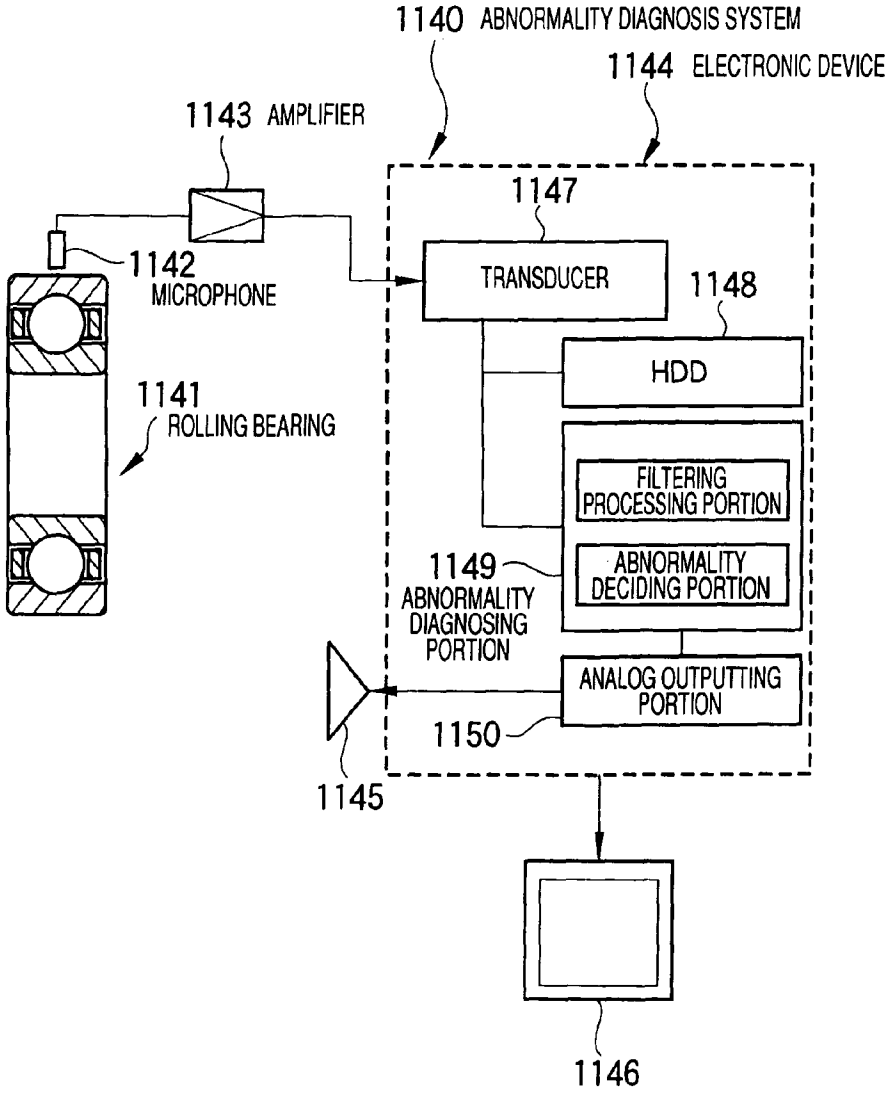
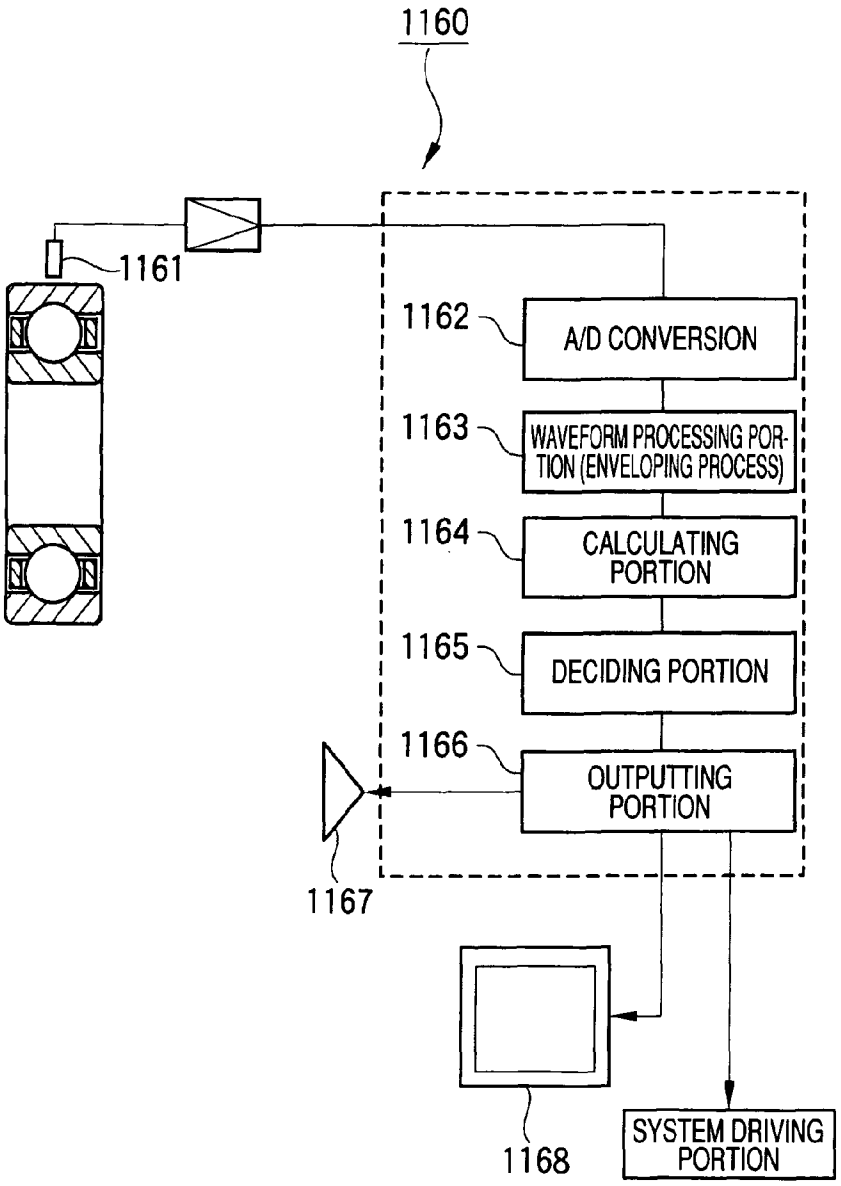

1140 ABNORMALITY DIAGNOSIS SYSTEM
1144 ELECTRONIC DEVICE
1143 AMPLIFIER
1147
1142
MICROPHONE
TRANSDUCER
1148
HDD
1141
ROLLING BEARING
FILTERING PROCESSING PORTION
1149
ABNORMALITY DIAGNOSING PORTION
ABNORMALITY DECIDING PORTION
ANALOG OUTPUTTING PORTION
1150
1145
1146

FIG. 55


1160
1161
1162
A/D CONVERSION
1163
WAVEFORM PROCESSING PORTION (ENVELOPING PROCESS)
1164
CALCULATING PORTION
1165
DECIDING PORTION
1166
OUTPUTTING PORTION
1167
1168
SYSTEM DRIVING PORTION

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/11114

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] G01M13/04, G01M19/00, G01M17/08, F16C41/00, B61F15/20, G01D21/00, G01B21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] G01M13/04, G01M19/00, G01M17/08, F16C41/00, B61F15/20, G01D21/00, G01B21/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2003
Kokai Jitsuyo Shinan Koho 1971-2003 Jitsuyo Shinan Toroku Koho 1996-2003

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2002-71519 A (NTN Corp.), 08 March, 2002 (08.03.02), Par. Nos. [0001], [0014], [0023] to [0070] & EP 1164550 A2 & US 2002-13635 A1	38-43 1-37,44-60
Y	JP 2001-21453 A (NSK Ltd.), 26 January, 2001 (26.01.01), Par. Nos. [0008], [0012] to [0046]; all drawings (Family: none)	1-24,46-48, 60
Y	JP 7-209143 A (Caterpillar Inc.), 11 August, 1995 (11.08.95), Par. Nos. [0002] to [0114]; all drawings & US 5566092 A1	1-23,37,49

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 December, 2003 (10.12.03)	24 December, 2003 (24.12.03)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/11114

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 6-200929 A (AB SKF), 19 July, 1994 (19.07.94), Par. Nos. [0006], [0014], [0015], [0024]; Figs. 1 to 2 & EP 594550 A1	4-5, 29,31, 36
Y	WO 98/11356 A1 (THE TIMKEN CO.), 19 March, 1998 (19.03.98), Full text; all drawings & JP 2001-500597 A & US 6161962 A1	6,17,22, 26-35,44,49, 51-59
Y	JP 47-9446 A (General Electric Co.), 15 May, 1972 (15.05.72), Full text; all drawings (Family: none)	7,9,23
Y	JP 3-152436 A (Koyo Seiko Co., Ltd.), 28 June, 1991 (28.06.91), Full text; all drawings (Family: none)	8,45,53, 55-57
Y	JP 2-240536 A (Fuji Electric Co., Ltd.), 25 September, 1990 (25.09.90), Full text; all drawings (Family: none)	10-14
Y	JP 6-42983 A (Omron Corp.), 18 February, 1994 (18.02.94), Par. Nos. [0019] to [0024]; all drawings & EP 581218 A1 & US 5407730 A1	25,36
Y	JP 2000-133474 A (Asahi National Shomei Kabushiki Kaisha), 12 May, 2000 (12.05.00), Full text; all drawings (Family: none)	32

Form PCT/ISA/210 (continuation of second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/11114

Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 1-37 relate to an abnormality diagnosing device for rolling stock mechanical equipment.
Claims 38-48 relate to a method and a device for monitoring the status of mechanical equipment.
Claims 49-52 relate to an abnormality diagnosing device for a mechanical device.
Claims 53-60 relate to a bearing having an abnormality detecting means.

A scope within which the International Preliminary Examination Organization considers to fulfill the requirement of unity of invention involves the respective four groups of the above claims.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (1)) (July 1998)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 650 191 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.10.2013 Bulletin 2013/42

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B61K 9/04 *(2006.01)*

(21) Application number: **12163973.6**

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AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
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BA ME

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50134 Firenze (IT)

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Modiano & Partners (IT)
Via Meravigli, 16
20123 Milano (IT)

Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) Method of detecting and signalling a hot box condition

(57) A method of detecting and signalling a hot box condition on a rail vehicle comprising the steps of acquiring temperature data from undercarriage components of the rail vehicle through temperature sensors provided in hot box detection devices (10); relaying temperature data through a wireless network of the hot box detection devices (10) to a data recorder.

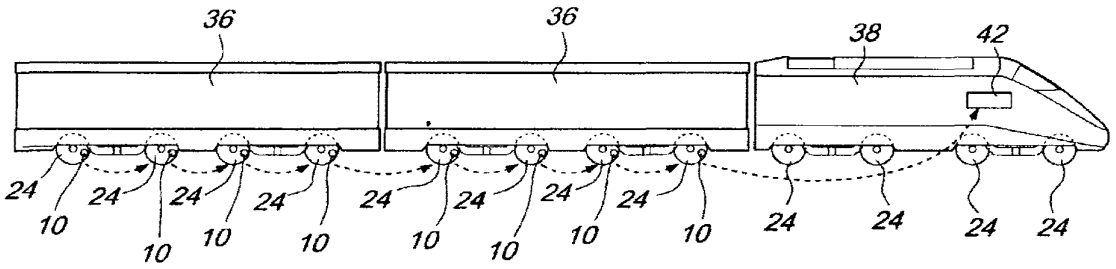


Fig. 2

EP 2 650 191 A1

Printed by Jouve, 75001 PARIS (FR)

BNSDOCID: <EP_____2650191A1_I_>

Description

Technical Field

[0001] This disclosure generally relates to the field of rail transportation and to determining a temperature of rail vehicle undercarriage components. In particular, this disclosure relates to detecting temperatures of rail vehicle undercarriage and relaying information relating to the detected temperatures.

Background

[0002] Safe and reliable operation of a railroad system may be dependent upon the integrity of the rolling mechanisms of the vehicles travelling over the rails, such as trains. Worn or damaged train wheel bearings may increase the rolling friction of the axle thereby increasing the power required to pull the train. In addition, worn or damaged bearings may cause excessive wear to the train axle and, in the case of failure of the bearing, may even cause the axle to lock up, preventing rotation of the wheel and thus resulting in a potential fire hazard due to the heat build up and potential sparking caused by friction of the locked wheel scraping along the rail.

[0003] Bearing temperatures may be scanned by sensing a temperature of the wheel bearing indirectly through a bearing box surrounding the wheel bearing on a rail car of a train. When the bearing temperatures are high due to overheating of the wheel bearing a hot box condition may exists. For example, infrared radiation (IR) sensors may be mounted along a rail to detect IR energy emitted by an outer wheel bearing of passing rail cars. The IR energy may be indicative of a temperature of the wheel bearing.

[0004] Wheel temperatures may be scanned by sensing a temperature of the wheel directly. When the bearing temperatures are high due to overheating of the wheel a hot wheel condition may exist. For example, infrared radiation (IR) sensors may be mounted along a rail to detect IR energy emitted by an outer wheel bearing of passing rail cars. The IR energy may be indicative of a temperature of the wheel bearing.

[0005] However, such a system may be limited to bearing or wheel temperatures being scanned only at specific points on the railway paths. For rail car transporting potentially dangerous or dangerous cargo there may be a need for the bearing or wheel temperatures to be scanned continuously so that any changes in temperature may be detected within a short time.

[0006] The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of the prior art system.

Brief Summary of the Invention

[0007] In a first aspect, the present disclosure describes a method of detecting and signalling a hot box condition on a rail vehicle comprising the steps of acquiring temperature data from undercarriage components of the rail vehicle through temperature sensors provided in hot box detection devices; relaying temperature data through a wireless network of the hot box detection devices to a data recorder.

[0008] In a second aspect, the present disclosure describes a system for performing the method of detecting and signalling a hot box condition on a rail vehicle, the system comprising temperature sensors provided in hot box detection devices to acquire temperature data from undercarriage components of the rail vehicle; and a wireless network of the hot box detection devices for relaying the temperature data to a data recorder.

Brief Description of the Drawings

[0009] The foregoing and other features and advantages of the present disclosure will be more fully understood from the following description of various embodiments, when read together with the accompanying drawings, in which:

Fig. 1 is a schematic representation of a device for detecting a hot box condition on a rail vehicle undercarriage component according to the present disclosure; and

Fig. 2 is a schematic representation of a system for detecting a hot box condition on a rail vehicle undercarriage component according to the present disclosure.

Detailed Description

[0010] This disclosure generally relates to a device **10** for detecting a hot box/ hot wheel condition on a rail vehicle undercarriage component.

[0011] With reference to Fig. 1, the hot box detection device **10** may comprise a housing **12**. The housing **12** may have a container-like structure. The housing **12** may have a structure to accommodate the temperature sensor and any required electronics. The housing **12** may be configured so as to be positioned on an undercarriage component of a rail vehicle. The housing **12** may have a suitable shape and structure to be positioned on the undercarriage component. The housing **12** may be composed of thermal insulation materials.

[0012] The device **10** may be coupled to the undercarriage component. The housing **12** may be coupled to directly on the undercarriage component. The housing **12** may be suitably coupled to the undercarriage component. In an embodiment, the housing **12** may be removably coupled to the undercarriage component. The housing **12** may be magnetically coupled to the undercarriage component. The housing **12** may be in magnetic contact with the undercarriage component. The magnetic coupling may be sufficiently strong to hold the device **10** as a sole means of direct fastening.

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[0013] The housing **12** may be provided with a magnet for magnetic coupling to the undercarriage component. The magnet may be disposed within the housing **12.** In an embodiment, the housing **12** may be provided with a plurality of magnets for magnetic coupling to the undercarriage component. The plurality of magnets may be disposed within the housing **12** and suitably arranged therein. The magnet or the plurality of magnets may be permanent magnets.

[0014] In an embodiment, a portion of the housing **12** may be magnetised for magnetic coupling to the undercarriage component. The portion of the housing **12** in contact with undercarriage component may be magnetised. The portion of the housing **12** may be constituted by a permanent magnet. The portion of the housing **12** may incorporate a permanent magnet. The permanent magnet may be incorporated into a wall of the housing **12.**

[0015] In an embodiment, the housing **12** may be magnetised for magnetic coupling to the undercarriage component. The housing **12** may be constituted by a permanent magnet. The housing **12** may incorporate a permanent magnet. The permanent magnet may be incorporated into a wall of the housing **12.**

[0016] The device **10** may further comprise a temperature sensor. The temperature sensor may be positioned within the housing **12.** The temperature sensor may detect heat from the target undercarriage component. The temperature sensor may acquire data from the target undercarriage component by detecting the temperature thereof. The temperature sensor may detect a hot box condition or a hot wheel condition through the evaluation of the IR signals emitted from the target undercarriage component.

[0017] In an embodiment, the temperature sensor may be an IR sensor for determining the temperature of the target undercarriage component. The infrared sensor may analyze the infrared emissions from the target undercarriage component to determine the temperature thereof. The infrared sensor may be pulsed and/or operated in intervals to consume only low power. Signals from the infrared sensor may be used to determine if hot box condition or a hot wheel condition persists.

[0018] The device **10** may comprise other detectors. The device **10** may comprise an acceleration detector to detect additional forces acting on a wheel subjected to scanning by the acceleration detector.

[0019] The temperature sensor may be positioned within the housing **12.** The temperature sensor may be positioned within the housing **12** in a position that allows heat from the target undercarriage component to be detected. The temperature sensor may be positioned within the housing **12** in a position that allows the temperature of the target undercarriage component to be measured.

[0020] The rail undercarriage **20** may comprise components such as an axle **22,** wheels **24,** wheel bearings **26** and axle stubs **28.** The device may be located so as to obtain IR data from the one of the target rail vehicle undercarriage components.

[0021] The device **10** may be located on the undercarriage component. The device **10** may be located on the target undercarriage component the temperature of which is to be measured by the temperature sensor. The device may be positioned on the axle **22,** wheels **24,** wheel bearings **26** or axle stubs **28.**

[0022] In an embodiment, the device **10** may be located on one undercarriage component adjacent to the target undercarriage component. The device **10** may be positioned on a wheel **24** and orientated to measure the temperatures of the wheel bearing **26** or the axle **22.** The device may be positioned on the axle **22** and orientated to measure the temperature of the wheel **24.** The device **10** may be positioned on an axle stub **28** and orientated to measure the temperatures of the wheel bearing **26** or the wheel **24.**

[0023] The rail vehicle may travel on the rails **32** of a rail track **30** that may be positioned on a rail bed, such as within a cross tie or a sleeper **34.**

[0024] The device **10** may be provided with electronics which includes a controller to control the temperature sensor. The controller may analyse the signals from the temperature sensor. The electronics may be configured to communicate wirelessly. The electronics may be configured to operate within a wireless network.

[0025] The device **10** may be powered by a battery. The temperature sensor may be powered by the battery. The electronics and associated controller may be powered by the battery. In an embodiment, the battery may be a lithium battery which is able to provide a power supply over a period of 1 to 2 years.

[0026] In an embodiment, the device **10** may be powered through rotational acceleration. The temperature sensor may be powered through rotational acceleration. The electronics and associated controller may be powered through rotational acceleration. The rotation force on the temperature sensor may generate electrical power for the operation of the temperature sensor.

[0027] The housing **12** is supported on the undercarriage component, and the housing **12** may support a generator configured to produce electrical power when the undercarriage component, such as a rail vehicle wheel or axle, turns as the rail vehicle moves. Circuitry may be supported in the housing **12** and may receive the electrical power.

[0028] Electrical power may be generated through electromagnetic induction. In an embodiment, the power supply may be an electromagnetic generator. The power source may comprise a magnetic core. In an embodiment, the magnetic core may have a plurality of stationary permanent magnets that are arranged in succession in the circumferential direction, with their poles alternating. The power supply may further comprise a winding encircling the magnetic core. The magnetic core may produce a magnetic flux which passes through the winding and also passes through an air gap. A ring having teeth may be positioned such that the teeth may pass through the air gap when the ring rotates. The air gap may be between

BNSDOCID: <EP_____2650191A1_I_>

the magnetic core and teeth provided on the ring.

[0029] When the ring rotates, the teeth move through the air gap between the alternating polarity poles, causing change in flux linkage with the winding and inducing voltage across the winding. The power supply may contain a full wave rectifier and a voltage regulator which converts the alternating current generated in the winding to direct current.

[0030] In an embodiment, the ring may be rotatably mounted in the housing **12**. The ring may be weighted such that as the undercarriage component rotates the weight would tend to remain in its lowest position in the housing **12**. The position which would be equivalent to the weight rotating within the housing **12** in the opposite direction as the rotation of the undercarriage component.

[0031] As the undercarriage component rotates, the magnetic core may rotate relative to the ring and the teeth. The relative rotation may move the teeth though the air gap so as to induce a voltage. The voltage may be used to supply power to the device **10** and the components therein.

[0032] With reference to Fig. 2, this disclosure also relates to a system **40** for performing a method of detecting and signalling a hot box condition on a rail vehicle **36**. The system **40** may comprise the devices **10** for detecting a hot box condition on a rail vehicle undercarriage component.

[0033] The system **40** may comprise temperature sensors for acquiring temperature data from undercarriage components of the rail vehicle **36**. The temperature sensors may be disposed in the devices **10**. The system may comprise a wireless network of the devices **10** for relaying the temperature data to a data recorder **42**.

[0034] In an embodiment, the data recorder **42** may be located in a rail vehicle **36**. In an embodiment, the data recorder **42** may be located in a locomotive **38** to which a plurality of rail vehicles **36** are linked.

[0035] The devices **10** may be removably coupled to the undercarriage components. The devices **10** may be coupled magnetically to the undercarriage components. The undercarriage components may be rotating components. The devices **10** may be positioned on the axle **22**, wheels **24**, wheel bearings **26** or axle stubs **28**.

[0036] The devices **10** may be powered through rotational acceleration force. The devices **10** may be powered through a battery.

[0037] The devices **10** may be magnetically coupled to undercarriage components.

[0038] In operation, the devices **10** may be switched on sequentially starting from locomotive **38** end towards the end of the train. For instance, each device **10** may self configure within a wireless network of the devices **10** at activation.

[0039] In an embodiment, the devices **10** may be configured to transmit data to the nearest device **10**. In an embodiment, the devices **10** may be configured to transmit data to the nearest active device **10** from the locomotive **38** side of the train. In Fig. 2 the arrows may indicate the relay of data from a device **10** to the next nearest active device **10** from the locomotive **38** side of the train. The data may be relayed to the data recorder **42**.

[0040] In an embodiment, each device **10** may be configured so as to transmit data to all the other devices **10**. Each device **10** may be configured so as to transmit data to all other devices **10** which are nearer to the locomotive **38**. The broadcast of the data may ensure that multipath and redundant transmissions up to the first device **10** proximate to the locomotive **38**.

[0041] The device **10** next to the locomotive **38** may transmit a signal to the data recorder **42**. The data recorder **42** may have a display to provide information to the train driver. The data recorder **42** may have an alarm display to inform the train driver of any dangerous condition.

[0042] A method of detecting and signalling a hot box condition on a rail vehicle may comprise the step of acquiring temperature data from undercarriage components of the rail vehicle. The temperature data may be acquired through temperature sensors provided in the devices **10**. The method may further comprise relaying the temperature data through a wireless network of the devices **10** to a data recorder.

[0043] The method may comprise the steps of sequencing the devices **10** and relaying the temperature data detected by each of devices **10** to the next device **10** in the sequence.

[0044] The method may comprise the step of broadcasting the temperature data detected by each of the devices **10** to the remaining devices **10** in the network.

[0045] The method may comprise the step of transmitting the temperature data to wayside stations. The wayside stations may be positioned along the train track **30**. The wayside stations may be positioned at intervals along the train track **30**. The temperature data may be transmitted to wayside stations by the data recorder **42**.

[0046] The method may comprise the step of powering the devices **10** through rotational acceleration force.

[0047] The method may comprise the step of coupling the device **10** to each undercarriage component wherein the housing **12** is coupled magnetically.

[0048] The skilled person would appreciate that foregoing embodiments may be modified or combined to obtain the device **10** or the system **40** of the present disclosure.

Industrial Applicability

[0049] This disclosure describes a device **10** which can be positioned with ease on the rail vehicle undercarriage component. The device **10** may be temporarily coupled to the rail vehicle undercarriage component. Such a temporary coupling may avoid the need for the device **10** to be manufactured as a part of the rail vehicle undercarriage component. Thus, the device **10** may be assembled without the need for retrofitting the under carriage component. The device **10** may be decoupled from the un-

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dercarriage component after use without undue effort. The device **10** may be used as a consumable item.

[0050] The device **10** may be in direct contact with the rail vehicle undercarriage component and thereby may be able to measure the temperature of the component directly.

[0051] This disclosure describes a system **40** comprising a network of devices **10** which are linked wirelessly for the transmission of data. The data acquired by a device **10** may be transmitted from said device to the next device **10** in line from the data recorder **42**. The data may be relayed through the series of devices **10** to the data recorder **42**.

[0052] The data may be relayed through a series of devices **10** in sequence. The data may be broadcast from one device **10** to other devices **10** in the network. The network of devices **10** may ensure multipath and redundant transmissions.

[0053] Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above- described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein.

[0054] Where technical features mentioned in any claim are followed by references signs, the reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, neither the reference signs nor their absence have any limiting effect on the technical features as described above or on the scope of any claim elements.

[0055] One skilled in the art will realise the disclosure may be embodied in other specific forms without departing from the disclosure or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting of the disclosure described herein. Scope of the invention is thus indicated by the appended claims, rather than the foregoing description, and all changes that come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

Claims

1. A method of detecting and signalling a hot box condition on a rail vehicle comprising the steps of:

   acquiring temperature data from undercarriage components of the rail vehicle through temperature sensors provided in hot box detection devices (10);
   relaying temperature data through a wireless network of the hot box detection devices (10) to a data recorder.

2. The method of claim 1 comprising the steps of sequencing the hot box detection devices and relaying the temperature data detected by each of the hot box detection devices (10) to the next hot box detection device (10) in the sequence.

3. The method of claim 1 or 2 comprising the step of broadcasting the temperature data detected by each of the hot box detection devices (10) to the remaining hot box detection devices (10) in the network.

4. The method of any one of the preceding claims comprising the step of transmitting the temperature data to wayside stations.

5. The method of claim 4 wherein the temperature data is transmitted to wayside stations by the data recorder.

6. The method of any one of the preceding claims comprising the step of powering the hot box detection devices (10) through rotational acceleration force.

7. The method of any one of the preceding claims comprising the step of coupling the hot box detection device (10) to each undercarriage component wherein the housing (12) is coupled magnetically.

8. A system (40) for performing the method of detecting and signalling a hot box condition on a rail vehicle, the system (40) comprising:

   temperature sensors provided in hot box detection devices (10) to acquire temperature data from undercarriage components of the rail vehicle; and
   a wireless network of the hot box detection devices (10) for relaying the temperature data to a data recorder.

9. The system of claim 8 wherein hot box detection devices (10) are removably coupled to the undercarriage components, wherein each hot box detection devices (10) being coupled magnetically.

10. The system according to claim 9 wherein the undercarriage components are rotating component.

11. The system according to claim 10 wherein the undercarriage component is a wheel.

12. The system according to claim 10 wherein the undercarriage component is an axle.

13. The system according to any one of the preceding claims 9 to 12 wherein hot box detection devices (10) are powered through rotational acceleration force.

14. The system according to any one of the preceding

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claims 9 to 12 wherein the hot box detection devices (10) are powered through a battery.

Amended claims in accordance with Rule 137(2) EPC.

1. A method of detecting and signalling a hot box condition on a rail vehicle comprising the steps of:

acquiring temperature data from undercarriage components of the rail vehicle through temperature sensors provided in hot box detection devices (10); and
relaying temperature data through a wireless network of the hot box detection devices (10) to a data recorder,

characterised in the step of removably coupling the hot box detection device (10) to each undercarriage component wherein the hot box detection device (10) is coupled magnetically.

2. The method of claim 1 comprising the steps of sequencing the hot box detection devices and relaying the temperature data detected by each of the hot box detection devices (10) to the next hot box detection device (10) in the sequence.

3. The method of claim 1 or 2 comprising the step of broadcasting the temperature data detected by each of the hot box detection devices (10) to the remaining hot box detection devices (10) in the network.

4. The method of any one of the preceding claims comprising the step of transmitting the temperature data to wayside stations.

5. The method of claim 4 wherein the temperature data is transmitted to wayside stations by the data recorder.

6. The method of any one of the preceding claims comprising the step of powering the hot box detection devices (10) through rotational acceleration force.

7. A system (40) for performing the method of detecting and signalling a hot box condition on a rail vehicle, the system (40) comprising:

temperature sensors provided in hot box detection devices (10) to acquire temperature data from undercarriage components of the rail vehicle; and
a wireless network of the hot box detection devices (10) for relaying the temperature data to a data recorder,

characterised in that the hot box detection devices (10) are removably coupled to the undercarriage components, wherein the hot box detection devices (10) are coupled magnetically.

8. The system according to claim 7 wherein the undercarriage components are rotating components.

9. The system according to claim 8 wherein the undercarriage component is a wheel.

10. The system according to claim 8 wherein the undercarriage component is an axle.

11. The system according to any one of the preceding claims 7 to 10 wherein hot box detection devices (10) are powered through rotational acceleration force.

12. The system according to any one of the preceding claims 7 to 10 wherein the hot box detection devices (10) are powered through a battery.

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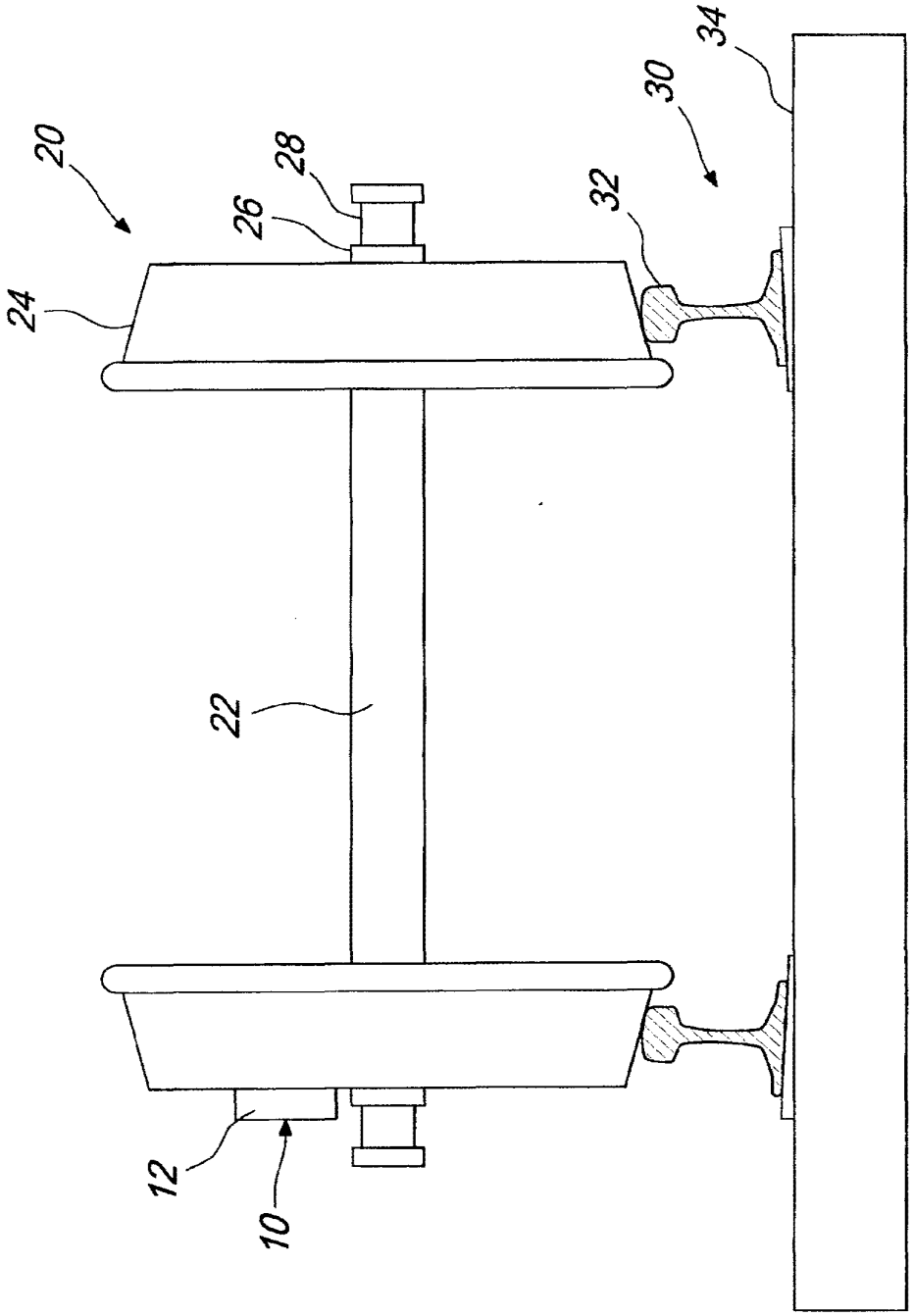


Fig. 1

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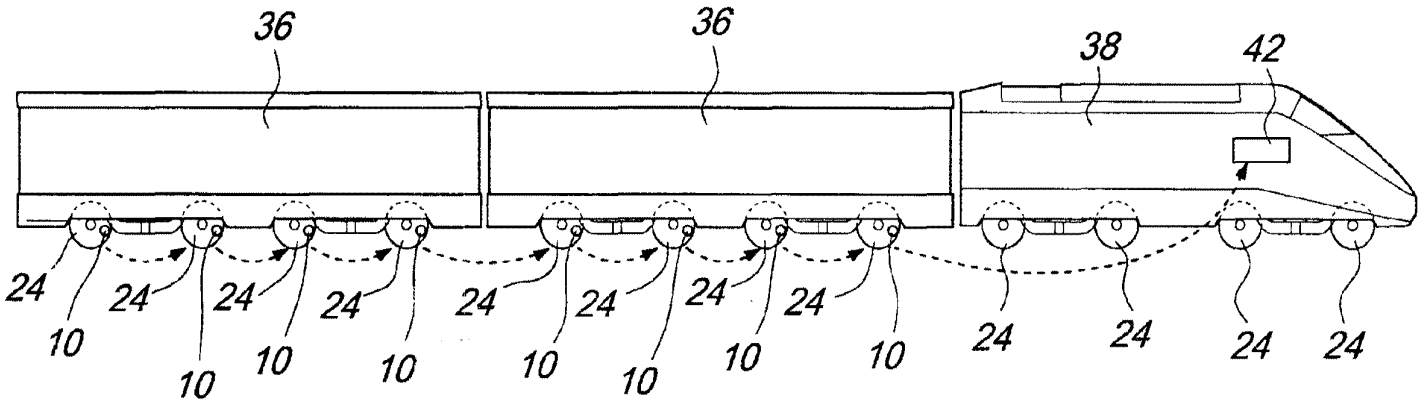


Fig. 2

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F16C 41/00 // H01R 13/24

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H2E EHE

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Online: WPI

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(54) Bearing assembly with sensors

(57) One or more sensors 26, 28, 30 are mounted on the inside surface of a stationary race (14) in a bearing housing (10). Parameters sensed by the sensors are fed along wires to contacts on the outside surface of the stationary race and detected by transmitters mounted in the housing. The detected information is electrically fed from the transmitters to an electronic system (80) located outside the housing. The race contacts may be engaged by spring-loaded balls in the transmitters. The parameters sensed include temperature, vibration, speed and load.

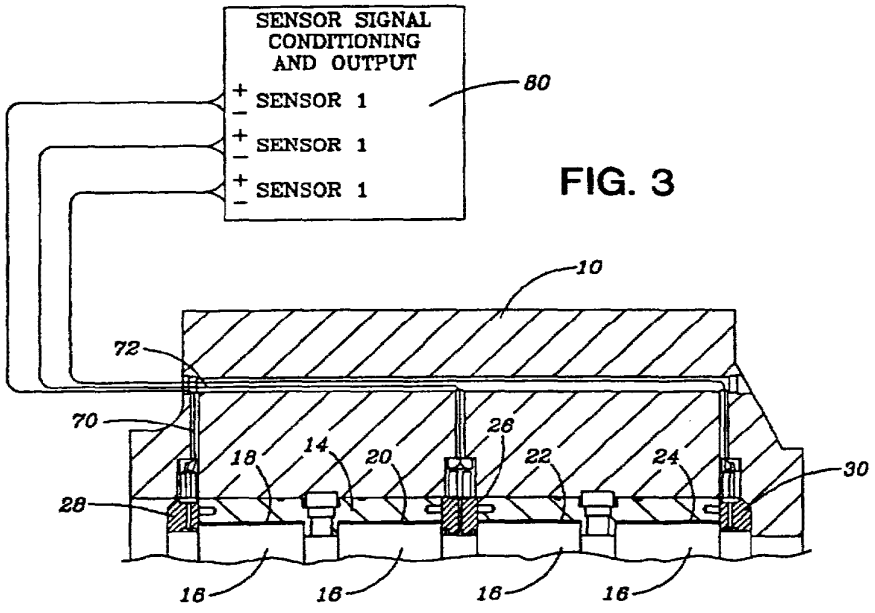


FIG. 3

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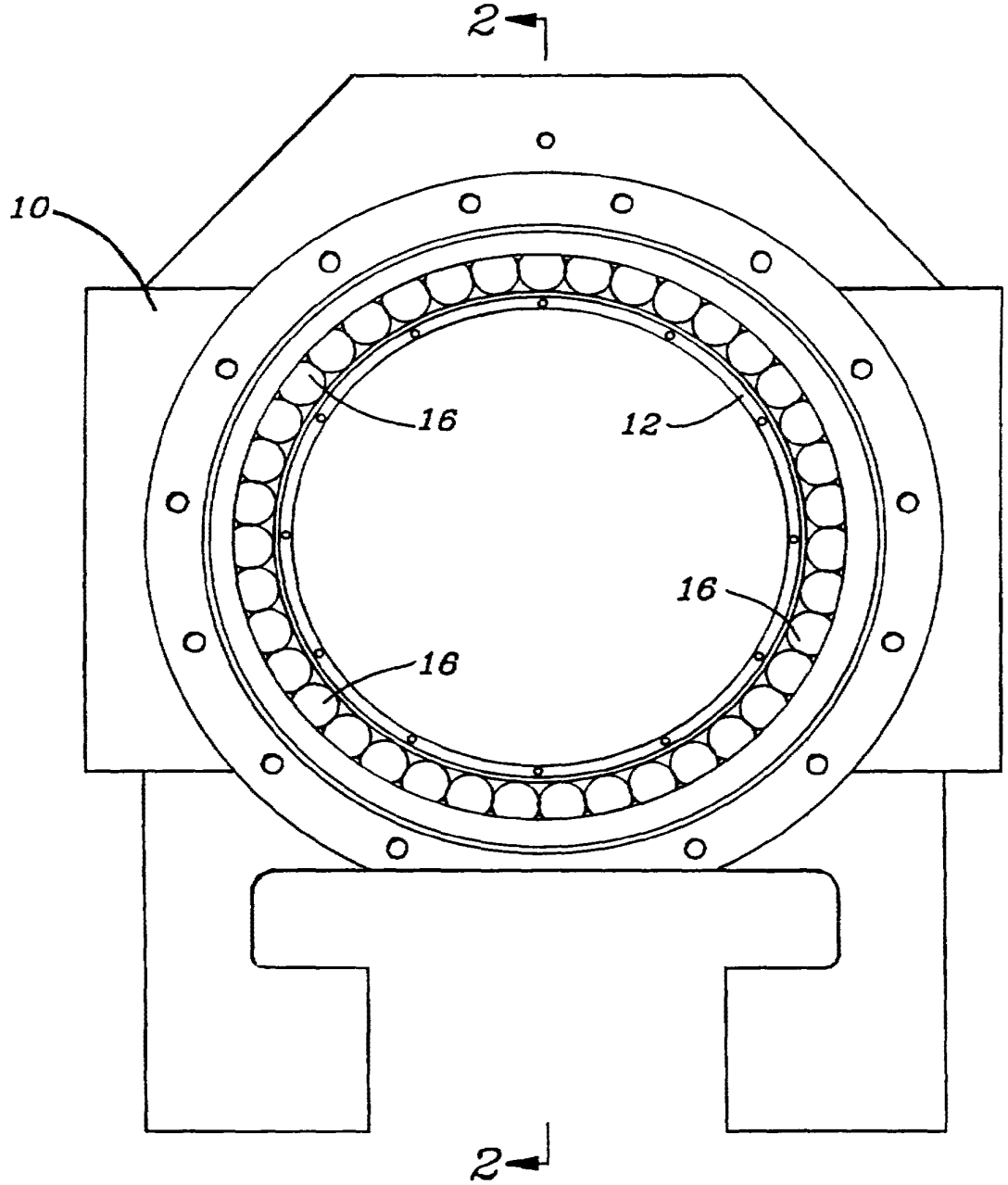


FIG. 1

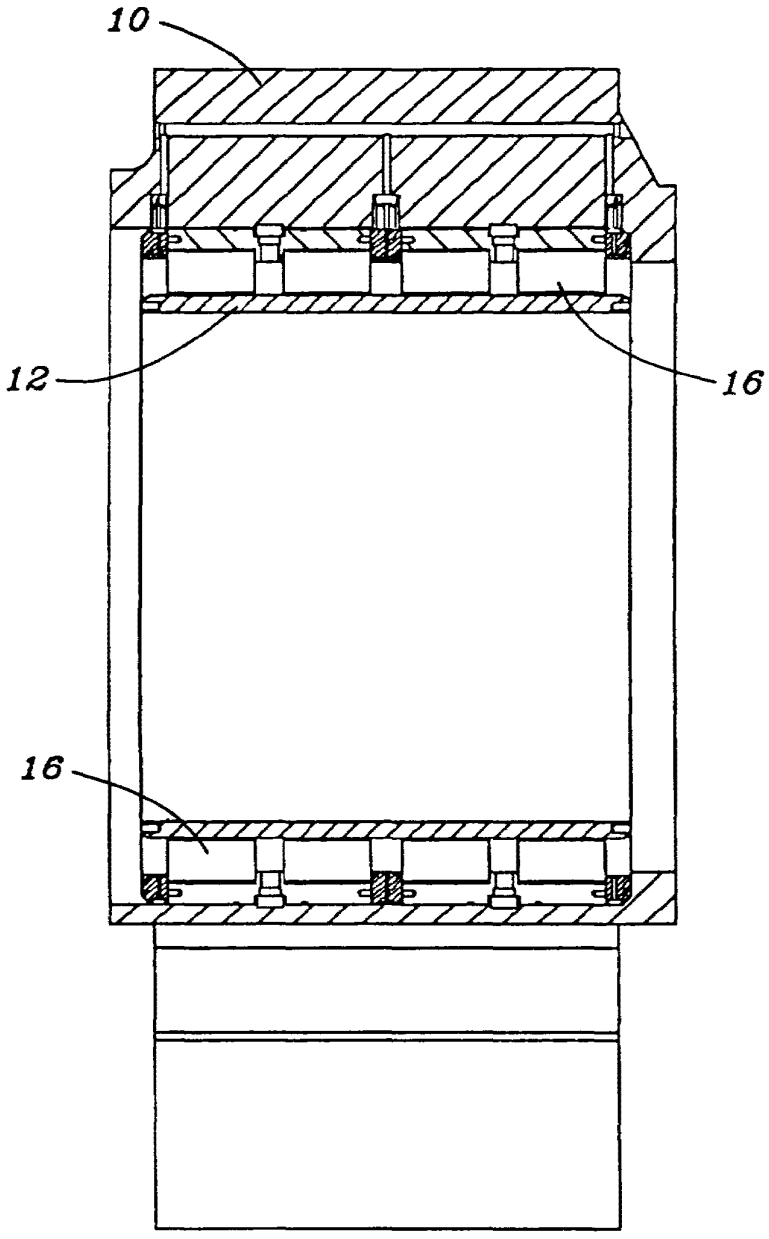


FIG. 2

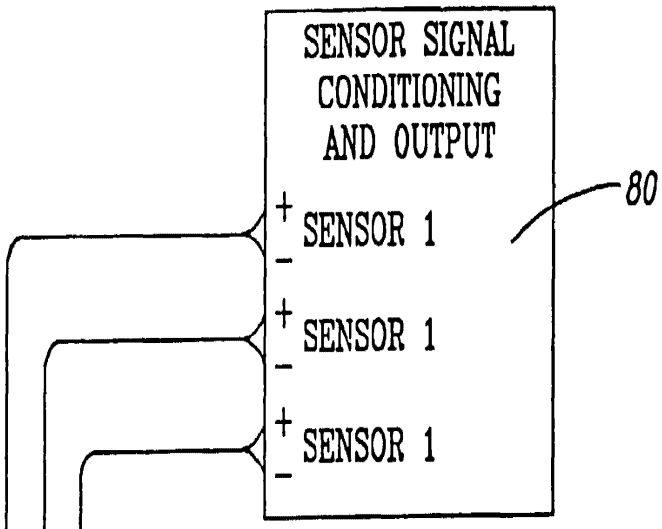
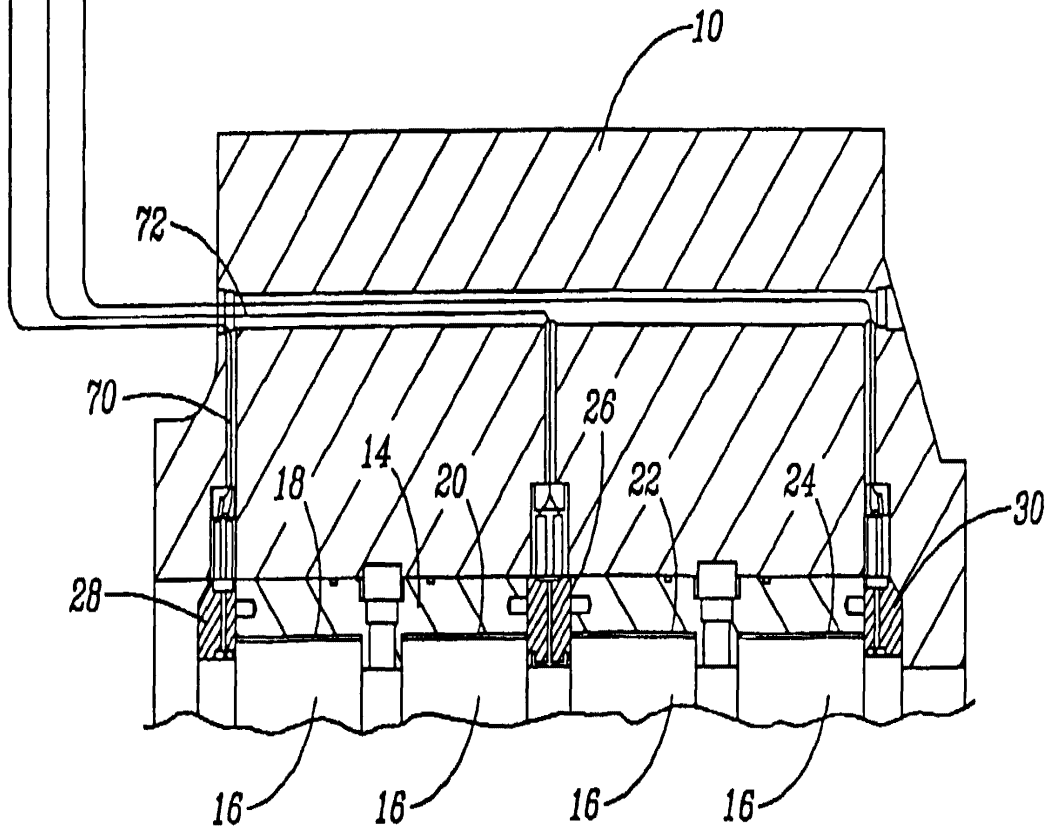

SENSOR SIGNAL
CONDITIONING
AND OUTPUT
+
SENSOR 1
−
+
SENSOR 1
−
+
SENSOR 1
−
80

FIG. 3


10
72
70
26
18
14
20
22
24
30
28
16
16
16
16

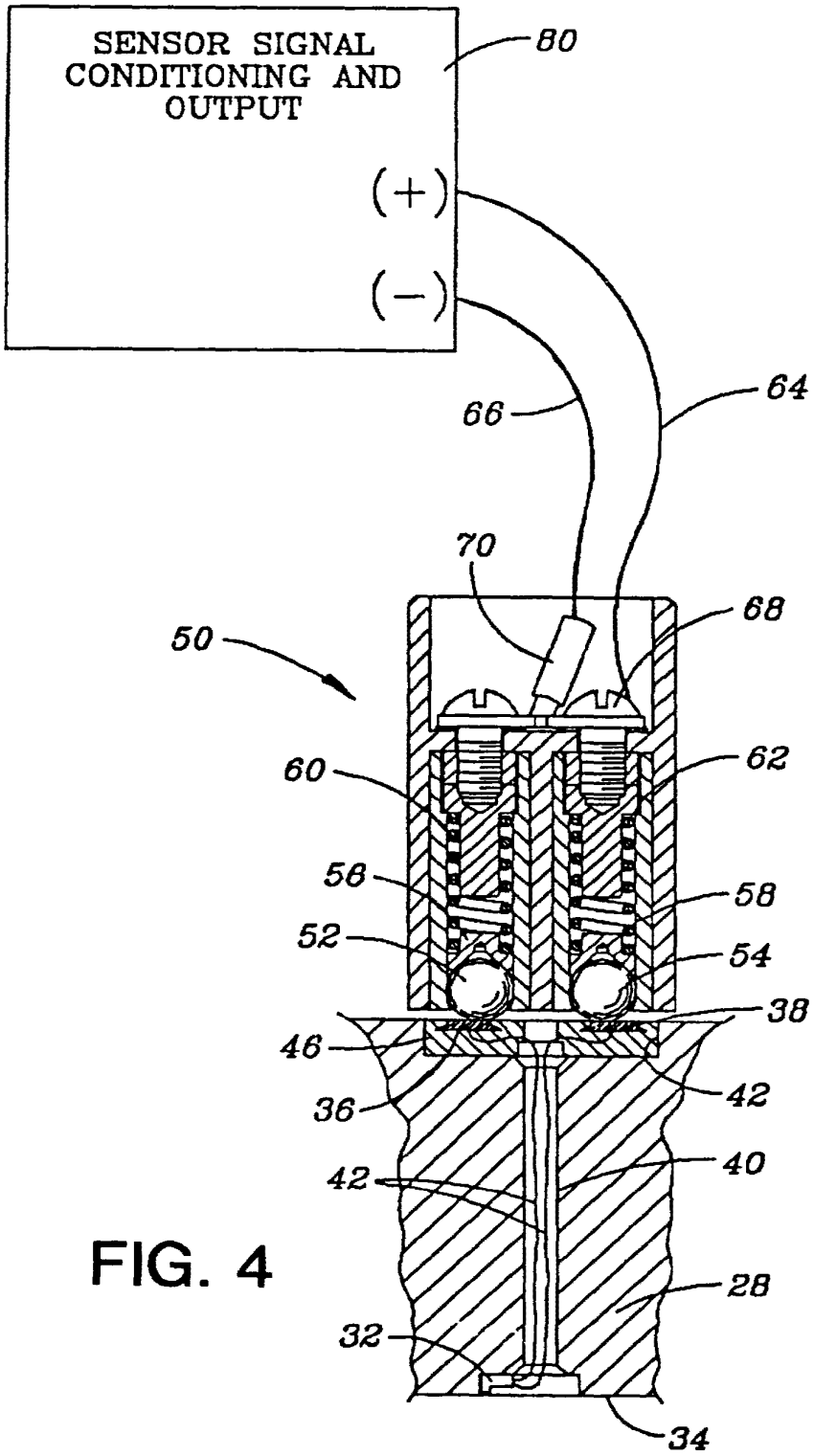

SENSOR SIGNAL CONDITIONING AND OUTPUT
80
(+)
(−)
66
64
70
68
50
60
62
58
58
52
54
38
46
42
36
42
40
28
32
34

FIG. 4

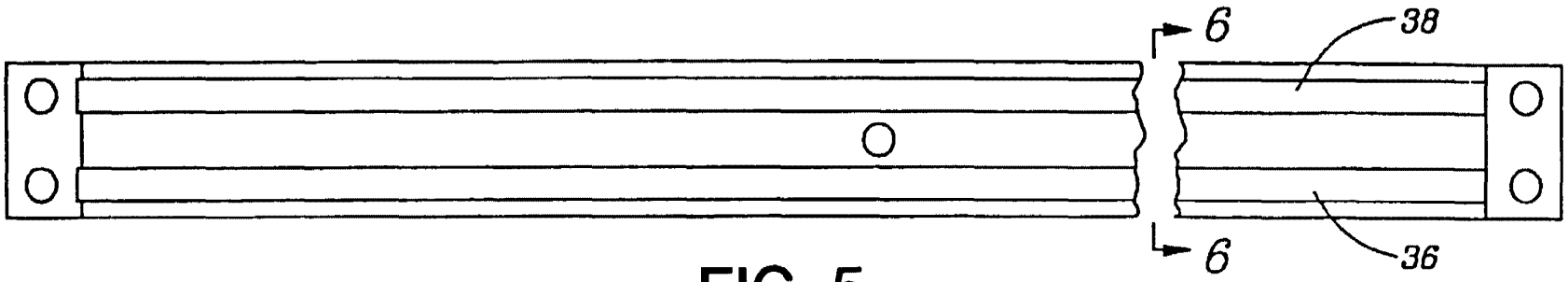


FIG. 5

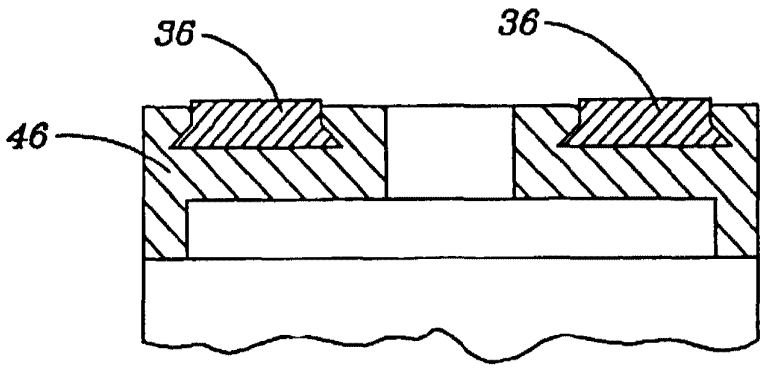


FIG. 6

BEARING WITH A SENSOR ARRANGEMENT FOR OBTAINING AN INDICATION OF VARIOUS PARAMETERS WITHIN THE HOUSING OF THE BEARING

This invention relates to bearings. More particularly, this invention relates to a combination of elements including a sensor to monitor conditions within the bearing and to transmit the information outside of the bearing housing.

There are numerous bearing applications where the bearing is mounted in a housing that denies access to the bearing by servicing personnel. There are bearing performance characteristics that are best measured from inside the bearing for a number of different reasons. For instance, temperature-measurement devices are more responsive the closer they are to the source of heat generation. Vibration monitors are less affected by noise if they are installed inside the bearing. In using both of these types of sensors, a more reliable measurement is obtained if the sensor is permanently mounted within the bearing eliminating installation differences and misapplication of the sensor.

Furthermore, in applications where the bearing is transferred to a number of different locations during its life, the ability to maintain the historical data pertaining to an individual bearing is of great advantage in diagnosing bearing conditions.

While better measurements are obtained from within the bearing, the information must be made available to the personnel responsible for servicing the bearing for this information to be useful in diagnosing problems occurring in the bearing and surrounding equipment. Therefore, only if a

method can be devised to relay this information out of the bearing will a measurement taken inside the bearing be of value.

According to an aspect of the invention, there is provided in combination: a housing;a rotatable member within said housing serving as a race;

a stationary race mounted in the housing having a greater inside diameter than the outside diameter of the rotatable member and serving as a raceway and sensor mount;

a plurality of rollers located in the annular space between the rotatable member and the stationary race;

at least one sensor located on the inside surface of the stationary race;

electrical contacts located on the outside surface of the stationary race, the stationary race having a hole interconnecting the sensor and the electrical contacts;

electric wires extending through said hole for sending electric signals from the sensor to the electrical contacts;

a transmitter mounted in said housing, said transmitter having members therein which contact the electrical contacts located on the outside surface of the stationary race; and

said housing having holes extending from the transmitter through the housing for receiving wires for transmitting signals from the transmitter to electronic systems located outside the housing.

In this way, the conditions within the bearing formed by the combination can be transmitted outside the bearing housing and measured without requiring the use of solid wires at the interface of the outer race of the bearing and the inside surface of the housing.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Fig. 1 is a front view of a large bearing system such as the large bearing used in a steel mill;

Fig. 2 is a view taken along line 2--2 of Fig. 1;

Fig. 3 is a fragmentary view on an enlarged scale showing a part of the bearing system shown in Fig. 2;

Fig. 4 is a sectional view showing an electrical system for transmitting the information sensed by a sensor to the outside of a housing;

Fig. 5 is a plan view showing the manner in which the contact strips on an outer race are mounted; and

Fig. 6 is a fragmentary view on an enlarged scale taken generally along line 6--6 of Fig. 5.

In the various Figures like parts are referred to by like numbers.

Referring to the drawings, and more particularly to Figures 1, 2 and 3, a housing 10 of the type used for supporting large bearings such as those used in steel mills is shown. A rotatable member 12 (see Fig. 2) is rotatably mounted within the housing 10. As shown in Fig. 2, the rotatable member 12 is a rotatable race; however, it is to be understood that under some circumstances and with some bearings, rather than

having a rotatable race, a rotatable shaft could extend entirely through the bore in the housing 10 and the shaft serve as a race.

A stationary race 14 (see Figures 2 and 3) is also mounted within the housing 10. The race 14 has a greater inside diameter than the outside diameter of the race 12. A plurality of rollers 16 are located in the annular space between the race 12 and the race 14.

The race 14 has raceways or race-roller contact areas 18, 20, 22 and 24. The race 14 also has a sensor mount 26 at its approximately axial centre and a sensor mount 28 at one axial end and sensor mount 30 at the other axial end. Thus, the race 14 within the housing serves not only as a means to provide raceways for the rollers 16 but also as a means to provide mounts for sensors. Therefore, as used here, the word "race" is intended to include the annular portion 14 and the sensor mounts 26, 28, and 30.

In the drawings three sensors axially spaced are shown. However, the actual number of sensors is dependent on how much resolution is wanted and also on the size and length of the bearing and area to be sensed by the sensor. However, of course, at least one sensor must be used. Parameters which can be sensed within the bearing include, but not limited to: temperature, vibration, speed and load.

As shown in Figure 4 a sensor 32 is mounted on the inside surface 34 of the sensor mount 28. Electrical contacts 36 and 38 are located on the outside surface of the sensor mount 28. A hole 40 extends from the sensor 32, through the sensor support 28 and up to the area of the electrical contacts 36

and 38. Electric wires 42 extend through the hole for sending electric signals from the sensor to the electrical contacts. The mount 28 of the race is provided with a groove 44. The electrical contact members 36 and 38 may consist of two nickel-plated brass strips laid side-by-side in the groove 44 and insulated from the bearing by a layer of plastics insulation 46.

The groove 44 in the outer surface of the sensor mount 28 extends circumferentially partially or fully along the outside surface of the sensor mount 28. The metal strips 36 and 38 and the insulation 46 also extend circumferentially partially or fully along the outside surface of the sensor mount. Multiple sets of metal strips 36 and 38 with insulation 46 may be mounted at different circumferential locations around the groove 44 to allow contact with the transmitter 50 for different angular orientations of the sensor mounts 26, 28, 30 within the housing 10. In this way different sensors 32 may be connected to the output electronic system 80 through each transmitter 50.

Referring to Figure 4 such a transmitter 50 has a pair of balls 52 and 54 in contact with the metal strips 36 and 38, respectively. The balls 52 and 54 are seated in ball seats 56 and 58 respectively and are biased against the strips 36 and 38 by springs 60 and 62 respectively. Wires 64 and 66 are connected to the terminals 68 and 82 respectively. The wires 64 and 66 extend through the ports 70 and 72 in the housing 10 (see Fig. 3). The wires lead out from the housing 10 to a sensor signal conditioning and output electronic system 80.

Only one sensor-transmitter-system has been described in detail. The structure of the other two sensor-transmitter-

systems of the apparatus is substantially the same as the sensor-transmitter described.

CLAIMS:-

1. In combination: a housing;a rotatable member within said housing serving as a race;

a stationary race mounted in the housing having a greater inside diameter than the outside diameter of the rotatable member and serving as a raceway and sensor mount;

a plurality of rollers located in the annular space between the rotatable member and the stationary race;

at least one sensor located on the inside surface of the stationary race;

electrical contacts located on the outside surface of the stationary race, the stationary race having a hole interconnecting the sensor and the electrical contacts;

electric wires extending through said hole for sending electric signals from the sensor to the electrical contacts;

a transmitter mounted in said housing, said transmitter having members therein which contact the electrical contacts located on the outside surface of the stationary race; and

said housing having holes extending from the transmitter through the housing for receiving wires for transmitting signals from the transmitter to electronic systems located outside the housing.

2. A combination according to claim 1, wherein said stationary race has a groove extending circumferentially partially along its outside surface and the electrical contacts are metal strips mounted in the groove.

3. A combination according to claim 2, wherein the transmitter members in contact with the metal strips extending circumferentially partially along the outside surface of the stationary race are spring loaded balls.

4. Abearing with sensor, substantially as hereinbefore described with reference to the accompanying drawings.

9

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9520926.8
Relevant Technical Fields (i) UK Cl (Ed.N) F2A (AD34) (ii) Int Cl (Ed.6) F16C	Search Examiner B B CASWELL Date of completion of Search 4 DECEMBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Documents considered relevant following a search in respect of Claims :- 1-4

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 1378685	(SKF) see especially page 2 lines 68-79	
A	GB 987205	(SCHAFER) see especially Figures 3 and 4	

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

PATENT ABSTRACTS OF JAPAN

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B60G 17/015
G05D 19/02
// F16F 9/50

(21)Application number : 03-089644

(22)Date of filing : 27.03.1991

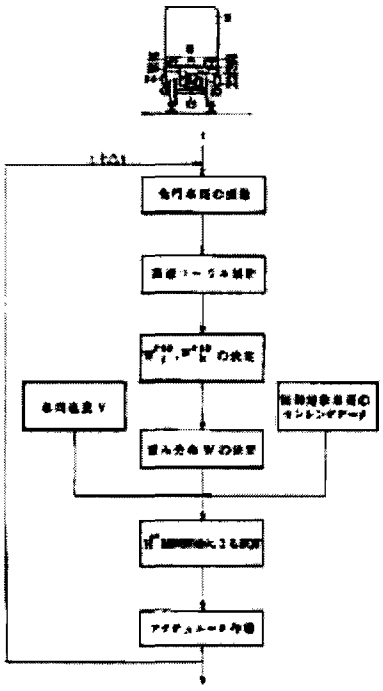
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TORII OSAMU
HIRATA TOSHIAKI

(54) METHOD FOR RESTRAINING VIBRATION OF RAILWAY VEHICLE BY ACTIVE CONTROL

(57)Abstract:

PURPOSE: To improve a control effect and comfortebleness by frequency analyz ing the vibration of e leading vehicle or vehicle in front of an objective vehicle of a composed train by carrying out H control such that the maximum value of the H control weight is in a half value width of the frequency and the distri bution of the weight in the half value width is a predetermined one.



CONSTITUTION: The frequency analysis of vibration of a vehicle is carried out by the outputs of respective vibration accelometers 21, 22, a relative displacement meter 23 and vertical displacement meter 24 of a leading vehicle of a composed train. That is, high speed Fourier conversion is carried out by a controller to determine a half value width (WPSD1, WPSDh) of power spectrum density and weight distribution W. The weight distribution W is determined to be between the maximum value and -10dB. H control

theory calculation is carried out on the basis of vehicle speed V end sensing data of the vehicle to be controlled to operate an actuator 25.

(19)日本国特許庁（ＪＰ）　(12)**公開特許公報**（Ａ）　(11)特許出願公開番号

特開平5－213195

(43)公開日　平成５年(1993)８月24日

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	Ｂ	9255－3D		
	Ｆ	9255－3D		
Ｂ６０Ｇ　17/00		8817－3D		

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(74)代理人　弁理士　押田　良久

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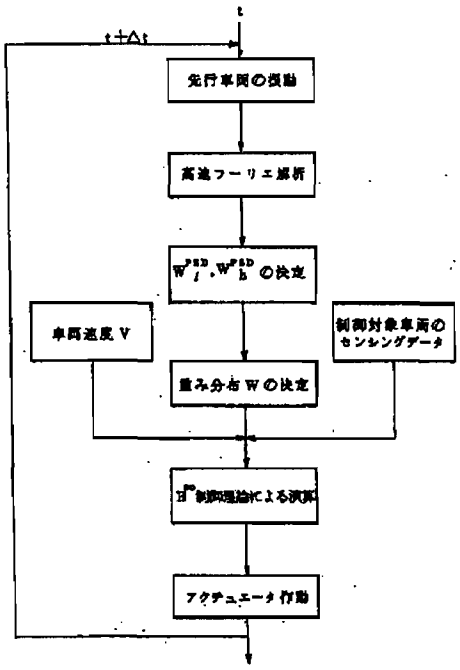
(54)【発明の名称】　鉄道車両のアクティブ制御による振動抑制方法

(57)【要約】

【目的】　鉄道車両の振動のアクティブ制御を行なうに当り制御効果をより高める。

【構成】　一編成列車の先頭車両か、対象車両に対する先行車両の振動を周波数解析し、その周波数の半値幅内にH^{∞}制御の重みが最大値を有し、かつその半値幅内の重みは最大値から－１０ｄＢ以内になる分析となるように決定したH^{∞}制御を施す。

【効果】　効果的な振動抑制を行なうことにより制御効果をより高めることができる。



1

【特許請求の範囲】

【請求項1】 車両の振動を抑制し乗り心地の向上を図るためのアクティブ制御付き台車の制御方法において、一編成列車の先頭車両か、あるいは対象車両の前方に位置する車両の振動を周波数解析し、その周波数の半値幅内にH■制御の重みが最大値を有し、かつその半値幅内の重みは最大値から－10dB以内になる分布となるように決定したH■制御を施すことを特徴とする鉄道車両のアクティブ制御による振動抑制方法。

【発明の詳細な説明】

【0001】

【産業上の利用分野】この発明は、鉄道車両の列車編成とH■制御理論に特有な振動抑制周波数の効率的な選択の長所を生かして行なう鉄道車両のアクティブ制御による振動抑制方法に関する。

【0002】

【従来の技術】鉄道車両の車体に発生する左右振動には、図11に示すように車体11の中心に揺動中心O_fがあるヨーイング、図12に示す車体11の下方に揺動中心O_lがある下心ローリング、および図13に示す車体11の上方に揺動中心O_uがある上心ローリングの3種類がある。前記左右振動を抑制する方法としては、車体と台車の間に振動方向に合せてアクチュエータを設置し、該車体の振動に対し逆位相の制御力を発生させるのが一般的である。

【0003】従来の鉄道車両のアクティブサスペンション装置としては、特開昭56－17754号公報の「車両の振動制御装置」および特開昭59－156860号公報の「車両の振動制御装置」等が知られている。その構成は、図14に示すように、車体11（車体前部11_f、車体後部11_rで示す）を支持するばね12_f、12_rの間に設置された複動形空気圧シリンダ13_f、13_rを空気圧サーボ弁15_f、15_rで駆動する方式となっており、該空気圧サーボ弁への制御入力は、前記車体11に設置された加速度検知計16_f、16_rの出力を用いて、積分、一次進み、一次遅れおよびゲイン要素から構成される数1あるいは数2の形のアナログ補修回路17_f、17_rにて決定される。

【0004】

【数1】

$$\frac{K(1+T_1S)}{s(1+T_2S)}$$

【0005】

【数2】

$$\frac{K(1+T_1S)(1+T_3S)}{s(1+T_2S)(1+T_4S)}$$

【0006】前記3種類の左右振動は、それぞれ異なった

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固有振動数を持つため、前記アナログ補修回路17_f、17_rをそれぞれの左右振動の固有振動数で最適なゲイン、位相を持つように設計すれば、常に左右振動を抑制することができる。なお、図中の18は空気源を示す。

【0007】

【発明が解決しようとする課題】鉄道車両はレールの不整により上下動、左右動、ローリングおよびヨーイングの振動加速度を受けている。これを二次ばねである空気ばねで高周波成分を遮断したり、左右動ダンパ、ヨーイングダンパで運動エネルギーを熱エネルギーに変えて車体になるべく伝達しないように工夫している。しかし、パッシブな系では、固定された共振周波数を無くすることはできない。また積極的に振動を抑制することは不可能である。

【0008】したがって、鉄道車両の振動抑制においては、アクティブ制御を取り入れることが乗り心地の飛躍的な向上に不可欠である。しかし、アクティブ制御はアクチュエータを高周波の外乱に対してもリアルタイムで高速に作動させる必要があり、センサーによる外乱のサンプリングから制御器内の演算をとおしてアクチュエータを作動させるまでの時間が短いほど良好な制御が得られ、これが重要となる。

【0009】最近、強力な制御理論として注目をあびている現代制御理論やH■制御理論は状態変数の多次元のマトリックス演算を行なう必要があり、いかに低次元の重み分布を求めて、効率的な演算で制御効果をあげるかが問題である。また、逆に車両編成という鉄道の性格上、フィード・フォワードが比較的実施しやすい環境にあり、これをうまく利用すれば制御の向上が望めるのも事実である。

【0010】しかし、制御理論として採用しようとしているH■制御は重みの最大値近傍の周波数域では相当抑制効果があるものの、少し周波数がずれると極端に効果が落ちる性質があり、全周波数域に渡って振動抑制効果を発揮させるのは難しい。

【0011】この発明は、かかる現状にかんがみ、鉄道車両の振動のアクティブ制御を行なうに当り、制御効果をより高め乗り心地の向上を図れる振動抑制方法を提供するものである。

【0012】

【課題を解決するための手段】H■制御は、制御系の伝達関数Gのゲイン‖G‖の周波数領域でのピーク値をある一定値γ以下に押える制御であることは既知である。すなわち、$\|G(j\omega)\|<\gamma$であり、ボード線図では図1に実線で示すようになる。

【0013】しかし、重み係数Wの分布を図2のように選択してH■制御を行なうと、図3に実線で示すように重みWの大の所で選択的にシャープに振動抑制効果が上がることがわかった。

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【００１４】また、鉄道車両の振動は軌道不整によるところが大きいので、先行車両の振動の高速フーリエ変換により、図１に示す制御無の外乱の周波数分布を知れば（ω^{PSD}_{max}）、それに一致するように後続車両の制御用の重み分布（$\omega^{H}_{max}=\omega^{PSD}_{max}$）を決定でき、図３に実線で示すように制御効果大（ゲインの小の所）の所のみを利用した制御ができる。

【００１５】この発明は上記知見に基いて完成されたものであり、車両の振動を抑制し乗り心地の向上を図るためのアクティブ制御付き台車の制御方法において、一編成列車の先頭車両か、あるいは対象車両の前方に位置する車両の振動を解析し、その周波数の半値幅内にH■制御の重みが最大値を有し、かつその半値幅内の重みは最大値から－１０ｄＢ以内になる分布となるように決定したH■制御を施すのである。

【００１６】

【作用】上記のごとく、H■制御は重み分布の決定が重要であり、重み大の所の周波数の振動が選択的かつ効果的に抑制される。したがって、先行車両の振動を解析し、振動のパワースペクトル密度の最大となる周波数域に重みが大きくなるように決定することにより後続車両のH■制御の効果を高めうる。

【００１７】すなわち、図４に示すように、先行車両（無制御車両の方がレールによる外乱を忠実に表現しているという点で望ましいが、特に限定はしない）車体振動加速度のパワースペクトル密度の半値幅（ω^{PSD}_{l}～ω^{PSD}_{h}間）内に重みの最大W_{max}が存在し、すなわち、

$\omega^{PSD}_{l} \leqq \omega^{H}_{max} \leqq \omega^{PSD}_{h}$　……１式

かつ、その間の重みが最大値から－１０ｄＢ以上である条件、すなわち、

$W(\omega) \geqq W_{max}-10dB$　……２式

（ただし、$\omega^{PSD}_{l} \leqq \omega \leqq \omega^{PSD}_{h}$）

により、十分な効果が期待できる。これを図示すると、Wは図５の斜線で示す範囲にあればよい。

【００１８】図４、図５に示すように、先行車両のパワースペクトル密度の最大値を０．１～２０Ｈｚ間の周波数域内に限定したのは、この範囲以外のレール不整による車体振動は本来少ないこと、また、２０Ｈｚを超える高周波数のアクティブ制御はアクチュエータの応答性、計算速度等を考慮すると現状では不可能といって差支えないからである。

【００１９】図４のデータは、ある一定の保守規定の元で維持されているレール上を走行する場合、あらかじめいくつかのパターンに分類しておくことで可能である。その各パターンに応じて代表的な重み分布を決定し、データベース化しておけば、リアルタイムで上記１式、２式の条件を満足するWをそのつど計算し決定する必要はなく、メモリーの呼びだしだけで制御することができ、演算時間を短縮することが可能である。

【００２０】

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【実施例】この発明の実施例を図面に基いて説明する。アクティブ制御付き台車の構成を図６、図７に示す。各車両の車体３１に左右振動加速度計２１、上下振動加速度計２２を設け、また台車と車体の間に左右相対変位計２３、アクチュエータ用シリンダ２５を設けるとともに、台車の左右側に上下変位計２４を設ける。そして、車体の底には制御器２６を設ける。なお、図中の２８は制御信号用の配線、２９はアクチュエータ圧力計、３０はアクチュエータに供給される空気の流量計である。

【００２１】上記装置は、この発明を実施するのに必要な最も簡単な構成であり、さらに上下変位計２４に並列して上下アクチュエータを設け、または左右動、ヨーイング、ローリングに対する各ダンパを組合せて併用することもできる。

【００２２】上記列車の先頭車両の各振動加速度計、相対変位計、上下変位計からの出力により車両の振動を周波数解析し、図８のフローチャートに示す要領でH■制御理論による演算を制御器２６で行ない、その制御信号によりアクチュエータを作動して車両の振動を制御、抑制する。

【００２３】上記H■制御は、状態変数として左右加速度、左右相対変位、アクチュエータ内圧、流量弁開口面積、開口面積変化率を用い、重みは左右加速度、左右相対変位、信号出力に対して付加した。ただし、左右加速度の重みにのみ周波数依存の分布を与え、他の重みは一定値とした。また、左右加速度に対する重みの型式は次の数３で与えるものとした。

【００２４】

【数３】

$$W(S)=\frac{S^2+2\xi_2\omega_n S+\omega_n^2}{S^2+2\xi_1\omega_n S+\omega_n^2}$$

【００２５】例えば、$\omega_n=2.2\pi$、$\xi_1=0.3$、$\xi_2=2$のときの分布は図９に示すようになり、ω_nの値により最大値を示す周波数が決まり、その結果図１０に示すようにアクティブ制御により振動制御の効果の大きい周波数域が決まる。図１０はこの発明により一両の車両にH■制御を加えた結果であり、振動低減に大きな効果のあることがわかる。なお、この際の条件は、車両にヨーイングモードのｓｉｎ波加振（振幅±６ｍｍ）を加えたものである。

【００２５】

【発明の効果】上記のごとく、この発明は鉄道車両のアクティブ制御を行なうに際し、より高い制御効果が得られるようにしてH■制御を施すから、効果的な振動抑制により乗り心地を向上できる。

【図面の簡単な説明】

【図１】H■制御の一般的特性を示すボード線図である。

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【図2】重み係数の周波数に対する分布を示す線図である。

【図3】図2の重み係数を用いた場合のH∞制御を示す線図である。

【図4】先行車両の振動を高速フーリエ解析した結果を示す線図である。

【図5】この発明の実施におけるH∞制御の重みWの決定方法を示す線図である。

【図6】この発明の実施にあたり用いたアクティブ制御付き台車を有する車両の構成を示す列車一部の説明図である。

【図7】図6の車両における制御装置の配置の概略を示す説明図である。

【図8】この発明の一実施例におけるフローチャートである。

【図9】この発明の実施における重みWの一例を示す線図である。

【図10】この発明の実施による車両一両のヨーイング加振時のH∞制御の結果を示す線図である。

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【図11】車両に発生するヨーイングの説明図である。

【図12】車両に発生する下心ローリングの説明図である。

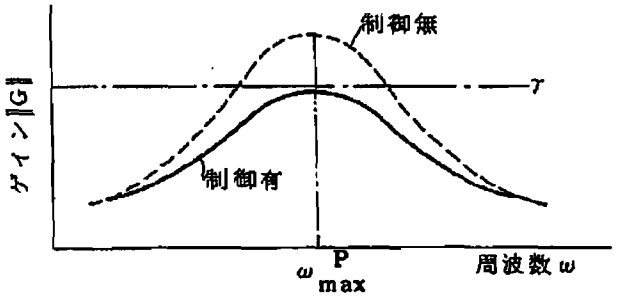
【図13】車両に発生する上心ローリングの説明図である。

【図14】従来の車両のアクティブサスペンション装置の一例を示す説明図である。

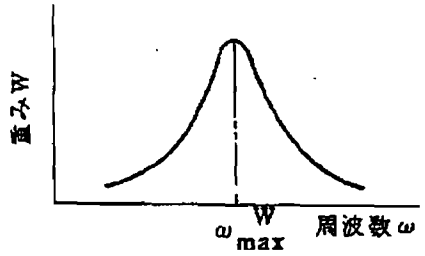
【符号の説明】

21　左右振動加速度計
22　上下振動加速度計
23　左右相対変位計
24　上下変位計
25　左右アクチュエータ用シリンダ
26　制御器
27　空気ばね
28　信号用配線
29　アクチュエータ圧力計
30　流量計
31　車体

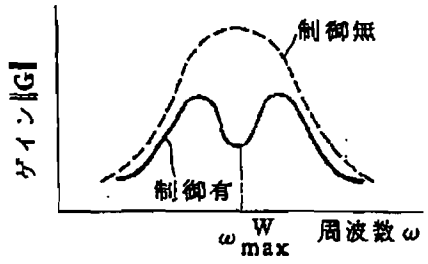
【図1】



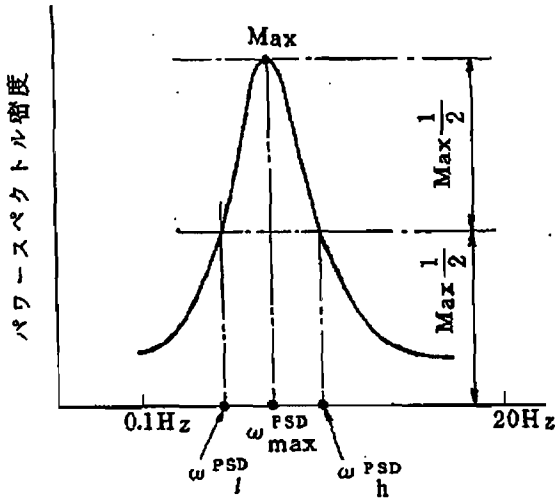
【図2】



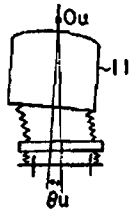
【図3】



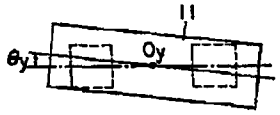
【図4】



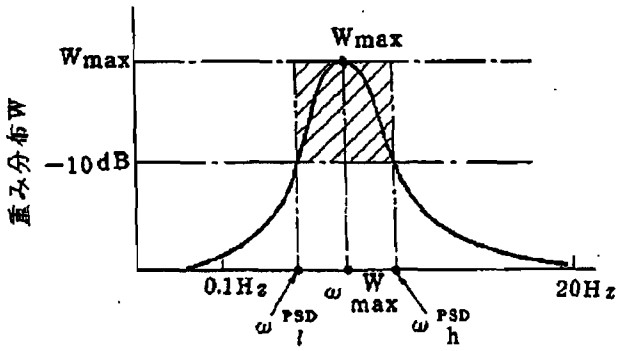
【図13】



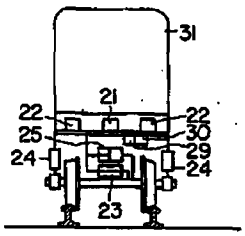
【図11】



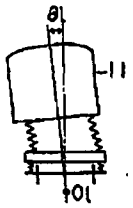
【図5】



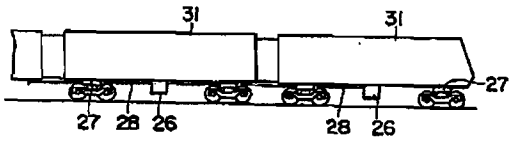
【図7】



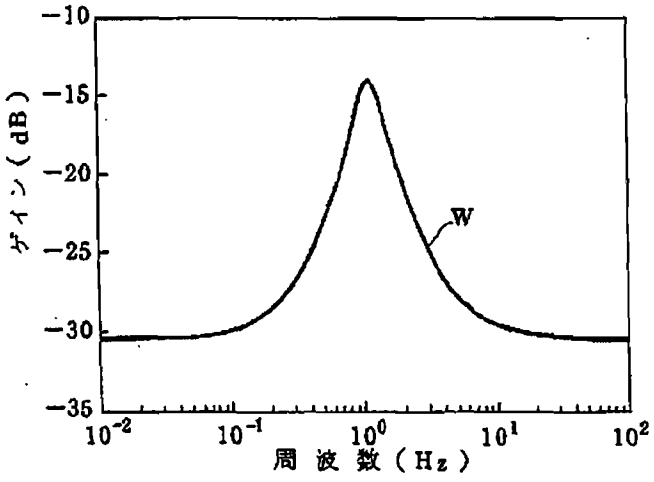
【図12】



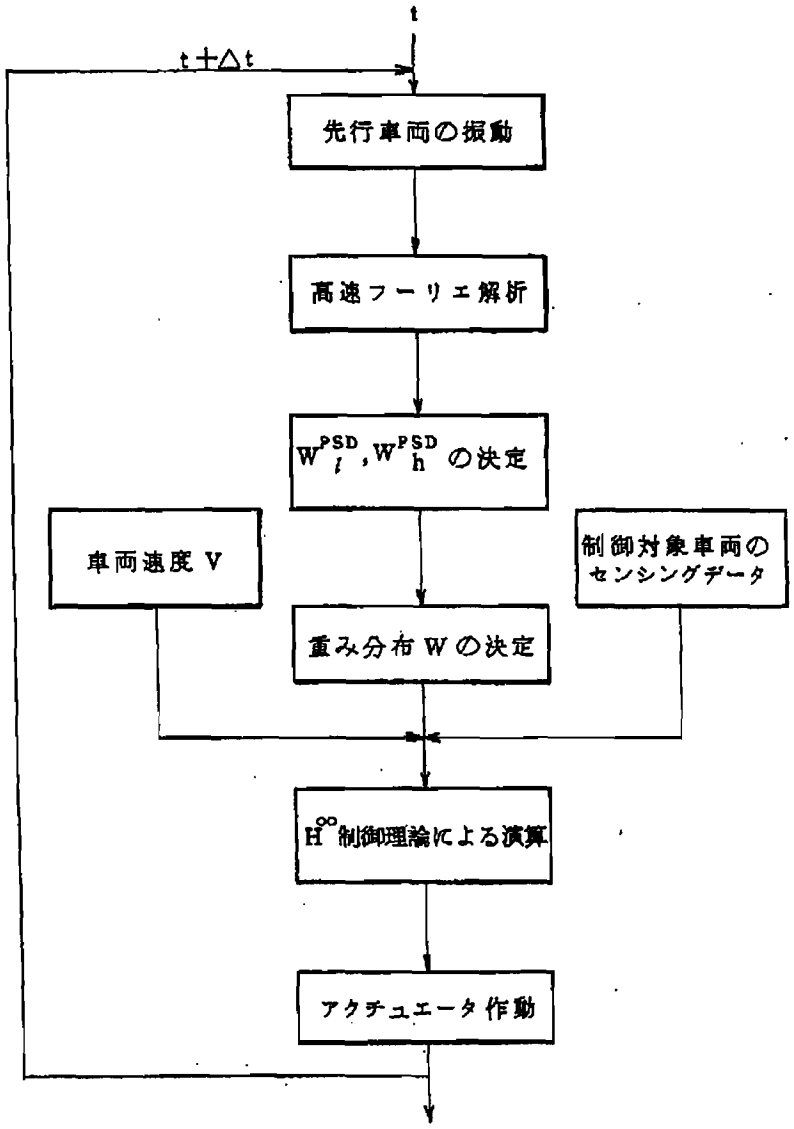
【図6】



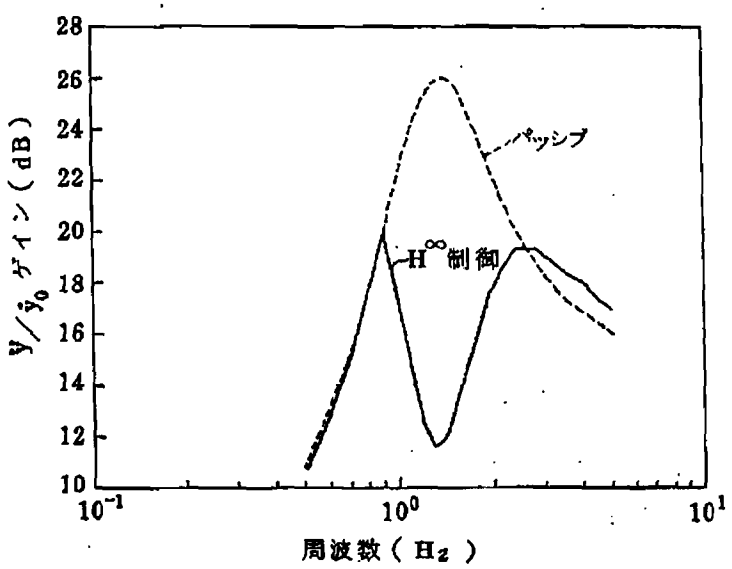
【図9】



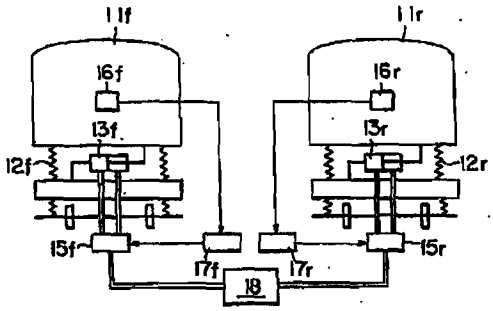
【図8】


t
t＋△t
先行車両の振動
高速フーリエ解析
W_l^{PSD}, W_h^{PSD} の決定
車両速度 V
制御対象車両のセンシングデータ
重み分布 W の決定
H^{∞} 制御理論による演算
アクチュエータ作動

【図10】



【図14】



フロントページの続き

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(71)Applicant : NEC CORP

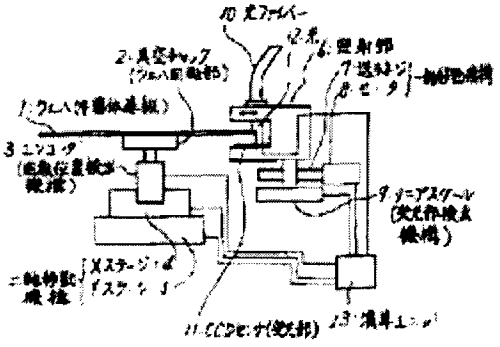
(72)Inventor : FUJIWARA MAKOTO

(54) CONTRACTION PROJECTING EXPOSURE APPARATUS

(57)Abstract:

PURPOSE: To prevent a decrease in processing capacity by simultaneously conducting a peripheral exposure of a wafer and an operation of a prealignment.

CONSTITUTION: An irradiating unit 6 irradiates a wafer 1 with a light 12 from an optical fiber 10. A CCD sensor 11 is provided at a position opposed to the unit 6 to obtain an output responsive to an amount of a light to be shielded. The unit 6 can detect a position by a linear scale 9. The wafer 1 is held and rotated by a vacuum chuck 2. The chuck 2 and the unit 6 are relatively displaced, and the chuck 2 is moved by X-Y stages 4, 5, thereby simultaneously conducting an operation of a prealignment and a peripheral exposure.



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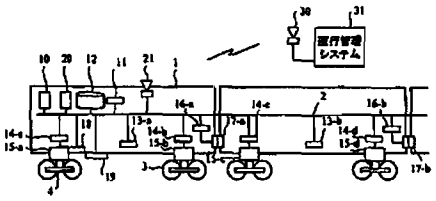
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(54)【発明の名称】適応車両走行制御システム及び適応車両走行制御方法

(57)【要約】
【課題】　本発明の目的は、列車走行等の際に、過去のデータを参照するとともに今後の走行予定経路から、予め制御力特性を最適化したり、さらに、車両重量や気象条件等動的に変化する要因に対しても各種センサ情報を計測することで適応的に最適化したりする、さらに、振動抑制制御した結果改善しない等の状況から装置故障の診断も行うことを目的とする。
【解決手段】　鉄道車両走行のための台車と車両間振動緩衝装置や車両間のダンパの制御力の強さを、車上に搭載したデータベースに蓄積した地図情報と、地図上の地点情報と共に蓄積されている過去の走行履歴から判断できる随時更新可能な最適な前記各制御力の強さ情報と、車上に搭載した位置検知システムが検知する走行地点情報と、ダイヤ情報と、揺れや振動を検知するセンサ情報と、制御力特性の変化を判断する機能から、適宜前記制御力の強さ調整する機能を車両制御システムに搭載する。
【選択図】　図１



【特許請求の範囲】
【請求項１】
車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段と、
地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とが蓄積されたデータベースと、
前記車両上に搭載された位置検知手段と
を有し、
前記位置検知手段が検知する走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整する
ことを特徴とする適応車両制御システム。
【請求項２】
請求項１記載の適応車両制御システムにおいて、
前記車両が鉄道車両である時には、前記車両が走行するダイヤ情報と前記車両が以後に走行する予定の経路の線路の形状とを参照し、
前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整する
ことを特徴とする適応車両制御システム。
【請求項３】
請求項１記載の適応車両制御システムにおいて、
前記車両が自動車車両である時には、前記車両が走行する経路の情報と前記車両が以後に走行する予定の経路の道路の形状とを参照し、
前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整する
ことを特徴とする適応車両制御システム。
【請求項４】
請求項１～請求項３のいずれか一つに記載の適応車両制御システムにおいて、
前記車両上に気象情報を入手する手段と、前記車両の重量を計測する手段と、前記車両の揺れ及び振動を検知する揺れ及び振動検知手段とを搭載し、
前記検知された各情報を前記位置検知手段が検知する走行地点情報と関連付けて前記データベースに蓄積すると共に、
前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整する
ことを特徴とする適応車両制御システム。
【請求項５】
請求項４記載の適応車両制御システムにおいて、
前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する警告手段を有する
ことを特徴とする適応車両制御システム。
【請求項６】
請求項４または請求項５のいずれか一つに記載の適応車両制御システムにおいて、
前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理する統計処理手段を有し、
前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新する
ことを特徴とする適応車両制御システム。
【請求項７】
請求項１～請求項６のいずれか一つに記載の適応車両制御システムにおいて、

前記車両が複数を連結して編成されているときは、各前記車両ごとに、少なくとも前記制御力調整手段とデータベースと位置検知手段とを搭載する
ことを特徴とする適応車両制御システム。
【請求項８】
車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段と、
地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とが蓄積されたデータベースと、
前記車両の位置を検知する位置検知手段と、
気象情報を入手する手段と、
前記車両の重量を計測する手段と、
前記車両の揺れ及び振動を検知する揺れ及び振動検知手段と
を前記車両に搭載し、
前記位置検知手段が検知する走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整すると共に、
前記気象情報を入手する手段、前記車両の重量を計測する手段、前記揺れ及び振動検知手段で検知された各情報を前記位置検知手段が検知する走行地点情報と関連付けて前記データベースに蓄積し、
前記データベースに蓄積された前記位置検知手段が検知する走行地点情報に関連付けられた前記検知された各情報を、地上の統合システムに送信する通信手段を設け、
前記地上の統合システムでは、複数の前記車両からの情報が統計処理され、その結果が前記通信手段を通じて前記車両に返信される
ことを特徴とする適応車両制御システム。
【請求項９】
請求項８記載の適応車両制御システムにおいて、
前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整する
ことを特徴とする適応車両制御システム。
【請求項１０】
請求項８または請求項９のいずれか一つに記載の適応車両制御システムにおいて、
前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する警告手段を有する
ことを特徴とする適応車両制御システム。
【請求項１１】
請求項８～請求項１０のいずれか一つに記載の適応車両制御システムにおいて、
前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理する統計処理手段を有し、
前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新する
ことを特徴とする適応車両制御システム。
【請求項１２】
請求項８～請求項１１のいずれか一つに記載の適応車両制御システムにおいて、
前記車両が複数を連結して編成されているときは、各前記車両ごとに、少なくとも前記制御力調整手段とデータベースと位置検知手段とを搭載する
ことを特徴とする適応車両制御システム。
【請求項１３】
車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段を有し、
データベースに地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とを蓄積し、

前記車両上で検知される走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整する
ことを特徴とする適応車両制御方法。
【請求項１４】
請求項１３記載の適応車両制御方法において、
前記車両が鉄道車両である時には、前記車両が走行するダイヤ情報と前記車両が以後に走行する予定の経路の線路の形状とを参照し、
前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整する
ことを特徴とする適応車両制御方法。
【請求項１５】
請求項１３記載の適応車両制御方法において、
前記車両が自動車車両である時には、前記車両が走行する経路の情報と前記車両が以後に走行する予定の経路の道路の形状とを参照し、
前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整する
ことを特徴とする適応車両制御方法。
【請求項１６】
請求項１３～請求項１５のいずれか一つに記載の適応車両制御方法において、
前記車両上の気象情報と、前記車両の重量と、前記車両の揺れ及び振動とを検知し、
前記検知された各情報を前記走行地点情報と関連付けて前記データベースに蓄積すると共に、
前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整する
ことを特徴とする適応車両制御方法。
【請求項１７】
請求項１６記載の適応車両制御方法において、
前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する
ことを特徴とする適応車両制御方法。
【請求項１８】
請求項１６または請求項１７のいずれか一つに記載の適応車両制御方法において、
前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理し、
前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新する
ことを特徴とする適応車両制御方法。
【請求項１９】
請求項１３～請求項１８のいずれか一つに記載の適応車両制御方法において、
前記車両が複数を連結して編成されているときは、少なくとも前記制御力調整手段とデータベースとを各前記車両ごとに搭載し、
前記走行地点情報の検知を各前記車両ごとに行う
ことを特徴とする適応車両制御方法。
【発明の詳細な説明】
【技術分野】
【０００１】
本発明は、鉄道車両や路線バス等において、路線を走行するときの揺れや振動を抑制するための抑圧制御力を適応的に最適化して制御を行う適応車両走行制御システム及び適応

車両走行制御方法に関する。

【背景技術】

【０００２】

近年のＩＴ（インフォメーションテクノロジー）化の進展や処理装置の高速化で、列車や航空機、自動車にも高速なネットワークや、高速なマイクロ処理装置が搭載されるようになってきている。また、このような機能を利用して、列車走行時に旅客に対して様々な情報を提供するシステムや、振動や揺れが少ない快適な走行制御が実現されるようになってきている。

【０００３】

ＩＴ技術を用いた電車としては、すでに技術の開示されたものがあり、駅案内情報や広告情報を表示するための表示装置が、扉の上部に取り付けられたりしている。また、車上ＬＡＮを用いて、車上機器の診断なども行っている（例えば、非特許文献１参照。）。

【０００４】

さらに、揺れや振動を低減する技術が開示されているものもあり、車上に路線情報を保持し、ＧＰＳ（Global Positioning System)等で位置を検知し、軌道の凹凸やトンネル走行時の揺れの軽減を図る技術が示されている（例えば、特許文献１、２、３参照。）。

【０００５】

以上の処理は、演算処理装置の性能向上やネットワーク通信技術の発達に伴って、列車での旅行をより快適なものにするための技術開発がされてきた成果である。

【０００６】

特に、列車走行時の揺れの低減に関しては、振動吸収装置自体の改良も続けられ、コイルや板バネ装置による振動吸収機構から、空気バネによる振動吸収機能の改善へと機構自体の改善も進んでいる。また加速時や減即時のショックの緩和もできるＶＶＶＦ（Variable Voltage Variable Frequency）制御や、一段ブレーキ制御のＡＴＣ（Automatic Train Control）等も実現されており、滑らかな加減速制御も実現されてきている。

【０００７】

さらに、カーブ走行時の乗り心地向上策として、振り子制御システムも開発され、カーブ走行時に車体をカーブの内側に傾ける制御等も行われるようになってきている。

【０００８】

【特許文献１】特公平５-８０３８５号公報

【特許文献２】特開２００３－２３７５７３号公報

【特許文献３】特開平８－２０７７６５号公報

【非特許文献１】鉄道技術連合シンポジウム予稿集 「列車内情報サービス提供システムの開発」 p.５８３～５８４ 平成１４年

【発明の開示】

【発明が解決しようとする課題】

【０００９】

本発明は、主として乗り心地に大きな影響を与える、走行時の不快な揺れや振動を適応的に低減することを目的としている。これに対して、前記従来技術では過去の走行履歴を参照してより現在の状態に適した制御の実現や、現在の走行環境に対応して適応制御するという点で配慮に欠けていたものである。

【００１０】

すなわち、台車のバネの強さや車体間のダンパ等は、走行前に設定されるのが一般的である。これに対し、走行中に強さを変更できる例としては、前記特許文献３に開示された技術があるが、これは明かり区間とトンネル内走行時の振動の違いを事前に仮定して、走行前に乗り心地が良くなる強さを設定し、走行地点を検知して変更する方式を開示するに留まっている。このため、走行途中、事前に仮定した条件と大きく離れていても、その乖離を検知して走行しながら制御の強さを適応的に最適化することはできない。

【００１１】

なお、仮定した条件とずれる要因としては様々で、例えば、各車両の乗客数の違いでも

車両重量や車両の重心位置が変化するので、最初に仮定した車両状況からズレが生じる。また車両が走行すれば機械的に必ず疲労するので、バネ定数や車両自体の機械的強度や剛性が変化する。これに対して、機械的メンテナンスは必ず行われているが、全てが規定どおりの正確な値にメンテナンスされるとは限らない。

【００１２】

さらに、軌道の状態も時間と共に変化するし、列車の走行も障害などの影響で、常に設定されたランカーブに従って走れるとは限らないので、軌道の状態と走行速度の関係で揺れの違いが発生することも考えられる。また、車両形状、例えば、先頭車、中間車、モータ車、パンタ付き車両、後尾車両等でも走行中の揺れや振動が異なることが考えられる。なお、列車は、通常往復運転するので、往路では先頭車だったものが、復路では最後尾車両になる。また分割併合運転なども運用としてある。

【００１３】

また、走る路線は、現状の鉄道路線を見れば明らかなように、盛土や高架橋等で路盤を敷き、トンネルやカーブ、坂道、鉄橋などが様々に組み合わされて、形成されることが普通である。これら路線状況の変化も、走行時の揺れに対して、一般的に異なる影響を与える。なお、軌道の状態は、前述したように時間と共に変化するので、最適な振動抑制制御特性も変化することが考えられる。さらに、走行しているときの自然条件、特に風雨等は、走行時の揺れや振動の特性に影響を与える。

【００１４】

さらに、車両の制御の変化の影響も考えられる。例えば、加速やブレーキ時に、制御時のショックが発生することがある。ブレーキ制御は、回生ブレーキや、ブレーキシューによる機械的ブレーキ等様々なブレーキ機構を用いる形態がでてきており、これらの制御のしかたでも、ショックの大きさが変化する。

【００１５】

これらダイナミックに変化する要因に対しても、その走行条件の違いを検知して、本発明は、常に最適に揺れや振動を抑圧するように、台車のバネ強度や、車体間ダンパの制御条件を適応的に最適化できるシステムを提供することを目的とする。

【課題を解決するための手段】

【００１６】

上記課題を解決し、本発明の目的を達成するため、請求項１に記載された発明は、車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段と、地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とが蓄積されたデータベースと、前記車両上に搭載された位置検知手段とを有し、前記位置検知手段が検知する走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整するようにしたものである。

【００１７】

また、請求項２に記載の発明による適応車両制御システムは、前記車両が鉄道車両である時には、前記車両が走行するダイヤ情報と前記車両が以後に走行する予定の経路の線路の形状とを参照し、前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整するものである。

【００１８】

請求項３に記載の発明による適応車両制御システムは、前記車両が自動車車両である時には、前記車両が走行する経路の情報と前記車両が以後に走行する予定の経路の道路の形状とを参照し、前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整するものである。

【００１９】

請求項４に記載の発明による適応車両制御システムは、前記車両上に気象情報を入手す

る手段と、前記車両の重量を計測する手段と、前記車両の揺れ及び振動を検知する揺れ及び振動検知手段とを搭載し、前記検知された各情報を前記位置検知手段が検知する走行地点情報と関連付けて前記データベースに蓄積すると共に、前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整するものである。

【００２０】

請求項５に記載の発明による適応車両制御システムは、前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する警告手段を有するものである。

【００２１】

請求項６に記載の発明による適応車両制御システムは、前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理する統計処理手段を有し、前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新するものである。

【００２２】

請求項７に記載の発明による適応車両制御システムは、前記車両が複数を連結して編成されているときは、各前記車両ごとに、少なくとも前記制御力調整手段とデータベースと位置検知手段とを搭載するものである。

【００２３】

さらに、本発明の目的を達成するため、請求項８に記載された発明は、車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段と、地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とが蓄積されたデータベースと、前記車両の位置を検知する位置検知手段と、気象情報を入手する手段と、前記車両の重量を計測する手段と、前記車両の揺れ及び振動を検知する揺れ及び振動検知手段と　を前記車両に搭載し、前記位置検知手段が検知する走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整すると共に、前記気象情報を入手する手段、前記車両の重量を計測する手段、前記揺れ及び振動検知手段で検知された各情報を前記位置検知手段が検知する走行地点情報と関連付けて前記データベースに蓄積し、前記データベースに蓄積された前記位置検知手段が検知する走行地点情報に関連付けられた前記検知された各情報を、地上の統合システムに送信する通信手段を設け、前記地上の統合システムでは、複数の前記車両からの情報が統計処理され、その結果が前記通信手段を通じて前記車両に返信されるようにしたものである。

【００２４】

また、請求項９に記載の発明による適応車両制御システムは、前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整するものである。

【００２５】

請求項１０に記載の発明による適応車両制御システムは、前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する警告手段を有するものである。

【００２６】

請求項１１に記載の発明による適応車両制御システムは、前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理する統計処理手段を有し、前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新するものである。

【００２７】

請求項１２に記載の発明による適応車両制御システムは、前記車両が複数を連結して編成されているときは、各前記車両ごとに、少なくとも前記制御力調整手段とデータベースと位置検知手段とを搭載するものである。

【００２８】
さらに、本発明の目的を達成するため、請求項１３に記載された発明は、車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段を有し、データベースに地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とを蓄積し、前記車両上で検知される走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整するものである。
【００２９】
また、請求項１４に記載の発明による適応車両制御方法は、前記車両が鉄道車両である時には、前記車両が走行するダイヤ情報と前記車両が以後に走行する予定の経路の線路の形状とを参照し、前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整するものである。
【００３０】
請求項１５に記載の発明による適応車両制御方法は、前記車両が自動車車両である時には、前記車両が走行する経路の情報と前記車両が以後に走行する予定の経路の道路の形状とを参照し、前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整するものである。
【００３１】
請求項１６に記載の発明による適応車両制御方法は、前記車両上の気象情報と、前記車両の重量と、前記車両の揺れ及び振動とを検知し、前記検知された各情報を前記走行地点情報と関連付けて前記データベースに蓄積すると共に、前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整するものである。
【００３２】
請求項１７に記載の発明による適応車両制御方法は、前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発するものである。
【００３３】
請求項１８に記載の発明による適応車両制御方法は、前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理し、前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新するものである。
【００３４】
請求項１９に記載の発明による適応車両制御方法は、前記車両が複数を連結して編成されているときは、少なくとも前記制御力調整手段とデータベースとを各前記車両ごとに搭載し、前記走行地点情報の検知を各前記車両ごとに行うものである。
【発明の効果】
【００３５】
本発明によれば、列車走行等の際に過去のデータを参照するとともに、今後の走行予定路線を見て、予め制御力特性を最適化できる場合は、揺れや振動を抑制するように走行位置に合わせて前もって制御力を最適化し、動的に変動する要因に対しては各種センサ情報から情報を入手し、動的に最適化できるようになる。
【００３６】
したがって、これらの制御により、列車等が走行中、概ねの走行環境に合わせた揺れや振動の抑制ではなく、走行位置によって適応的に抑制できるので、常に快適な乗り心地を提供できるようになる。また、揺れや振動を抑制しようとして制御した結果、改善しない等の状況から、装置の故障かもしれないなどの警報情報も出力できるので、メンテナンス作業の効率化もできるようになる。

【発明を実施するための最良の形態】
【００３７】
すなわち本発明においては、列車走行等の際に、過去のデータを参照するとともに今後の走行予定経路から、予め制御力特性を最適化し、さらに、車両重量や気象条件等動的に変化する要因に対しても各種センサ情報を計測することで適応的に最適化する。さらに、振動抑制制御した結果改善しない等の状況から装置故障の診断も行うという目的のシステムを、ＩＴ技術と発達した制御処理プロセッサ技術を用いて効率的に実現した。
【実施例】
【００３８】
以下、本発明の一実施例を説明する。図１は、本発明の基本構成の一例を示したものである。図１において、鉄道車両１は、複数の車両が連結された場合を示しており、各車量に装備する装置は同様の構成になるので、３両目以降は省略してある。
【００３９】
まず、車両内に装備する装置構成を説明の後、各装置が連携して動作し、本発明が目的とする適応制御システムの動作について説明する。各装置は、車両内に引きとおした車上ＬＡＮ２を通して接続されている。但し、ここでは一例としてＬＡＮを使用した例を示しているが、一対一の制御線で接続しても、本発明が目的としている制御機能を実現することは可能である。
【００４０】
台車４は、駆動台車であれば車輪３を駆動して列車を走行させる。通常、鉄道列車はモータ駆動車両と、駆動されない付随車両が組み合わされて構成される。機関車で牽引されるタイプの鉄道列車は、機関車と付随車両から構成される。走行中の揺れや振動をできるだけ車両に伝えないように、該台車４と車両の間には空気バネなどの台車と車両間振動緩衝装置１５（ａ，ｂ，ｃ，ｄの枝番は、同じ機能であるが各台車に分かれて装備されていることを示すために使用）が設備されている。
【００４１】
該台車と車両間振動緩衝装置１５の動作を制御する装置が、バネ力調整制御装置１４（枝番ａ，ｂ，ｃ，ｄは、同じ機能であるが各台車に分かれて装備されていることを示すために使用）である。該バネ力調整制御装置１４は、車上ＬＡＮ２を通して列車走行制御装置１０に接続されている。該列車走行制御装置１０からの指令に従い、バネ力調整制御装置１４で台車と車両間振動緩衝装置１５のバネ力を適切に調整する。
【００４２】
１両単独で走行するのでなければ、図１に示すように車両を接続して走行する。本発明では、列車間で異なる揺れや振動の影響を抑制するために、車両間ダンパ装置１７を用いる。該車両間ダンパ装置１７（枝番ａ，ｂは、同じ機能であるが各車両間に分かれて装備されていることを示すために使用）を制御する装置が、車両間ダンパ力制御装置１６（枝番ａ，ｂは、同じ機能であるが各車両間に分かれて装備されていることを示すために使用）である。
【００４３】
位置検知装置１１は、当該列車の走行位置を検知するための装置である。位置検知機能を実現する装置としては、ＧＰＳ（Global Positioning System）の利用や、地上側に地点検知用のタグなどを設置しそのタグ情報と移動距離から位置を検知する装置、或いは、特徴的な目印を認識して位置を特定する装置等、幾つか実現手法が考えられるが、本発明では適切な位置検知手法を選択すればよく、特定の位置検知装置の使用に限定されるものではない。
【００４４】
車上ＤＢ１２は、路線の地図情報や物理的な形状、即ちトンネルやカーブ、高架などの路線情報を蓄積すると共に、過去の走行位置と揺れや振動の測定状況や車両の編成状況、現在の台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力の設定値等を蓄積したり、現在の走行の揺れや振動の状況を位置検知装置１１の位置検出結果と共に蓄積し

たりするものである。センサ類１３は、走行中の揺れや振動などを検知するための装置であり、図２を用いて後ほど構成例を説明する。

【００４５】

ブレーキ制御装置１８やモータ制御装置１９は、文字通り列車を止めたり走行させたりするブレーキやモータの動きを制御するものであり、列車走行制御装置１０からの指令で、制御を実行する。本図では、図面の見易さを考慮して、便宜上ブレーキ制御装置１８やモータ制御装置１９は一組のみ示しているが、列車編成を考慮して必要数だけ装備されるものである。

【００４６】

入出力装置２０は、例えば、現在のバネ力調整制御装置１４や車両間ダンパ力制御装置１６の制御の強さやセンサ類１３の検出状況を監視したり、これから走行する路線データ（固定的なカーブや坂道、トンネル、駅の配線状況、ダイヤに従った駅での到着番線など）の入力機能を必要に応じて提供したりする。地上車上間通信装置２１は、走行予定の線区の気象状況やダイヤの乱れ状況等を、地上通信装置３０と交信して運行管理システム３１から取得する通信機能を提供する。

【００４７】

次に走行中、台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を適応的に最適化する動作について説明する。

【００４８】

列車の走行は、予め計画されたダイヤに従って走行する。車両の運用については、毎日同じ車両が同じ路線を同じ時間帯に走行するわけではなく、日々割り当てられた計画に従って走行することになる。このため、走行路線が異なれば、分岐やカーブの配線の状況、路盤や線路の凹凸の状況、分岐の状況も異なるし、乗客の数もダイナミックに変化するので車両の重量や重心の位置が異なる。

【００４９】

また、気象条件や、車両や軌道の経年変化やメンテナンスによって、状況は必ず変化する。これら状況の変動要因はあるが、これまでは、技術開発と経験からある条件を仮定して、車両間振動緩衝装置１５や車両間ダンパ装置１７の制御の強さを予め定め、揺れや振動を概ね抑制できるように設定し、乗客の不快感を低減するようにしていた。本発明では、前記のようにダイナミックに変化する走行条件に対応して、台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を最適化する動作を実行するものである。

【００５０】

図３を用いて、列車走行制御装置１０で実行する本発明のシステム全体の制御の流れを説明する。

【００５１】

まず処理１０１で、台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力をデフォルト値にセットすると共に、該値で正常動作していることを確認する。ここでは入出力装置２０で取扱者が内容を確認し、その設定を変更したい場合は、入出力装置２０から変更要求をセットする。該マニュアル要求があった場合は、マニュアル要求を処理１０２で処理し、車上ＤＢ１２に要求値をセットする。次に各センサからの情報、即ち、処理１０３で位置情報、処理１０４でその他のセンサ情報を入力する。

【００５２】

処理１０４で入力するセンサ情報としては、図２にセンサ類１３の構成の一例を示すように、重量センサ５１、振動センサ５２、加速度センサ５３、ジャイロ５４、ヨーレイトセンサ５５等から出力される情報である。これらの情報から、現在の車両の状況を検知する。次に処理１０５で、車上ＤＢ１２の情報を参照し、マニュアル優先で台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力をセットしたいという要求があった場合は、マニュアルセット情報を参照し、該値に従って制御力をセットする。

【００５３】

もし、自動セット要求であれば、現在のセンシング情報を参照し、過去の制御状況から

学習して最適制御力として蓄積されている情報を検索し、該情報に従って自動的に、車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力をセットするように、バネ力調整制御装置１４と車両間ダンパ力制御装置１６に命令を出力する。この制御の手法については、後ほどさらに詳しく説明する。

【００５４】

処理１０６では、揺れや振動の計測値を、現在の制御力の値や、走行位置、速度、車両重量などと共に車上ＤＢ１２に蓄積する。その内容は、例えば図５の表１に示すようなものであり、後ほど内容について説明する。処理１０７では、揺れや振動の状況を予め許容範囲として設定していた値と、現状の観測値を比較して乗り心地評価を行う。処理１０８で、その評価値が許容範囲を逸脱しているかどうか判定し、逸脱していなければ処理１０２からの処理を繰り返す。逸脱していた場合は、処理１０９を実行する。

【００５５】

まず処理１０９で、逸脱した揺れや振動の原因を分析する。図４を用いて原因分析処理について説明する。最初に、処理１５１でセンサ類１３の出力を取り込む。センサ類１３の構成の一例は図２に示されている通りである。重量センサ５１は、台車４に取り付けられている前記台車と車両間振動緩衝装置１５に接続され、緩衝用のバネの沈み込みの状況や、装置にかかる圧力を計測する。

【００５６】

この重量センシング情報を列車走行制御装置１０に送り、該情報から、該列車走行制御装置１０で、現在の重量の見積と車両の形状（座席の数や車両の構造等）を考慮し、何人ぐらいの乗客が乗っていて着席客と立ち客の状況推定も行い、車両の重心の高さも推定する。振動センサ５２は、細かな周期の振動、例えば振動の周期のピークが数Hz以上の縦揺れや横揺れを計測し、各周波数帯での振幅を計測する。加速度センサ５３やジャイロ５４では、変化の周波数が数Hz以下の低い帯域での変化量を計測し記録する。

【００５７】

ヨーレイトセンサ５５では、車両の進行方向に対する横の捻れ動作を計測し、記録する。図２では、列車走行時の揺れや振動を計測したり、その要因を特定するために計測する装置として、重量センサ５１、振動センサ５２、加速度センサ５３、ジャイロ５４、ヨーレイトセンサ５５を例示したが、振動や揺れの計測で不要なものは当然取り付ける必要は無いし、さらに詳しく計測したければ必要に応じて計測装置を追加すればよい。

【００５８】

例えば、揺れや振動に影響を及ぼす風雨の影響も車上単独で計測したければ、風力計や雨量計を装備すればよいし、画像計測などで線路の状況や振動の状況を計測したければ、計測用のカメラを装備してもよい。特に図示していないが、本例では現状の気象観測システムを有効に利用することを考え、気象に関する情報は地上側に設備されているセンサで計測した情報を、図１に示した運行管理システム３１から無線通信で送信してもらうことを仮定している。本発明のシステムとしては、必要なセンシング情報をシステムに適した形態で、入手すればよい。

【００５９】

処理１５２では、これら取り込んだセンシング情報と、現状の走行条件として仮定した状況を詳細に比較検討する。走行条件として仮定する項目としては、車両重量、車両の重心の位置、風雨の状況、走行路線の形状（トンネルや明かり区間等の違い）と線路の整備状況、スラブやバラスト、高架や盛土など軌道の建設状況等である。

【００６０】

走行条件として仮定した項目と現状の差異は、１）車両重量などは、重量センサ５１の出力と設定値との比較で乖離を判定、２）車両の重心の位置も車両の形状と推定重量から、着席乗客や立ち乗客を見積もって乖離を推定、３）自然条件である雨や風の状況は、運行管理システムから受信した値と比較することで乖離を判断、４）走行路線の形状や軌道の建設状況は走行ダイヤと位置検知情報、及び過去の走行履歴を参照することで仮定した走行環境との乖離を判断する。

【００６１】
処理１５３で、前記乖離判定と揺れの特徴から最も揺れや振動が増加した原因として大きいと判断できるものから順にプライオリティをつける。例えば、仮定した重量よりも重かったことが原因である場合は、軌道環境の良し悪しに敏感に反応するようになるので、加速度センサの変化の度合いが大きかったり、振動センサの周期と振幅が増大したりする現象が、乗客数の変動が無ければ、走行している間定常的に観測されることになる。風が強い場合は、特定の方からの比較的低周波の揺れが観測されることから判断する。
【００６２】
軌道状況が変化した場合は、何度か走行して同じ地点で同じような揺れや振動が観測されるので、蓄積したデータの解析から判断できる。この路線状況の変化に起因すると判断された場合は、図３の処理１０５で予め設定するために参照するＤＢへ反映し、走行前に自動的に調整できるようにする。
【００６３】
制御機能が劣化している場合は、要因として特に揺れや振動抑制が劣化するとは考えられないときに、定常的に以前の履歴と比較して揺れや振動の状況が劣化している場合に推定される原因となる。さらに制御力を変えるように指示を出しても、状況が変化しない場合は、機器故障という判断もできる。このような推定論理を用いて、処理１５３で判定する。
【００６４】
処理１５４では、処理１５３でプライオリティを判断して対策したにもかかわらず状況が改善しなかった場合に、順次対策をするための対策履歴を参照して、今回行うべき対策の選択をする。次に判断１５５で、考えられる全ての対策をしても状況が改善しなかったかどうかを判断し、改善していなかった場合は、処理１５６に分岐し、デフォルトの制御力に設定を指示して、未知の揺れや振動要因であったことを記録し、機器劣化や故障の可能性も有りその判断結果も記録する。
【００６５】
まだ全ての制御対策をしていない場合は、判断処理１５７に分岐し、そこで、制御力調整処理として最初の処理かどうか判断して、最初の処理であれば処理１５９の対策処理を実施する。最調整処理であれば、処理１５８で前回の設定をリセットし、今回の対策処理を有効にするように指示して揺れや振動の要因分析処理を完了させる。即ち、図３に示す処理１０９の処理が完了する。
【００６６】
処理１０９で、対策処理が決定されるので、その対策指示を処理１１０～処理１１４で実施する。処理１１０は、逸脱原因が、前提とした車両重量からの乖離であると判断された場合の対策である。該処理１１０では、車両重量が現状の制御力に設定した前提重量より重いために揺れや振動が増加したとの判定結果のときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力を硬くするように変更する指示を出力する。
【００６７】
一方、車両重量が現状の制御力に設定するために前提とした重量より軽いために揺れや振動が増加したとの判定結果であったときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力を柔らかくするように変更する指示を出力する。
【００６８】
処理１１１は、逸脱原因が前提とした自然環境からの乖離であると判断された場合の対策である。処理１１１では、例えば、風向風力が現状の制御力に設定した前提重量より大きいために揺れや振動が増加したとの判定結果のときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力を硬くするように変更する指示を出力する。さらに、車両間ダンパ力制御装置１６に対して、風上側の車両間ダンパ装置１７の制御力を強くするように指示を出力する。
【００６９】

処理１１２は、逸脱原因が前提とした軌道の状況からの乖離である判断された場合の対策である。該処理１１２では、軌道の状況が現状の制御力に設定した前提軌道条件よりの劣化、例えば線路表面の凹凸や、線路の左右の曲がりが増大したために揺れや振動が増加したとの判定結果であったときには、その凹凸や左右の線路の曲がりの周期や大きさに適合したバネ力になるように、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力の調整指示を出力する。

【００７０】

アクティブに車体を傾ける制御として列車では、特にカーブ通過時の乗り心地向上対策として、車体の振り子制御が行われる場合があり、既に実現されている。この制御は、一般的にダイヤを参照し現在位置を検出しながら路線データを参照して、カーブを認識すると車体をカーブの内側に傾斜させる制御が行われる。本発明では、該振り子制御を実施するものではないが、振り制御機構が搭載されている車両では、その特性も認識して協調制御することができる。

【００７１】

すなわち本発明において、例えば、設定速度より高速でカーブすれば推定過重が増加するので、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力を硬くするように指示するし、振り子制御が何らかの原因で計画どおり実施されない場合は、遠心力の大きさをジャイロ５４や加速度センサ５３から検知し、台車と車両間振動緩衝装置１５の制御力を硬くするように制御する。

【００７２】

処理１１３は、逸脱原因が前提とした制御力指示に対して予定した制御力との乖離がある場合の対策である。該処理１１３では、制御力指示に対して予定した制御力より不足したために揺れや振動が増加したとの判定結果であったときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力をさらに硬くするように変更する指示を出力する。また、車両間ダンパの制御力が不足していた場合は、車体間ダンパ力制御装置１６に対して、車両間ダンパ装置１７の制御力をさらに強くするように指示を出力する。

【００７３】

一方、制御力指示に対して予定した制御力より超過したために揺れや振動が増加したとの判定結果であったときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力をさらに柔らかくするように変更する指示を出力する。また、車両間ダンパの制御力が超過していた場合は、車体間ダンパ力制御装置１６に対して、車両間ダンパ装置１７の制御力をさらに柔らかくするように指示を出力する。

【００７４】

処理１１４は、逸脱原因を推定して対策をしたが、処理に作りこんだ全ての対策を行っても結局改善が見られなかった場合の処理である。この場合は図４の処理１５６の結果に相当する場合で、デフォルトの制御力に設定を指示して、未知の原因で揺れや振動があったことを記録し、機器劣化や故障の可能性も有り、その判断履歴や結果を蓄積データ用に加工する。

【００７５】

これら、処理１１０から処理１１４の何れかの処理を実行した後、処理１１５で制御実施履歴と結果を車上ＤＢ１２に格納後、処理１０２に戻り処理を繰り返す。以上の処理について走行中周期的に実行を続けて、機器故障や未知の揺れや振動等の要因が検知されない限り、揺れや振動に対して不快感を大きくしないような乗り心地環境を提供する。

【００７６】

さらに図５の表１には、制御した処理周期ごとに処理１１５でデータを車上ＤＢ１２に蓄積し、履歴を残すためのデータフォーマットの一例を示している。表の縦列方向のひとかたまりが、一回の周期で記録するデータ例である。表の左端に項目を示している。

【００７７】

制御周期として、表の最上段に示すように、仮にｎ番目からの例を示している。次の列

がｎ＋１番目、次ぎがｎ＋２番目で、ここでは５秒間隔で記録する場合を示しているが、該記録周期は、制御の実態を考慮し、例えば、定量的な情報がまだ確立されていない場合は、車上ＤＢの容量を大きくし、記録周期を短くして詳細な情報を収集したり、一方、十分に路線情報が集まり変化が少なければ記録周期をのばし、車上ＤＢ容量を節約したりすることもできる。

【００７８】

実情に合わせて、記録周期と車上ＤＢ容量を決定し、制御を続ける間、記録を継続することを右端の列は示している。項目としては、搭載するセンサ情報に関係して、列車番号や編成番号、時刻やそのときの位置に関連付けて、揺れや振動を方向別に、振幅、周波数、加速度、ヨーレート、そのときの制御力の強さ、列車速度、推定重量、気象上のデータを設定している。この項目は、当然搭載するセンサの種類、観測する項目の違いにより変化する。ここでは、図１に例示したシステムを対象に例示している。

【００７９】

図６は、列車の走行環境をイメージして、どのように制御されるか状況を表示したものである。３両編成の列車を、Ａ列車２０１、Ｂ列車２０２、Ｃ列車２０３で示している。線路の配線２００は、各一本の線が各列車の走る線路を示していて、駅中間部分は複線である。各列車の進行方向は列車に付属させた矢印で示している。駅はＡ駅２０５とＢ駅２０６の２駅のみを示し仮想的な路線である。

【００８０】

ここに示すように、ダイヤと車両運用計画が決まれば、これから走行する路線の環境を予め知ることができ対応した最適制御力を走行地点に関連付けて各列車に設定できる。即ち、どこで分岐し、トンネルがどこにあり、どのような軌道環境、例えばカーブや高架橋、スラブ軌道やバラスト軌道などの状況、また、過去の走行データの蓄積からどのように線路環境が変化しているかなどの情報から、走行位置に関連付けて予め走行前に最適な制御力を図３の処理１０５でセットでき、これら条件に対しては予め適切な制御環境を整える。

【００８１】

一方、動的な条件、例えば、Ａ駅、Ｂ駅とも４本の番線があるが、Ａ列車は、Ａ駅に停車中に乗客の乗り込みで、重量が増えたと仮定する。すると、図３の処理１１０が動作し、台車と車両間振動緩衝装置１５の制御力を硬く変更して、走行をすることになる。また、Ｃ列車は、ダイヤからＢ駅で分岐してカーブして行く方の番線に到着することになっている例を示している。

【００８２】

図では分岐線路上に在線している例であるが、前記処理１０５で走行環境に起因して制御力を設定する機能からこのように分岐する部分に入る前に、この先に分岐があり横方向の揺れが大きいことが分かるので、予め、分岐の手前で、台車と車両間振動緩衝装置１５や車体間バンパ装置１７を硬めに設定して揺れを押さえるように制御する。

【００８３】

また、線路部２０４は、過去の走行から線路の歪みが大きいと判断されている部分を示しており、Ａ列車は進行と共に、この線路部２０４に進入する前に、最適な制御力に台車と車両間振動緩衝装置１５を調整する。Ｂ列車２０２は、カーブを走行中の状態を示している。ここで仮にＢ列車に適切な振り子装置が装備されていないとすると、遠心力でカーブの外側に車体が傾斜しようとする。この傾斜を押さえるために、カーブ部分に進入する前に進行方向左側の車両間振動緩衝装置１５の制御力を硬めにしたり、車体間バンパ装置１７も硬めに設定したりする。

【００８４】

一方、Ｂ列車に振り子装置が装備されていた場合は、振り子装置の特性に合わせて揺れや振動が抑制されるように制御するか、通常の直線走行時の制御力のままで走行することになる。このように、過去のデータやセンサ類１３の情報を用いて適応的に台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を調整して、揺れや振動を抑制して乗

り心地を改善する。

【００８５】

車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力の強さは、列車単位で見ると当該列車での平均的な制御となるが、車上ＤＢ１２も車両単位にデータを蓄積しておき、車両単位で図３に示した処理を実行すれば、よりきめ細かな制御ができる。さらに、列車の編成状況をセットすれば、編成の連結状態も考慮して制御もできる。この状況を、図７を用いて説明する。

【００８６】

ここまでは、鉄道車両１の形状や走行時の状態について言及しなかったが、鉄道車両は各車両ごとに若干形状や機能も異なっていることが普通である。図７は４両編成の仮想的な車両編成例で、矢印で進行方向を示す。通常電車などは、ある決まった編成単位で運用されることが普通であり、編成の両端車両２５０と２５４には運転席２５５（枝番ａ，ｂは、同じ機能であるが各々の車両間に分かれて装備されていることを示すために使用）が設備される。

【００８７】

モータ制御装置１９は、全車両に装備されることもあるが、図に示すように編成内のある車両２５１に装備され、その他の車両には取り付けられない場合が多い。また、パンタグラフ２５３も装備車２５２にだけに取り付けられ、その他の車両には無いというように、各車両ごとに形状や重量バランスが若干異なっていることが普通である。また、図では進行方向を矢印で示すように図面左側から右側としているが、車両形状が全く同じでも、先頭車と中間車、後尾車とでは受ける風圧の影響が異なってくる。

【００８８】

このため、車両の形状や機能、進行方向を考慮して、図３に示す処理を個々の車両毎に実施し、よりきめ細かな制御も、図１に示す構成で実現できる。即ち、図示するように各車両ごとに取り付けたセンサ類１３からの情報を車両ごとに、列車走行制御装置１０で演算し、出力を各車両ごとに個別に設定することで実現する。また、軌道の歪みや湾曲等でその位置に到達したときに発生する揺れや振動の対策も、各車両毎に該走行環境が劣化している走行位置に入る前に制御力を調整すれば、よりきめ細かな制御が可能になる。

【００８９】

図８は、列車が仮想の線区を走行するときの運転曲線２６０の一例を示している。縦軸が速度で、横軸は位置を示している。Ａ駅を出発した列車がＣ駅方向に走る場合で、当然駅を出発するときに加速をして、Ｂ駅やＣ駅に止まるときに減速をする。しかし、駅間で図示するように、カーブや工事などで速度制限区間２６５がある場合等は、減速を強いられるし、駅間での最高速度も必ず同じというわけではなく、異なることも多い。

【００９０】

図では、加速区間を２６１、２６３で示し、減速区間を２６２、２６４、２６５で示している。まず、加速区間では力行ノッチ制御が入り、減速区間では減速ノッチ制御が入ることになる。低速走行区間では、惰行などを組合せながら目標速度に追従するように制御され、通常あまりノッチ制御は頻繁ではない。このため、加減速区間では、ノッチ変更や加減速のために、列車の前後の加速度でショックを感じることがある。

【００９１】

このショックを緩和するためには、台車と車両間振動緩衝装置１５や車体間ダンパ装置１７の制御力を硬めに設定して、前後の揺れを押さえた方が良い。駅中間の低速走行では、加減速制御は頻繁ではなく、線路の凹凸などの影響を台車と車両間振動緩衝装置１５や車体間ダンパ装置１７で吸収できるように、制御力を弱めに設定した方が良い。このような制御も、図１に示す構成で、ダイヤ情報と、位置検知情報から予め制御可能であり、図３に示す処理１０５で使用する情報として、車上ＤＢ１２に蓄積することで実現する。

【００９２】

図９は、列車走行制御装置１０で実行する車上ＤＢの更新処理の一例を示している。車上ＤＢには走行するごとに、走行中の制御状況とセンサでのセンシング結果が、図５の表

１に示す形で車上ＤＢ１２に蓄積されて行く。走行環境は恒常的に一定と言うわけではなく、線路の状況や路盤の状況等は、時間と共に変化する。このため、当該路線に対して最適な台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力も変化してゆく。

【００９３】

ところで、通常この変化は、気象の変化や車両重量の変化と異なり、ある位置が特定され、また時間的に経年変化というオーダーでゆっくりと変化して行く。一方、メンテナンス工事も行われるので、この場合には路盤や線路の特性がステップ的に変化することが考えられるが、この場合でも走行位置に関連付けてデータを解析することにより、どのように状況が変わったか推測できる。このようなことから、図９に示すように同じ線区を走行したときのデータを何回分か纏めて解析すればその特徴が判断できる。

【００９４】

図では、仮に第ｍ回目の走行データ２７０から、ｍ＋１回目の走行データ２７１、ｍ＋２回目の走行データ２７２、ｍ＋ｋ回目の走行データ２７３を統計処理２７４で処理する例を示している。例えば、ある特定位置の線路が波打ったように表面が劣化したとすると、その位置で特に揺れや振動が大きくなるという走行データが優位的に見られることになるので、その位置を走行する場合は、台車と車両間振動緩衝装置１５や車両間ダンパ装置１７に対して、最適となるように予め当該線区を走行する場合の制御力設定情報２７５を更新する。

【００９５】

このようにして、当該車両が走行した線区に対して、予見できる地点での台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の最適制御を予め随時更新して、適応的に揺れや振動を最適に抑制する。もし当該車両が、初めてその線区を走行する場合は、運行管理システム３１から制御力設定情報２７５を受信するか、入出力装置２０を通して情報をセットしてもらい、その情報を読み込んで、制御力を設定する。

【００９６】

図１０は、地上ＤＢに制御力設定情報２７５を集中して蓄積管理する場合のシステム構成例を示している。即ち、機能的には図１に示したシステムで実現する適応的な揺れや振動の最適低減と同じであるが、予め既知の走行状況に対して走行前に読み込む制御設定情報２７５を地上側ＤＢ３０１に集中管理するシステム構成である。

【００９７】

この場合、車上ＤＢ１２は、地図情報や該地上データベースが受け取った情報を蓄積したり、一連の走行で取得した図５の表１に示した走行データを一時保管したりすることに使用し、該一連の運用で走行した後、或いは走行中に随時運行管理システムに送信し地上側列車走行制御ＤＢ管理装置３０２に伝達する。伝達の手法としては、無線通信を使用することもできるし、ディスクメモリ装置や固体メモリ装置等様々なメディアから、適切な手法から選択して用いればよい。

【００９８】

地上側列車走行制御ＤＢ管理装置３０２は、各走行毎の図５の表１に示す走行データを受け取り、地上側ＤＢ３０１に蓄積し、列車走行制御装置１０で実行する処理と同じように、集中管理している各編成車両単位に地上側ＤＢ３０１の変更処理を実施する。そして、各編成車両単位に変更処理した情報は制御力設定情報２７５と同じ形式で蓄積する。

【００９９】

各情報は、前記同様無線通信や、固体蓄積媒体を通して走行前に車上ＤＢ１２に送られ、列車走行制御装置１０が随時参照し、適切に台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を、過去のデータから参照される範囲では予め調整しておき、稼動中は図３に示した処理と同じ処理を車上の列車走行制御装置１０で実行し、車両重量や気象条件、或いは軌道の状況の変化で揺れや振動の抑制が十分でないと判断した場合は、適応的に台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を調整して、揺れや振動の抑制を最適化する。

【０１００】

図１のシステム構成でも図１０に示したシステム構成でも、バネ力調整制御装置１４や車両間ダンパ力制御装置１６は、台車と車両間振動緩衝装置１５と車両間ダンパ装置１７に付随して分散配置する構成を示しているが、これらの装置機能を列車走行制御装置１０に集中し、制御出力結果を台車と車両間振動緩衝装置１５と車両間ダンパ装置１７に対して制御線で伝達する構成も実現可能であるし、論理を大規模集積回路化し、台車と車両間振動緩衝装置１５と車両間ダンパ装置１７に組み込んで実現することも可能である。

【０１０１】

すなわち、システム構成として、ブロック構造化を基本にフレキシビリティを優先させるか、システム構成の簡素さを優先させるか、運用を考え適宜最適なシステム構成形態を選択すればよい。

【０１０２】

図１１は、これまで鉄道車両を対象に説明してきたが、それ以外の交通システムへ適用した場合の一例を示したものである。自動車用ナビゲーション装置が広く普及してきて、目的地を設定すると、経路案内をしてくれる機能も実現されてきている。また、自動車ナビゲーション装置は、機能の基本として位置検知機能があり、好みの機能を選択するための入出力装置も備えている。

【０１０３】

この機能を利用すると、これまで説明してきた制御力の最適化機能の実現が自動車でも可能になる。図に示すように、自動車３５０に搭載されたナビゲーション装置３５１があり、その表示部分の拡大図を３５４とする。現在位置３５７と目的地３５８を入力し、経路誘導された結果が、実線で示す３５５であったとする。

【０１０４】

この経路誘導結果と、ナビゲーション装置３５１に接続されたセンサ類１３によって計測された過去の走行結果の揺れや振動の計測結果を保持している車上ＤＢ３６０の情報、或いは、ナビゲーションサービスセンタ等から入手した情報から、路面がいたみ振動が大きくなる道路区間３５６が見つかったとすると、該道路区間３５６に進入する前に、予めショックアブソーバ３５２や３５３の制御力を適切に調整し、揺れや振動を押さえるように制御する。

【０１０５】

車上ＤＢ管理装置３５９は、車上ＤＢ３６０の記録データの更新、例えば、図９に準じて、同じ道路通った時のデータを幾つか集め統計処理して、車上ＤＢ３６０の情報の更新を行う。これらの制御は、ナビゲーション装置３５１の持つ入出力インターフェイスを通して、自動で実施するのか、或いはしないのかなどは、運転者の好みで随時設定できるようにしておくことで、運転者の思考に合わせることもできる。

【０１０６】

さらに、本発明を自動車に応用する場合には、例えば乗り合いの路線バスに適用することにより、鉄道車両の場合とほぼ同等の機能を発揮させることができる。すなわち、このような乗り合い路線バスにおいては、走行する路線が予め設定され、常にその路線に沿って運行されるので、鉄道車両における線路に類似した管理や処理、制御が可能となるものである。

【０１０７】

また乗用車においても、図１０に示すように地上ＤＢを設置して、複数の自動車からの情報を集約することによって、より広範な機能を実現することが可能になる。すなわち、この地上ＤＢには、多数の自動車からの情報を集約することにより、自動車が走行する道路の情報を網羅的に収集することができ、これによって鉄道車両における線路に類似した管理や処理、制御が可能となる。なお、このような地上ＤＢは、タクシー会社等に設けて運用することや、ユーザーが組織を結成して運用することができるものである。

【０１０８】

以上説明したように、本発明により列車走行等の際に、過去のデータを参照するとともに今後の計画走行路線を見て、予め制御力特性を最適化できる場合は、揺れや振動を抑制

するように走行位置に合わせて前もって制御力を最適化し、動的に変動する要因に対しては各種センサ情報から情報を入手し、動的に最適化できるようになる。そして、装置の故障かもしれないなどの警報情報も出力でき、乗り心地を常に最適に保つように制御できると共に、メンテナンス作業の効率化もできるようになる。

【０１０９】

なお本発明は、上述の説明した実施形態に限定されるものではなく、特許請求の範囲の記載を逸脱しない限りにおいて、種々の変形が可能とされるものである。

【図面の簡単な説明】

【０１１０】

【図１】本発明の基本構成を示す構成図である。

【図２】車両に搭載するセンサ類の構成を示す構成図である。

【図３】適応車両走行制御システムのメイン制御フローチャート図である。

【図４】走行車両の揺れや振動の要因分析処理フローチャート図である。

【図５】走行車両の揺れや振動の要因分析処理の説明に用いる表１図である。

【図６】路線をイメージしての揺れや振動の抑制制御の実施例を示す構成図である。

【図７】車両編成の構成例を示す構成図である。

【図８】加減速制御時のショックを低減する制御例を示す構成図である。

【図９】ＤＢの更新制御の模式図である。

【図１０】地上ＤＢ主体の車両制御システムの構成例を示す構成図である。

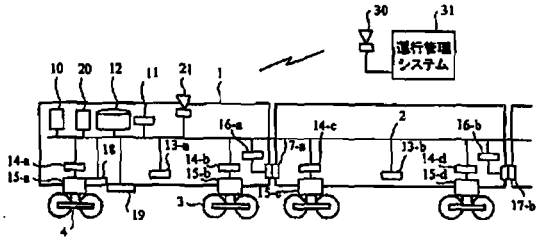
【図１１】自動車を対象にしたシステム構成例を示す構成図である。

【符号の説明】

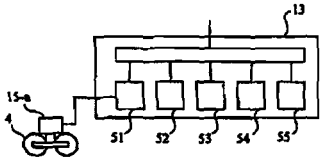
【０１１１】

１…鉄道車両、２…車上ＬＡＮ、３…車輪、４…台車、１０…列車走行制御装置、１１…位置検知装置、１２…車上ＤＢ、１３…センサ類、１４…バネ力調整制御装置、１５…台車と車両間振動緩衝装置、１６…車両間ダンパ力制御装置、１７…車両間ダンパ装置、１８…ブレーキ制御装置、１９…モータ制御装置、２０…入出力装置、２１…地上車上間通信装置、５１…重量センサ、５２…振動センサ、５３…加速度センサ、５４…ジャイロ、５５…ヨーレイトセンサ、２７０～２７３…走行データ、２７４…統計処理、２７５…制御力設定情報２７５，３０１…地上側ＤＢ、３０２…地上側列車走行制御ＤＢ管理装置

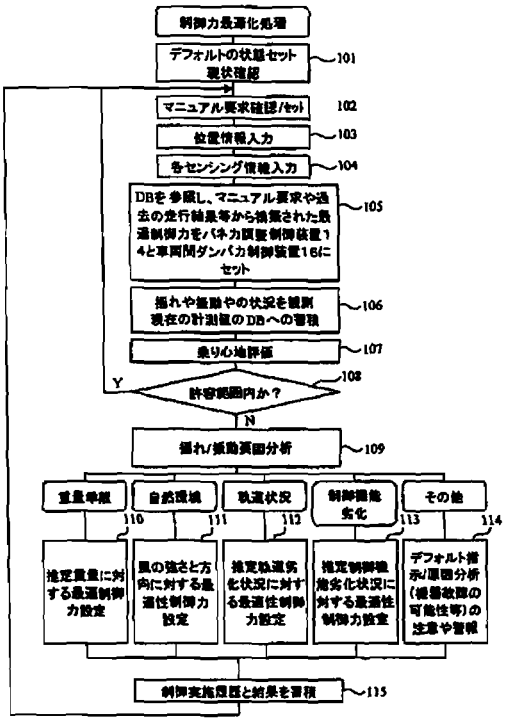
【図１】



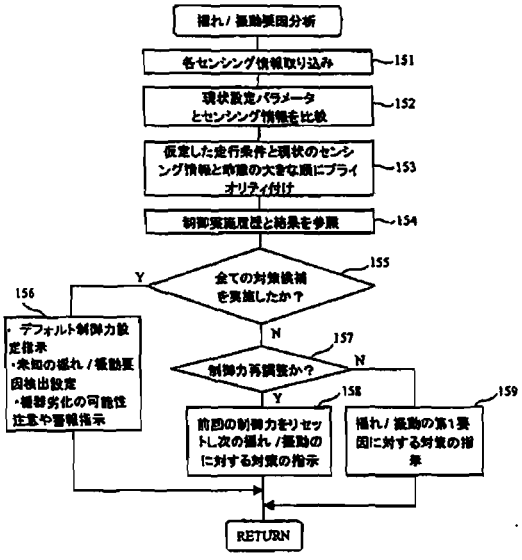
【図２】



【図３】



【図４】

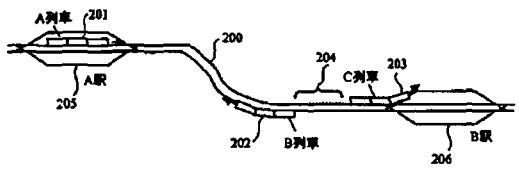


【図５】

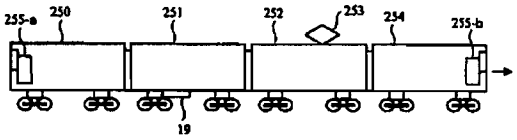
表1

列番X、編成Y	n	n+1	n+2	.....
日時	2002.1.16 17:23:40	2002.1.16 17:23:45	2002.1.16 17:23:50	.....
位置	A編、上り 起点からLa km	A編、上り 起点からLa+1 km	A編、上り 起点からLa+2 km	.....
揺れ/振動量 進行方向: 横方向: 垂直:	振幅,周波数,加速度 wPn,fPn,aPn wRn,fRn,aRn wVn,fVn,aVn	wPn+1,fPn+1,aPn+1 wRn+1,fRn+1,aRn+1 wVn+1,fVn+1,aVn+1	wPn+2,fPn+2,aPn+2 wRn+2,fRn+2,aRn+2 wVn+2,fVn+2,aVn+2	.....
ヨーレート	Yn	Yn+1	Yn+2	.....
振動対策力 全車バネ: 車体制ダン:	SSn DDn	SSn+1 DDn+1	SSn+2 DDn+2	.....
列車速度	Vn	Vn+1	Vn+2	.....
推定重量	Wn	Wn+1	Wn+2	.....
集合状態 風力/方向: 雨/雪量:	風力/風向 雨量/積雪量 Fn/Rn LRn/sLSn	Fn+1/Rn+1 LRn+1/sLSn+1	Fn+2/Rn+2 LRn+2/sLSn+2	.....

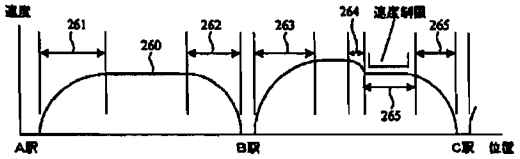
【図６】



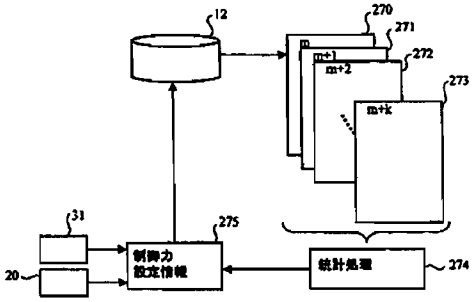
【図７】



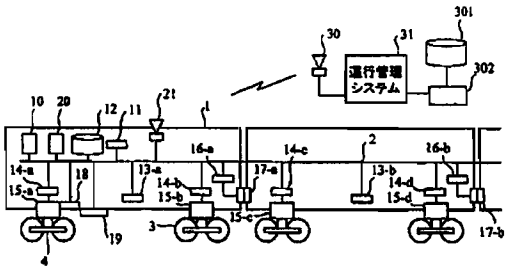
【図８】



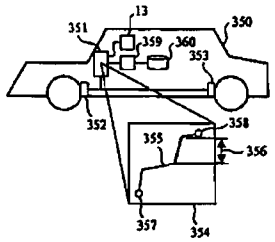
【図９】



【図１０】



【図１１】



フロントページの続き

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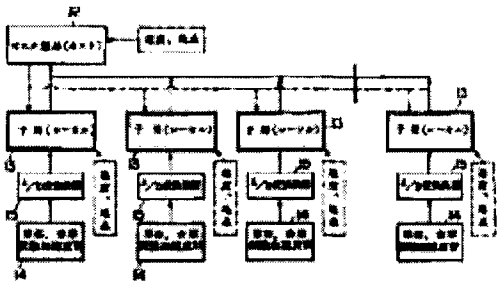
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ISHIKAWA RYUTARO

(54) METHOD FOR MEASURING RIDING COMFORT AND VIBRATION OF RAILWAY VEHICLE

(57)Abstract:

PURPOSE: To provide a method by which the riding comfort of all vehicles constituting a train can be evaluated and the vibration of each vehicle can be displayed and recorded in real time.

CONSTITUTION: A vehicle vibration measuring and processing slave station 13 which inputs the leftward and rightward vibrational acceleration signals and upward and downward vibrational acceleration signals detected by means of vibrational accelerometers 14 to a processor and evaluates the riding comfort levels and vibrations of the vehicles constituting a train is provided at every vehicle or at every several vehicles. A master station 12 which controls all slave stations 13 and receives data-processed indexes converted into the riding comfort levels and vibrations of all vehicles is provided in one vehicle in the train and the riding comfort and vehicle vibrations of the train are evaluated, displayed, and recorded in real time.



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特開平8－15099

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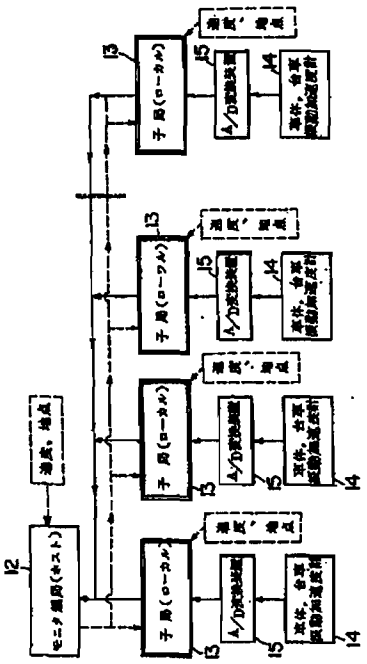
(74)代理人　弁理士　押田　良久

(54)【発明の名称】　鉄道車両の乗り心地と車両振動の測定方法

(57)【要約】

【目的】　編成列車の全車両の乗り心地の評価と車両振動をリアルタイムに表示、記録できる測定方法を提供する。

【構成】　車体または台車に設けた振動加速度計により検知した左右振動加速度信号及び上下振動加速度信号を処理装置に入力し、演算処理して乗り心地レベル及び車両振動として評価する車両振動測定処理子局を編成列車の１車両または数車両ごとに設け、前記子局のすべてを統括し、編成全車両の乗り心地レベル及び車両振動に変換されたデータ処理済みの指標を受信する親局を編成中の１車両に設け、編成列車の全車両の乗り心地と車両振動をリアルタイムに評価し表示及び記録する。



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【特許請求の範囲】

【請求項１】　車体または台車に設けた振動加速度計により検知した左右振動加速度信号及び上下振動加速度信号を処理装置に入力し、演算処理して乗り心地レベル及び車両振動として評価する車両振動測定処理子局を編成列車の１車両または数車両ごとに設け、前記子局のすべてを統括し、編成全車両の乗り心地レベル及び車両振動に変換されたデータ処理済みの指標を受信する親局を編成中の１車両に設け、編成列車の全車両の乗り心地と車両振動をリアルタイムに評価し表示及び記録し得ることを特徴とする鉄道車両の乗り心地と車両振動の測定方法。

【請求項２】　親局と子局との間は、親局が順番に子局を呼び出すシリアル通信によることを特徴とする請求項１記載の鉄道車両の乗り心地と車両振動の測定方法。

【請求項３】　一車両に設けた複数個の各種振動加速度計により車体の全モード別の振動加速度を算出し、車体挙動のデータとして記録することを特徴とする請求項１記載の鉄道車両の乗り心地と車両振動の測定方法。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】この発明は、編成列車の全車両の乗り心地の評価と車両振動をリアルタイムに表示、記録できる測定方法に関する。

【０００２】

【従来の技術】従来、鉄道車両の乗り心地を評価する方法として、例えば該車両の振動加速度を求め、測定した振動と人体の等間隔曲線との比較によるものがある。乗り心地を評価するには、車両の動揺状態を時間的変化を含めて総括的に把握する必要があるが、前記従来方法ではこれらの点が考慮されていなかった。

【０００３】そこで、前記問題点を排除するため、動揺発生頻度測定評価方法において、振動測定手段によって振動測定を行ない、振動測定の測定信号に含まれる周期信号の周期及びその波高値を測定し、周期及びその波高値の一定測定軌間内における発生頻度を求め、振動信号に含まれる周期及びその波高値の発生頻度の分布によって動揺状態の評価を行なう方法（特公平５－６５４号公報）、車両の床面や窓枠上等に置けるポケット型簡易装置により、上下、左右の一定区間の振動ピーク値や限度を超えた回数を係数することにより、乗り心地の状態を簡便に知ることができる車両動揺測定装置（特公平２－７００９号公報）が提案されている。

【０００４】しかし、前記特公平５－６５４号公報及び特公平２－７００９号公報に開示された動揺発生頻度測定評価方法及び動揺測定装置は、車両の乗り心地を該車両の振動頻度から評価するものではあるが、リアルタイムの処理、表示を行なうものではない。また、これらの装置は１車両を対象としたもので、編成列車の全車両を一体に乗り心地や車両振動をリアルタイムに測定するものでもない。

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【０００５】

【発明が解決しようとする課題】前記のごとく、従来の動揺発生頻度測定評価方法や動揺測定装置は、全て１車両を対象とした乗り心地や振動の測定装置であり、例えば編成列車の先頭車両と後尾車両とでは後尾車両の乗り心地が悪いといわれているが、編成列車の全車両の乗り心地を比較する場合のように、編成列車の全車両の乗り心地や車両振動を測定するには、各車両のすべてに設けた測定装置により個々に得られた結果を一つにまとめて処理するため煩雑な作業が必要であり、系統立てて簡単に比較ができなかった。

【０００６】この発明は、前記の現状に鑑み、編成列車の全車両にわたって一体的に乗り心地や振動の測定が行なえる鉄道車両の乗り心地と車両振動の測定方法を提供するものである。

【０００７】

【課題を解決するための手段】前記目的を達成するため、この発明の鉄道車両の乗り心地と車両振動の測定方法は、車体または台車に設けた振動加速度計により検知した左右振動加速度信号及び上下振動加速度信号を処理装置に入力し、演算処理して乗り心地レベル及び車両振動として評価する車両振動測定処理子局を編成列車の１車両または数車両ごとに設け、前記子局のすべてを統括し、編成全車両の乗り心地レベル及び車両振動に変換されたデータ処理済みの指標を受信する親局を編成中の１車両に設け、編成列車の全車両の乗り心地と車両振動をリアルタイムに評価し表示及び記録する。

【０００８】また、前記鉄道車両の乗り心地と車両振動の測定方法において、親局と子局との間は、親局が順番に子局を呼び出すシリアル通信によることを特徴とする。

【０００９】更に、一車両ごとに設けた複数個の各種振動加速度計により車体の全モード別の振動加速度を算出し、車体挙動のデータとして記録することを特徴とする。

【００１０】

【作用】編成列車の全体の乗り心地と振動測定には、各車両の乗り心地と車両振動を車体または台車に設けた振動加速度計により検知した左右振動加速度信号及び上下振動加速度により処理する子局と、各子局が処理した値を表示、記録する親局から構成され、親局と各子局の間は通信で結合することにより、編成列車全体の乗り心地や車両振動を親局でリアルタイムに表示、記録することができる。

【００１１】各子局は、車体に設置した振動加速度計からの検知信号を、次のような処理を行なうことにより車両の乗り心地レベル（ｄＢ）で出力することができる。

【００１２】車体の各振動加速度は、図７の等間隔曲線の逆数の特性を持ったフィルタを用いて重み付けを行な

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いａw（ｔ）とする。そして、得られた乗り心地レベルＬは、下記表１に示す区分により評価する。

【００１３】

【数１】

$$L=10\log\left\{\frac{1}{T}\int_0^T\frac{a^2_w(t)}{a^2_{ref}}dt\right\}\qquad 1式$$

【００１４】ただし、　Ｌ　：　乗り心地レベル（ｄＢ）

ａｒｅｆ　：　基準加速度（いき値）　10^{-5}（ｍ／ｓ^2）

ａw（ｔ）　：　重みづけ後の振動加速度　（ｍ／ｓ^2）

Ｔ　：　平均時間

【００１５】

【表１】

区分	乗り心地レベル	評価
①	83dB未満	良↑↓悪
②	83dB以上　88dB未満	
③	88dB以上　93dB未満	
④	93dB以上　98dB未満	
⑤	98dB以上	

【００１６】前記１式では、平均時間Ｔを設定する必要があるため、例えばＴ＝２ｓｅｃもしくは５ｓｅｃとすることで、過去２秒間もしくは過去５秒間の値を求めることができる。これを図８に示すように、振動加速度信号を処理装置に入力し、該処理装置内においてＡ／Ｄ変換装置によりディジタル化した後、前記１式により演算処理して乗り心地レベルＬを求め、出力、記録するが、この際のＡ／Ｄ変換時のサンプリングタイムをΔｔ、例えばΔｔ＝１０ｍｓｅｃとし、Δｔごとに行なうことによりリアルタイムの評価ができる。また、例えば、図９に示すように、その時点で得られた値と過去Ｔ秒間のＴ／Δｔ個のデータとの平均を取って出力、記録してもよい。

【００１７】また、車両振動の測定には、車両振動で一番重要な振幅のピーク値の測定を行なうよう子局において振動加速度計より得られる値から計算、処理する。この振幅のピーク値により各車両の振動の比較ができる。

【００１８】例えば、振動加速度計より得られる値に各周波数ごとのフィルタをかけることで各周波数帯域の振動ピーク値が得られる。図１０（ａ）は得られる振動加速度波形（生波形）に、ローパスフィルタをかけた後の波形を図１０（ｂ）に示す。該図中のＡ（ｎ）は振幅のピーク値で、１／２Ｂ（ｎ）がそのときの振動数となるが、このフィルタ処理を多種類バンドパスフィルタ等、行なうことにより、低周波から高周波にわたって車体の

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各周波数ごとの振幅のピーク値が得られる。

【００１９】前記の乗り心地、車両振動の計算、処理を各車両の各子局で個々に行ない、得られた結果のみを時々刻々親局に送信する。親局は、各子局から送られてくるデータ（結果）を処理するだけで、全車両にわたっての乗り心地や車両振動を測定できることになる。また、一車両ごとに設けた複数個の各種振動加速度計により車体の全モード別の振動加速度を算出し、車体挙動のデータとして記録することができる。

【００２０】前記のように、編成列車の各車両の車両振動を処理する役割の子局と編成列車の全車両の処理後のデータを受信して表示、記録及び測定する親局に分けることにより、各局の演算負担を軽減すると共に、編成列車の全車両にわたっての乗り心地と振動測定を同時にリアルタイムで処理することができる。

【００２１】

【実施例】この発明の実施例を図面に基づいて説明する。図１に示すように、車体前後振動加速度計ａと、車体左右振動加速度計ｂ、ｃと、車体上下振動加速度計ｄ、ｅ、ｆ、ｇの７個の振動加速度計を、車両の全自由度（６自由度）の振動モードを計算できるように車体１０の床面に設置する。更に、前後の台車１１に左右振動加速度計及び上下振動加速度計ｈ、ｉ、ｊ、ｋを設ける台車振動を測定できるようにしてよい。そして、下記の計算により車体の振動モードを抽出する。

【００２２】車体前後モード　＝　ａ

車体左右モード　＝　（ｂ＋ｃ）／２

車体ヨーモード　＝　（ｂ－ｃ）／２

車体上下モード　＝　（ｄ＋ｅ＋ｆ＋ｇ）／４

車体ロールモード　＝　（ｄ－ｅ＋ｆ－ｇ）／４

車体ピッチモード　＝　（ｄ＋ｅ－ｆ－ｇ）／４

【００２３】また、乗り心地の計算では、左右については、車体左右振動加速度計ｂ、ｃを用い、上下については、車体上下振動加速度計ｄまたはｅ、もしくは（ｄ＋ｅ）／２と、ｆまたはｇ、もしくは（ｆ＋ｇ）／２を用いる、前後についてはａを用いる。これにより一両の前位側と後位側の上下、左右の乗り心地と前後の乗り心地を得ることができる。また、前記のごとく車体の６自由度を計算しないのであれば、図２に示すように車体１０の床面の台車中心上に車体左右振動加速度計ｂ、ｃと、その位置に車体前後振動加速度計ａと車体上下振動加速度計ｄ、ｆを設置したものでもよい。これにより、一両の前位側と後位側の上下、左右、前後の乗り心地を得ることができる。

【００２４】前記図１に示す振動加速度計の配置を、図３に示すように９両編成の列車の全車両の１両目～９両目に設置し、各振動加速度計からの検知信号を処理する子局１３を各車両に設ける。なお、１両目車両用の子局１３は２両目車両に搭載した。そして、各車両の各子局１３で処理された処理後のデータを受信して表示、記録

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及び測定する親局１２を２両目車両に搭載した。子局１３と親局１２の間はシリアル通信線により接続した。なお、子局１３は例えば前後車両の２車両ごとに１子局を設けるなど数車両ごとに設けてもよい。

【００２５】前記編成列車における乗り心地と車両振動の測定装置の機器構成を図４に示す。各車両（１両目～９両目）は、それぞれ各振動加速度計１４で検知した検知信号はＡ／Ｄ変換装置１５に通してディジタル化して各子局１３に入力する。各子局１３では後記の処理を行ない得られたデータ（結果）を親局１２に送信する。そして、親局１２はそのデータ（結果）をモニタ表示し記録する。また、測定が行なわれる。この際、測定点を明らかにするため、車両速度や地点情報入力ができるように構成される。なお、各子局１３においても同様に車両速度や地点情報入力ができるようにする。また、ディジタル化されたＡ／Ｄ変検後の各振動加速度計の信号も子局に記録される。

【００２６】前記実施例装置における乗り心地の計算は、前述した方法により行なわれ、乗り心地レベル（ｄＢ）として出力される。この結果はデータとして親局１２に送信すると同時に子局１３でも記録しておき、後のデータ処理に役立てる。この際の処理の流れを図５のブロック図に示す。各振動加速度計で検知した検知信号はＡ／Ｄ変換装置に通してディジタル化し図７の等間隔曲線の逆数の特性を持ったフィルタを用いて重み付けした後、前記１式により計算する。この方法により、サンプリングタイムΔｔごとに過去２秒間または過去５秒間の乗り心地が左右、上下及び前後について得られる。

【００２７】車体振動については、生データを親局に送信するのではなく、車体振動の最大値が問題となることが多いので、前記の方法により各振動モードごとに図６に示すような周波数帯域にフィルタにより分け、過去２秒間のその周波数帯域での最大値を子局により演算する。なお、各周波数帯域の分け方は更に細分化してもよい。また、台車振動も前記と同様な方法でフィルタ後の値から最大値を出力演算結果を親局に送信する。更に、車体振動も各モードに分けずに、各振動加速度計の最大値を出力するようにしてもよい。

【００２８】前記のようにして得られた各子局のデータ（結果）を親局は受信する。またこのときの車両速度や地点情報も入力する。この発明の方法によれば、親局では各車両の同時点でのデータが得られるので、後のデータ処理や各車両の乗り心地、車両振動の比較が簡単にできる。

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【００２９】

【発明の効果】この発明によれば、編成列車の各車両の車両振動を処理する役割の子局と編成列車の全車両の処理後のデータを受信して表示、記録及び測定する親局に分けることにより、各局の演算負担を軽減すると共に、編成列車の全車両にわたっての乗り心地と振動測定を同時にリアルタイムで処理することができる。

【図面の簡単な説明】

【図１】この発明の実施例における、車体床面及び台車に配置した各種振動加速度計の説明図である。

【図２】この発明の実施例において、車体床面の進行方向中央の前後に各種振動加速度計を設置した場合の説明図である。

【図３】この発明を実施するための装置を有する編成列車の一例を示す説明図である。

【図４】この発明の実施例における振動加速度の処理の流れを示すブロック図である。

【図５】この発明の実施により乗り心地をリアルタイムに評価するためのΔｔ時間ごとに行なう処理の流れを示すブロック図である。

【図６】この発明の実施により各振動モードごとの周波数帯域での最大値をリアルタイムに評価するためのΔｔ時間ごとに行なう処理の流れを示すブロック図である。

【図７】等間隔曲線を示すグラフである。

【図８】この発明の実施により乗り心地をリアルタイムに評価するためのΔｔ時間ごとに行なう処理の流れを示すブロック図である。

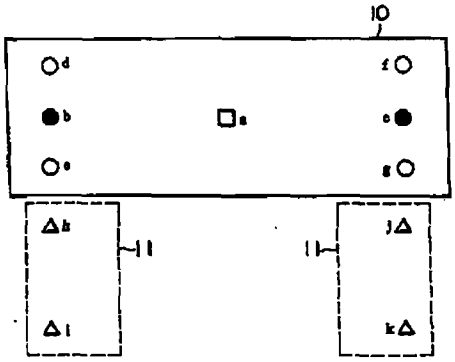
【図９】その時点で得られた値と過去Ｔ秒間のＴ／Δｔ個のデータとの平均の関係を示す説明図である。

【図１０】図１０（ａ）は車体または台車の上下または左右の振動加速度波形を示すグラフ、図１０（ｂ）はローパスフィルタを通した後の振動加速度波形を示すグラフである。

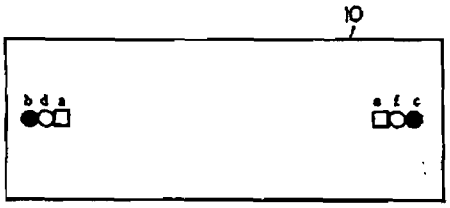
【符号の説明】

１～９　車両ＮＯ.
１０　車両
１２　親局
１３　子局
１４　振動加速度計
１５　Ａ／Ｄ変換装置
ａ　車体前後振動加速度計
ｂ、ｃ　車体左右振動加速度計
ｄ、ｅ、ｆ、ｇ　車体上下振動加速度計
ｈ、ｉ、ｊ、ｋ　台車左右、上下振動加速度計

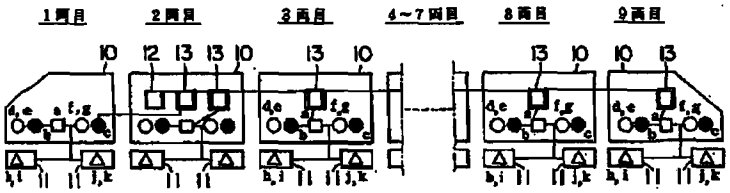
【図１】



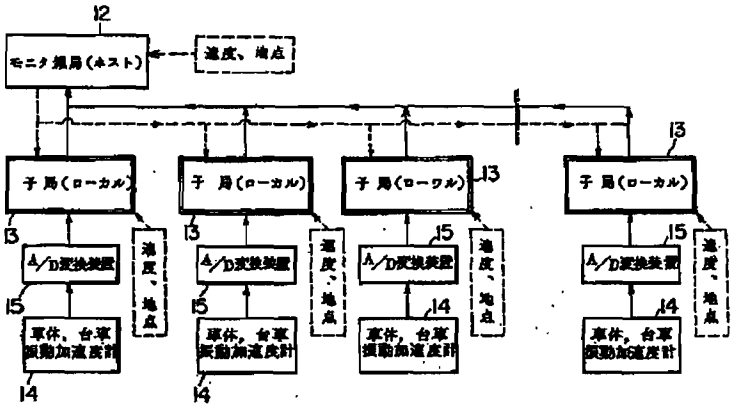
【図２】



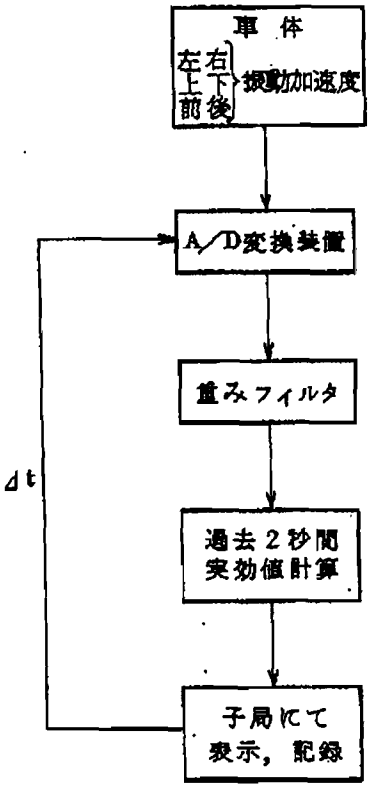
【図３】



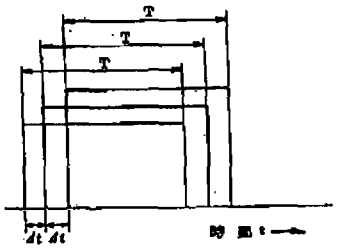
【図４】



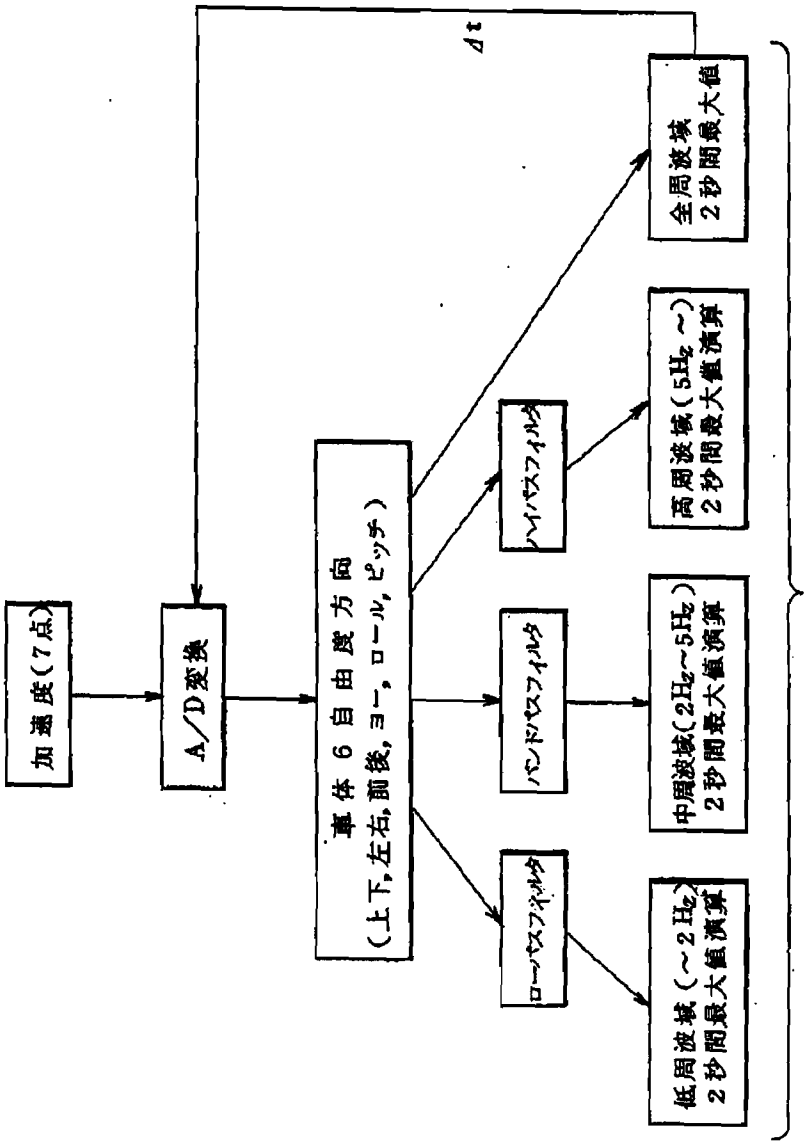
【図５】



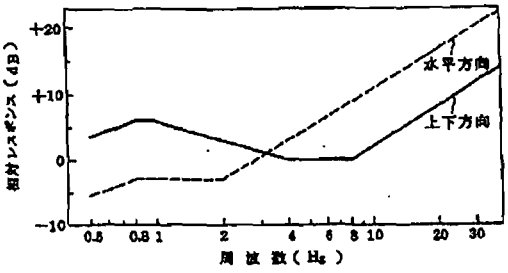
【図９】



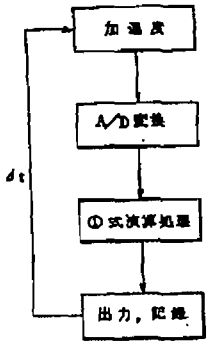
【図6】


加速度(7点)
A/D変換
車体6自由度方向
(上下,左右,前後,ヨー,ロール,ピッチ)
Δt
ローパスフィルタ
バンドパスフィルタ
ハイパスフィルタ
低周波域(～2Hz)
2秒間最大値演算
中周波域(2Hz～5Hz)
2秒間最大値演算
高周波域(5Hz～)
2秒間最大値演算
全周波域
2秒間最大値

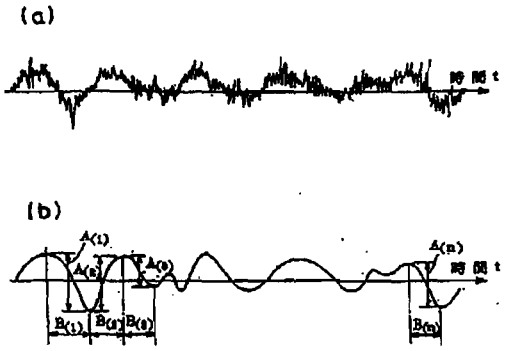
【図7】


+20
+10
0
−10
0.5
0.8 1
2
4
6
8 10
20
30
水平方向
上下方向
周 波 数（Hz）

【図8】


加 速 度
A/D変換
Δt
① 式演算処理
出力，記録

【図10】


(a)
時 間 t
(b)
A(1)
A(2)
A(3)
A(n)
時 間 t
B(1)
B(2)
B(3)
B(n)

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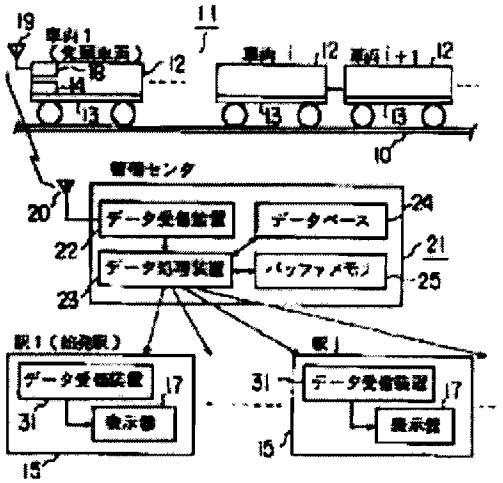
(72)Inventor : UNE YASUSHI

(54) TRAIN CONGESTION DEGREE INDICATION METHOD AND ITS INDICATION SYSTEM

(57)Abstract:

PROBLEM TO BE SOLVED: To provide more accurate information on the degree of congestion for each rolling stone of a train arriving at for passengers waiting for the net train on the platform of a station.

SOLUTION: The weight of passenger per rolling stone is continuously measured for the measuring period of time T from time when a train 11 arrives at each station 15 until time when the train leaves the station, the number of passengers except those having left the train Naij corresponding to the minimum weight which is continuously measured during the measuring period of time per rolling stock, and the number of passengers all aboard Nbij corresponding to the weight at the time when measuring has been over, are obtained first. The estimated number of passengers leaving the train Bij+1 at the nest station, which can be obtained based on the actual number of passengers leaving a train in the past, is subtracted from the number of passengers all aboard obtained as mentioned above for the present station, the number of remaining passengers Cij+1 per rolling stock at the next station is thereby computed, the number of remaining passengers per rolling socke is made a congestion condition Dij+1 per rolling stock, and it is outputted so as to be indicated for an indication device 17 at the next station.



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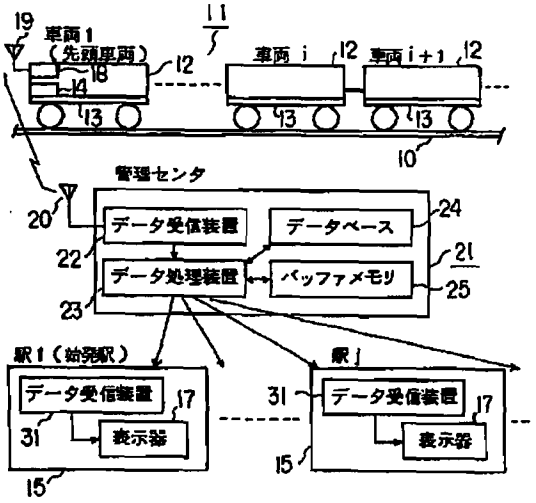
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(54)【発明の名称】　列車混雑度表示方法及びその表示システム

(57)【要約】
【課題】　駅１５のホーム１６で次の列車１１を待っている乗客に対して到着列車の各車両１２のより正確な混雑状況の情報を提供する。
【解決手段】　列車１１が各駅１５に到着してから該当駅を出発するまでの計測期間Ｔにおける各車両毎の乗客重量を連続測定し、この連続測定された各車両の計測期間における最小重量に対応する降車後乗客数N_{aij}と計測期終了時の重量に対応する乗車後乗客数N_{bij}とを求め、この求められた現在駅の乗車後乗客数から、過去の実績降車客数にて得られる次駅の予測降車客数B_{ij+1}を減算して、次駅における各車両の残留乗客数C_{ij+1}を算出し、この算出された各車両の残留乗客数を各車両の混雑状況D_{ij+1}として次駅の表示装置１７に表示出力する。



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【特許請求の範囲】

【請求項１】　列車が各駅に到着してから該当駅を出発するまでの計測期間における各車両毎の乗客重量を連続測定し、

この連続測定された各車両の計測期間における最小重量に対応する降車後乗客数と計測期終了時の重量に対応する乗車後乗客数とを求め、

この求められた現在駅の乗車後乗客数から、過去の実績降車客数にて得られる次駅の予測降車客数を減算して、次駅における各車両の残留乗客数を算出し、

この算出された各車両の残留乗客数を各車両の混雑状況として次駅の表示装置に表示出力することを特徴とする列車混雑度表示方法。

【請求項２】　列車が各駅に到着してから該当駅を出発するまでの計測期間における各車両毎の乗客重量を連続測定する乗客重量測定装置と、

この乗客重量測定装置にて連続測定された各車両の計測期間における最小重量に対応する降車後乗客数と計測期終了時の重量に対応する乗車後乗客数とを求める乗客数抽出手段と、

列車が任意駅の一つ前の駅に到着した時に前記乗客数抽出手段で得られる前駅の乗車後乗客数から任意駅に到着した時に前記乗客数抽出手段で得られる任意駅の降車後乗客人数を減算して任意駅における各車両の実績降車客数を算出する実績降車客数算出手段と、

各駅毎に算出される各車両の実績降車客数を記憶する実績降車客数メモリと、

前記乗客数抽出手段で求められた現在駅の乗車後乗客数から、前記実績降車客数メモリに記憶された次駅の実績降車客数から得られる次駅の予測降車客数を減算して、次駅における各車両の残留乗客数を算出する残留乗客数算出手段と、

この算出された各車両の残留乗客数を各車両の混雑状況として次駅の表示装置に表示出力する表示制御手段とを備えた列車混雑度表示システム。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、鉄道機関において、各駅のホームで列車を待つ乗客に対して次に到着する列車の混雑状況を表示装置に表示する列車混雑度表示方法及びこの方法を採用した列車混雑度表示システムに関する。

【０００２】

【従来の技術】都市近郊の通勤列車等においては、例えば、列車がホームに停車した場合におけるホームの出口近傍や入口近傍に停車する車両には多くの乗客が乗車して乗車率が高くなり、ホームの中間に位置する車両は少ない乗客しか乗車しない。

【０００３】その結果、列車の一部の車両の混雑度のみが高くなり、鉄道会社にとって、乗客の輸送効率が低下

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するのみならず、乗客にとっても不快な通勤を強いられることになる。

【０００４】このような不都合を解消するために、次に到着する列車における各車両の混雑度（乗車率）を測定して例えばホームや改札口の上方位置に取付けられた電光表示器に各車両毎の混雑度（乗車率）を表示して、乗客に混んだ車両を避けて空いた車両に乗車するように注意を促す案が提唱されている（特開平２－１３３２７８号公報）。

【０００５】すなわち、図８（ａ）に示すように、複数の車両２からなる列車１が駅のホームに停車する場合、ホームにおける各車両２の停止位置は予め定められているので、レール３における各車両２の停止位置に荷重検出器４を取付け、この各荷検出器４で得られた車両の重量を測定する。そして、演算制御器５で各車両２の乗車客数を算出して、さらに、この乗車客数を車両の定員で除算して各車両毎の乗車率（混雑度）を算出する。そして、算出された各車両毎の乗車率（混雑度）を次駅へ送信する。

【０００６】次駅では、一つ前の駅から受信した次にホームに到着する列車の各車両の乗車率（混雑度）を図８（ｂ）に示すように、ホームや改札口の上方位置の電光表示器７に表示する。

【０００７】したがって、ホームの乗客又は改札口からホームに入る乗客は次にホームに到着する列車においてどの車両が混んでいるかを即座に判断でき、空いた車両が停車する位置へ移動することが可能である。

【０００８】

【発明が解決しようとする課題】しかしながら図８に示す列車の各車両の混雑度の表示手法においても、まだ改良すべき次のような課題があった。すなわち、乗換え駅や大きな駅においては、列車の降車客が多くて、この駅を通過する列車においては、この駅を発車する時点で各車両の乗客が大幅に減少して、ホームで該当列車に乗車する客に対して、乗車車両の変更を促す図８（ｂ）に示す各車両毎の乗車率（混雑度）を表示することが無意味になる場合もある。一方、客にとっては、特にホームを移動する必要がないのに、移動を結果的に強制されることになり、乗客に対するサービスが逆効果となる懸念がある。

【０００９】その結果、一つの列車における各車両相互間の乗車率の偏在がさらに拡大して、乗客の降り乗りに要する時間が増加し、鉄道運送業務全体の輸送効率が低下する懸念がある。

【００１０】また、例えば乗換え駅における他の線路に対する乗換え通路がホームのある特定位置に存在する場合は、この乗換え通路近傍に停止する車両の乗車率（混雑度）が極端に高いが、該当駅でこの車両のほとんどの乗客が降車して、この駅を発車する時点においては、該当車両の乗車率（混雑度）が極端に低下する場合もあ

る。

【0011】このような場合においては、ホームの乗客はこの空いた車両に乗車することが好ましい。しかし、表示案内には該当車両の乗車率（混雑度）が極端に高いと表示される。したかって、結果的にホームの乗客を誤った位置へ導く懸念がある。

【0012】本発明はこのような事情に鑑みてなされたものであり、各車両の乗客重量を連続測定することによって、次駅における各車両から乗客が降りた後の残留乗客数を予測でき、この残留乗客数を混雑状況として表示でき、駅のホームにいる列車待ちの客に対してより有用な情報を提供でき、かつ1列車内における各車両相互間の乗車率を均一化でき、全体としての輸送効率を向上できる列車混雑度表示方法及び列車混雑度表示システムを提供することを目的とする。

【0013】

【課題を解決するための手段】上記課題を解消するために本発明の列車混雑度表示方法においては、列車が各駅に到着してから該当駅を出発するまでの計測期間における各車両毎の乗客重量を連続測定し、この連続測定された各車両の計測期間における最小重量に対応する降車後乗客数と計測期終了時の重量に対応する乗車後乗客数とを求め、この求められた現在駅の乗車後乗客数から、過去の実績降車客数にて得られる次駅の予測降車客数を減算して、次駅における各車両の残留乗客数を算出し、この算出された各車両の残留乗客数を各車両の混雑状況として次駅の表示装置に表示出力するようにしている。

【0014】また、本発明の列車混雑度表示システムにおいては、列車が各駅に到着してから該当駅を出発するまでの計測期間における各車両毎の乗客重量を連続測定する乗客重量測定装置と、乗客重量測定装置にて連続測定された各車両の計測期間における最小重量に対応する降車後乗客数と計測期終了時の重量に対応する乗車後乗客数とを求める乗客数抽出手段と、列車が任意駅の一つ前の駅に到着した時に乗客数抽出手段で得られる前駅の乗車後乗客数から任意駅に到着した時に乗客数抽出手段で得られる任意駅の降車後乗客人数を減算して任意駅における各車両の実績降車客数を算出する実績降車客数算出手段と、各駅毎に算出される各車両の実績降車客数を記憶する実績降車客数メモリと、乗客数抽出手段で求められた現在駅の乗車後乗客数から、実績降車客数メモリに記憶された次駅の実績降車客数から得られる次駅の予測降車客数を減算して、次駅における各車両の残留乗客数を算出する残留乗客数算出手段と、この算出された各車両の残留乗客数を各車両の混雑状況として次駅の表示装置に表示出力する表示制御手段とを備えている。

【0015】このように構成された列車混雑度表示方法及びその表示システムの各駅における到着列車の混雑度の算出原理を説明する。列車が一つの駅に到着して車両の扉が開くと当駅で下車する乗客が車両から降りるので、該当車両の乗客重量は一旦低下する。そして、当駅で下車する乗客が全て降車すると、次に当駅から乗車する客が該当車両に乗車するので、乗客重量は上昇する。そして、扉が閉じて列車が当駅を発車する時点においては、乗客重量は一定になる。

【0016】列車が駅に到着してから該当駅を出発するまでの計測期間における最小重量から降車後乗客数を求め、計測期終了時の重量から乗車後乗客数を求めることができる。よって、一つ前の駅の乗車後乗客数から当駅の降車後乗客数を減算することによって、当駅の各車両の降車乗客数を算出できる。このように、各駅における各車両の降車乗客数を過去の実績データとして蓄積することが可能である。

【0017】そして、現在駅で得られた各車両における乗車後乗客数から次駅の予測降車客数を減算して、次駅における各車両の残留乗客数が予測できる。この残留乗客数が次駅において、乗客が各車両から降りた時点における実際の混雑度となる。

【0018】したがって、たとえ現在駅で特定車両の乗車率（混雑度）が高かったとしても、次の駅で該当車両からの降車乗客数が多いと過去の実績に基づいて予想される場合は、次駅において該当車両の混雑度は低いと表示される。逆に、予測降車乗客数が少ない場合は、表示される混雑度は高いまま維持される。このように、ホームで列車を待つ乗客にとって、自己がこれから乗車しようとする車両の正しい乗車率（混雑度）を確認できる。

【0019】

【発明の実施の形態】以下本発明の一実施形態を図面を用いて説明する。図1は実施形態の列車混雑度表示方法が採用された列車混雑度表示システムの概略構成を示す模式図である。

【0020】鉄道線路のレール10上を走行する列車11は例えば10両を越える複数の車両12で編成されている。なお、各車両12には先頭から順番に車両番号i（i＝1，2，3，4，…）が付されている。そして、各車両12の床下には、該当車両12の重量を計測する重量計13が設置されている。乗客が全く乗っていない状態の車両重量は予め測定されており、重量計13は測定重量から車両重量を減算した乗客のみの乗客重量Wi（i=1,2,3,4.…）を出力する。各車両12の各重量計13から出力される各車両12の乗客重量Wi（i=1,2,3,4.…）は先頭の車両12の送信データ作成部14へ伝送される。

【0021】受信データ作成部14は各重量計13から乗客重量Wiを受領すると、各乗客重量Wiに対して所定のデータ処理を行って、データ処理結果をデータ送信装置18へ送出する。データ送信装置18は受信データ作成部14から受領したデータ処理結果をアンテナ19から電波出力する。

【0022】各列車11から電波出力されたデータ処理

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結果は鉄道線路に沿って敷設されたアンテナ２０を介して例えば鉄道会社の本社に設置された管理センタ２１のデータ受信装置２２で受信される。データ受信装置２２は各列車１１から受信したデータ処理結果をデータ処理装置２３へ送出する。データ処理装置２３はデータ処理結果をデータベース２４及びバッファメモリ２５の記憶内容を用いてデータ処理を実施する。

【００２３】一方、鉄道線路に沿って始発駅から終着駅までの複数の駅１５が配設されている。各駅１５には、列車１１の走行方向に沿って始発駅から終着駅慶で順番に駅番号ｊ（ｊ＝１，２，３，４，…）が付されている。そして、図２に示すように、各駅１５のホーム１６の各ホーム入口の上方位置には電光表示板で構成された表示器１７が取付けられている。

【００２４】各表示器１７には、図３で示すように、列車の各進行方向に対応する２種類の列車パターン２６，２７が表示される。各列車パターン２６，２７は先頭車両から末尾車両までの複数の車両パターン２６ａ，２７ｂで構成されている。そして、各車両パターン２６ａ，２６ｂはそれぞれ次にこのホーム１６に到着する列車１１の各車両１２の混雑度に応じた色で表示される。例えば［緑色］は混雑でない通常状態を示し、［黄色］は混雑を示し、［赤色］は大混雑を示す。

【００２５】次に、各部における詳細動作を順番に説明する。図４は、列車１１が駅１５のホーム１６に到着してから該当駅１５を発車するまでの期間（計測期間Ｔ）における各車両１２の乗客重量W_i（i=1,2,3,4.…）の変化を示す図である。列車１１が駅１５のホーム１６に到着して扉が開くと、乗客が降車するので乗客重量W_iは低下し、全ての降車客が降りた時点で、乗客重量W_iは最小値を示す。この最小値を該当駅１５（駅番号ｊ）における該当車両１２（車両番号ｉ）の降車後乗客重量W_{aij}と定義する。また、全ての降車客が降りた後に、該当駅１５のホーム１６で待っていた客がこの車両１２に乗込むと乗客重量W_iが上昇する。そして、全ての客が乗車して、扉が閉じて、列車１１が該当駅１５（駅番号ｊ）を発車した時点における乗客重量W_iを乗車後乗客重量W_{bij}と定義する。

【００２６】したがって、一つ前の駅１５（駅番号ｊ－１）の乗車後乗客重量W_{bij-1}が既知の場合、該当駅１５（駅番号ｊ）で降車した降車乗客重量W_{cij}が演算により求まる。

【００２７】各車両１２の各重量計１３は速度計等から列車１１の停止期間に対応する計測期間Ｔを検出して、この計測期間Ｔにおける乗客重量W_iを連続して計測して、送信データ作成部１４へ送出する。

【００２８】各列車１１の送信データ作成部１４は自己の列車１１の走行位置を常時監視しており、該当列車１１が駅１５のホーム１６に到着すると該当駅１５の駅番号ｊを把握できる。

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【００２９】そして、送信データ作成部１４は図６に示す流れ図に従ってデータ処理を実行する。Ｓ（ステップ）１において、該当列車１１がｊ番目の駅１５のホーム１６に到着すると、各車両１２の各重量計１３から計測期間Ｔにおける連続した乗客重量W_{ij}（i=1,2,3,4,…）を受信する（Ｓ２）。次に、各連続乗客重量W_{ij}から各車両１２における降車後乗客重量W_{aij}（i=1,2,3,4,…）を検出し（Ｓ３）、さらに、乗車後乗客重量W_{bij}（i=1,2,3,4,…）を検出する（Ｓ４）。そして、自己の列車１１を特定する列車番号と検出した降車後乗客重量W_{aij}（i=1,2,3,4,…）と乗車後乗客重量W_{bij}（i=1,2,3,4,…）とをデータ送信装置１８を介して、管理センタ２１へ送信する（Ｓ５）。

【００３０】管理センタ２１のデータ受信装置２２は各列車１１から受信した列車番号と降車後乗客重量W_{aij}と乗車後乗客重量W_{bij}とをデータ処理装置２３へ送付する。

【００３１】デー処理装置２３のデータベース２４には、図５に示すように実績降車客数メモリ２８、実績乗車客数メモリ２９及び列車運行情報メモリ３０が形成されている。

【００３２】実績降車客数メモリ２８内には、各駅１５（駅番号ｊ＝１，２，３，４，…）における各車両１２（車両番号ｉ＝１，２，３，４，…）の過去の実績の降車客数が記憶されている。同様に、実績乗車客数メモリ２９内には、各駅１５における各車両１２の過去の実績の乗車客数が記憶されている。また、列車運行情報メモリ３０内には、各列車番号毎に、該当列車１１の各駅１５における到着ホーム（停車番線）、到着時刻、発車時刻等の列車運行に関する運行ダイヤが記憶されている。

【００３３】バッファメモリ２５内には、各列車１１から受領した現在駅１５（駅番号ｊ）及び一つ前の駅１５（駅番号ｊ－１）における降車後乗客重量W_{aij}，W_{aij-1}と乗車後乗客重量W_{bij}，W_{bij-1}とを記憶保持する。

【００３４】そして、データ処理装置２３は図７の流れ図に従ってデータ処理を実行する。先ず、Ｑ１にて、データ処理部２３は一つの列車１１からｊ番目の駅１５を発車した直後に該当駅１５における列車番号と降車後乗客重量W_{aij}と乗車後乗客重量W_{bij}とを受信すると、データベース２４の列車運行情報メモリ３０を検索して（Ｑ２）、該当列車１１の次駅１５（駅番号ｊ＋１）及び次駅１５における停車番線（停車ホーム）を決定する（Ｑ３）。

【００３５】次に、乗客一人当りの平均重量は例えば６０Ｋｇ等の予め統計的に求まっているので、降車後乗客重量W_{aij}と乗車後乗客重量W_{bij}とからｊ番目の駅１５における降車後乗客数N_{aij}（i=1,2,3,4,…）と乗車後乗客数N_{bij}（i=1,2,3,4,…）を算出する（Ｑ４）。この求めた降車後乗客数N_{aij}と乗車後乗客数N_{bij}と

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をバッファメモリ２５に記憶保持しておく（Ｑ５）。

【００３６】次に、データベース２４の実績降車客数メモリ２８から次駅１５（駅番号ｊ＋１）における各車両１２（車両番号i=1,2,3,4,…）の実績降車客数Ｅij+1を読出して（Ｑ６）、この読出した実績降車客数Ｅij+1を次駅１５（駅番号ｊ＋１）での予測降車客数Ｂij+1（i=1,2,3,4,…）とする（Ｑ７）。そして、この予測降車客数Ｂij+1を用いて次駅１５（駅番号ｊ＋１）における該当列車１１における各車両１２の予測残留乗客数Ｃij+1（i=1,2,3,4,…）を下式を用いて算出する（Ｑ８）。

【００３７】Ｃij+1＝Ｎbij　－Ｂij+1　　i=1,2,3,4,…

次駅１５（駅番号ｊ＋１）における予測残留乗客数Ｃij+1が求まると、この予測残留乗客数Ｃij+1を各車両１２の定員で除算して、次駅１５（駅番号ｊ＋１）における各車両１２（i=1,2,3,4,…）における乗客の乗車前の混雑度（乗車率%）Ｄij+1（i=1,2,3,4,…）を算出する（Ｑ９）。

【００３８】Ｄij+1＝Ｃij+1÷定員×１００　　(%)

算出した各車両１２の乗車前の混雑度Ｄij+1（i=1,2,3,4,…）を次駅１５（駅番号ｊ＋１）へ列車番号と共に送信する（Ｑ１０）。

【００３９】次に、現在駅１５（駅番号ｊ）における各車両１２の実績降車客数Ｅij（i=1,2,3,4,…）をバッファメモリ２５に保存されている一つ前の駅１５（駅番号ｊ－１）における乗車後乗客数Ｎbij-1と現在駅１５（駅番号ｊ）の降車後乗客数Ｎaij を用いて下式で算出する（Ｑ１１）。

【００４０】

Ｅij＝Ｎbij-1　－Ｎaij　　i=1,2,3,4,…

そして、Ｑ１２にて、この算出された実績降車客数Ｅijに対して補正を加える。すなわち、車両１２が混雑している場合は、列車１１がホーム１６に到着して各車両１２の扉が開くと、扉近傍の客が自己がこの駅１５で下車しない場合においても、一旦ホーム１６へ降車し、降車客が全て降車したのち再度同一車両１２へ乗車する。このような場合、測定された降車後乗客数Ｎaij が実際より少なくなる。その結果、算出された実績降車客数Ｅijが実際より多くなる。この一旦ホーム１６へ降車する乗客数は、前駅１５における発車後の各車両１２の混み程度を示す乗車後乗客数Ｎbij-1 に応じて、経験的にほぼ一定値に定まるので、算出された実績降車客数Ｅijからこの乗客数を減算する。

【００４１】そして、補正された後の実績降車客数Ｅij（i=1,2,3,4,…）をデータベース２４の実績降車客数メモリ２８へ登録する（Ｑ１３）。具体的には、実績降車客数メモリ２８の対応する平均的な客数を該当実績降車客数Ｅijで学習して、さらに正確な値に更新する。

【００４２】次に、現在駅１５（駅番号ｊ）における各車両１２の実績乗車客数Ｆij（i=1,2,3,4,…）をバッファメモリ２５に保存されている降車後乗客数Ｎaij と乗車後乗客数Ｎbij とを用いて算出する（Ｑ１４）。

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【００４３】

Ｆij＝Ｎbij　－Ｎaij　　i=1,2,3,4,…

この求めた実績乗車客数Ｆijをデータベース２４の実績乗車客数メモリ２９へ登録する（Ｑ１５）。

【００４４】なお、この実績乗車客数メモリ２９に登録された各駅１５，各車両１２の実績乗車客数Ｆijは後日該当鉄道会社における列車ダイヤ編成や駅舎建設の参考データに使用される。

【００４５】以上で、一つの列車１１が一つの駅１５（駅番号ｊ）を発車した時における次駅１５（駅番号ｊ＋１）での各車両１２の乗車前の混雑度Ｄij+1の算出処理が終了したので、駅番号ｊを更新して（Ｑ１６）、Ｑ１へ戻り、次の駅１５からのデータ受信を待つ。

【００４６】管理センタ２１のデータ処理装置２３から列車番号と各車両１２の乗車前の混雑度Ｄij+1（i=1,2,3,4,…）を受信した次の駅１５（駅番号ｊ＋１）のデータ受信装置３１は、乗車前の混雑度Ｄij+1（i=1,2,3,4,…）を該当列車１１が到着するホーム１６の表示器１７に図３に示すように各車両１２の各車両パターン２６ａ，２７ｂ毎に色別表示する。

【００４７】例えば［緑色］は混雑でない通常状態を示し、［黄色］は混雑を示し、［赤色］は大混雑を示す。この各車両パターン２６ａ，２７ｂを［緑色］，［黄色］，［赤色］に色別表示する場合における混雑度Ｄij+1の各境界値（表示範囲）は各鉄道会社が過去の実績に基づいて決定する。

【００４８】このように構成された列車混雑度表示方法が採用された列車混雑度表示システムにおいては、各駅１５のホーム１６の上方位置の表示器１７に表示される次にこのホーム１７に到着する列車１１の各車両１２の混雑度Ｄijは一つ前の駅１５で測定された乗車後乗客重量Ｗbij-1 から得られた乗車後乗客数Ｎbij-1 から当駅１５で該当車両１２から降車する予測降車客数Ｂijを減算した当駅での予測残留乗客数Ｃijから求めている。

【００４９】したがって、ホーム１６で列車１１の到着を待っている乗客にとっては、ホーム１６に到着してまだ当駅１５で降車予定の乗客が乗車した状態の混雑度ではなくて、当駅１５で降車客が各車両１２から降車した後の混雑度Ｄijが表示される。したがって、これから、乗車しようとする車両１２の正確な混雑度が把握でき、当駅１５を発車する列車１１の各車両１２相互間の混雑度がより一層均一化できる。

【００５０】その結果、乗客にとって不快な通勤を少しでも回避でき、鉄道会社にとっても、各列車１１における乗客の降乗りの所要時間を短縮でき、全体の輸送効率を向上できる。

【００５１】なお、本発明は上述した実施形態に限定されるものではない。例えば管理センタ２１のデータ処理

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装置２３や列車１１の送信データ作成装置１４における各データ処理を実行する制御プログラムは例えばＦＤ（フロッピーディスク）やＣＤ－ＲＯＭ等の記録媒体から供給することも可能である。

【００５２】

【発明の効果】以上説明したように本発明の列車混雑度表示方法及び列車混雑度表示システムにおいては、現在駅における各車両の乗客重量を連続測定して、次駅における各車両から乗客が降りた後の残留乗客数を予測し、この残留乗客数を混雑状況として次駅に表示している。

【００５３】したがって、次駅のホームにいる列車待ちの客に対して、これから乗車しようとする車両の乗車時点における正確な混雑状況を把握できるより有用な情報を提供でき、かつ鉄道会社にとっても１列車内における各車両相互間の乗車率を均一化でき、全体としての輸送効率を向上できる。

【図面の簡単な説明】

【図１】　本発明の一実施形態の列車混雑度表示方法が採用された列車混雑度表示システムの概略構成を示す模式図

【図２】　同実施形態システムにおける駅のホームに対する表示器の配設位置を示す図

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【図３】　同表示器の表示内容を示す図

【図４】　各列車の駅に到着してから出発するまでの各車両の乗客重量特性図

【図５】　同実施形態システムのデータベースの記憶内容を示す図

【図６】　同実施形態システムの列車における送信データ作成装置の動作を示す流れ図

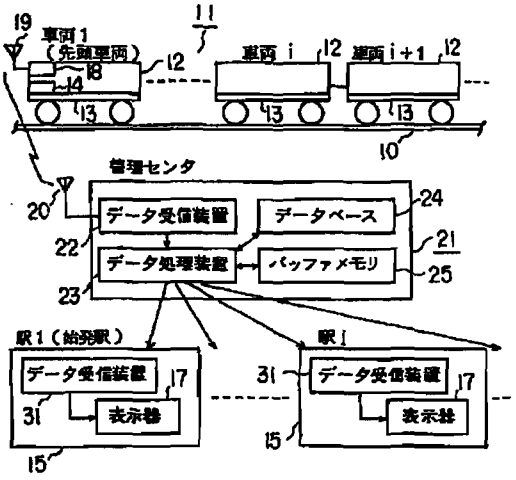
【図７】　同実施形態システムの管理センタにおけるデータ処理装置の動作を示す流れ図

【図８】　従来の各車両の混雑度表示手法を示す図

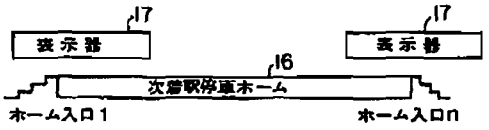
【符号の説明】

１１…列車
１２…車両
１３…重量計
１４…送信データ作成装置
１５…駅
１６…ホーム
１７…表示器
２１…管理センタ
２３…データ処理装置
２４…データベース
２８…実績降車客数メモリ

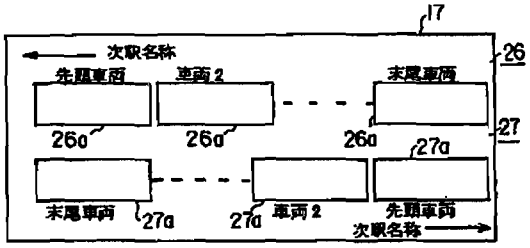
【図１】



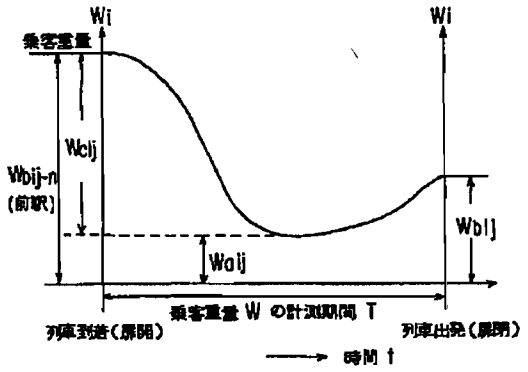
【図２】



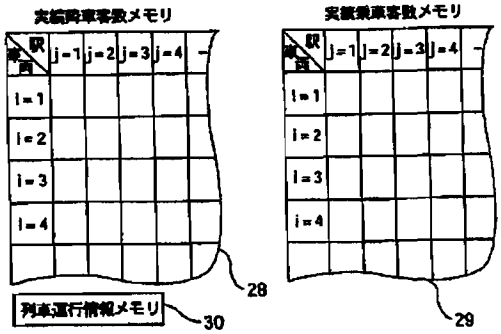
【図３】



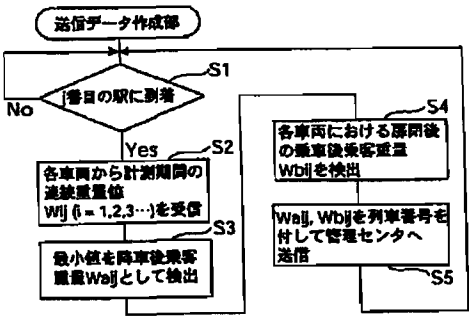
【図4】


Wi
乗客重量
Wi
Wclj
Wbij-n
(前駅)
Wblj
Walj
乗客重量 W の計測期間 T
列車到着(扉開)
列車出発(扉閉)
時間 t

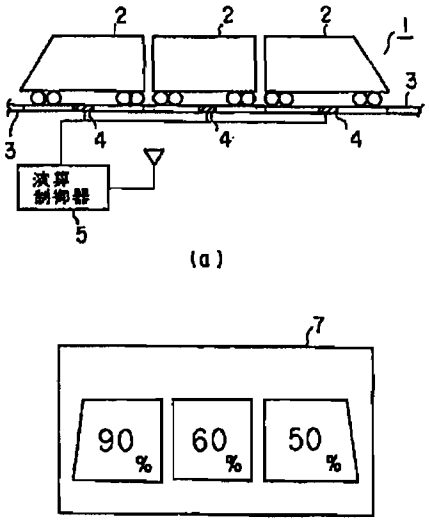
【図5】


実績降車客数メモリ
実績乗車客数メモリ
車両
駅
j=1
j=2
j=3
j=4
i=1
i=2
i=3
i=4
28
29
列車運行情報メモリ
30

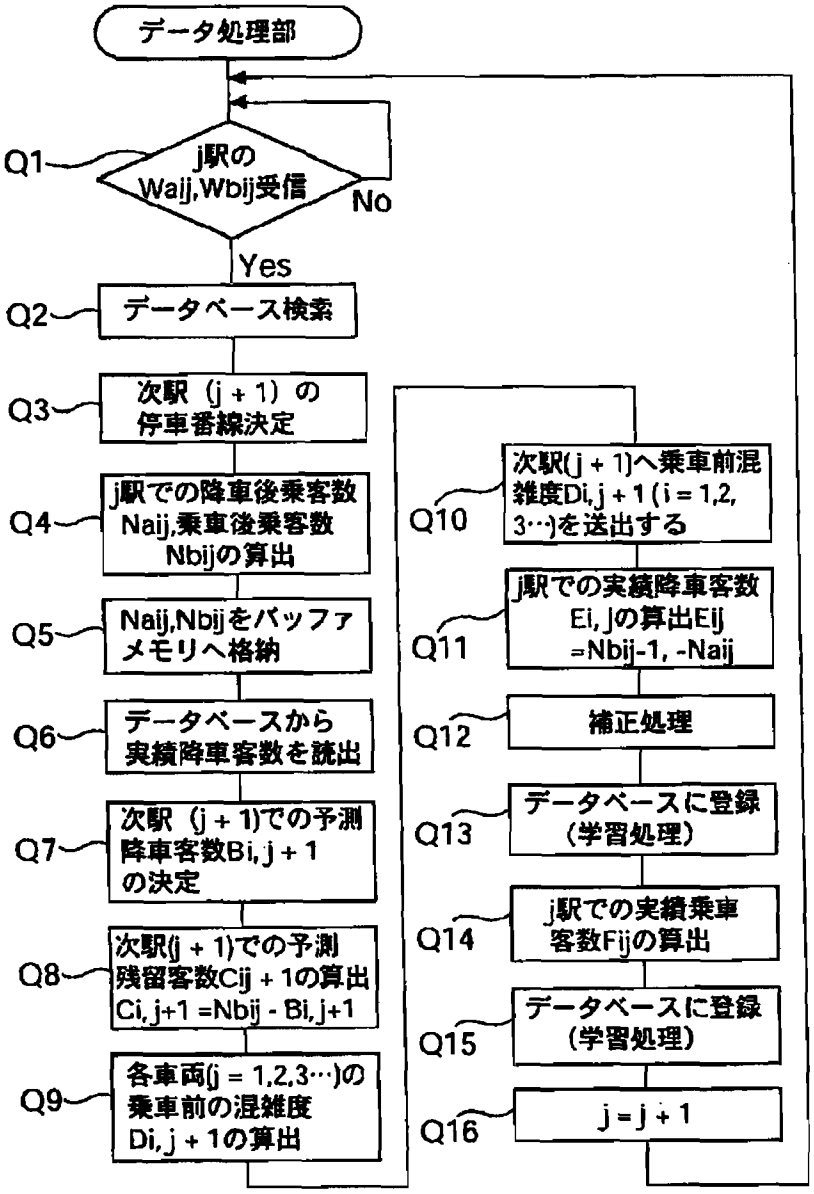
【図6】


送信データ作成部
S1
i番目の駅に到着
No
Yes
S2
各車両から計測期間の
連続重量値
Wlj (i = 1,2,3…)を受信
S3
最小値を降車後乗客
重量Walとして検出
S4
各車両における扉閉後
の乗車後乗客重量
Wblを検出
Wal, Wblを列車番号を
付して管理センタへ
送信
S5

【図8】


2
2
2
1
3
3
4
4
4
演算
制御器
5
(a)
7
90 %
60 %
50 %
(b)

【図７】


データ処理部
Q1
j駅の
Waij,Wbij受信
No
Yes
Q2
データベース検索
Q3
次駅（j＋1）の
停車番線決定
Q4
j駅での降車後乗客数
Naij,乗車後乗客数
Nbijの算出
Q5
Naij,Nbijをバッファ
メモリへ格納
Q6
データベースから
実績降車客数を読出
Q7
次駅（j＋1)での予測
降車客数Bi,j＋1
の決定
Q8
次駅(j＋1)での予測
残留客数Cij＋1の算出
Ci,j+1 =Nbij - Bi,j+1
Q9
各車両(j＝1,2,3…)の
乗車前の混雑度
Di,j＋1の算出
Q10
次駅(j＋1)へ乗車前混
雑度Di,j＋1(i＝1,2,
3…)を送出する
Q11
j駅での実績降車客数
Ei,jの算出Eij
=Nbij-1, -Naij
Q12
補正処理
Q13
データベースに登録
（学習処理）
Q14
j駅での実績乗車
客数Fijの算出
Q15
データベースに登録
（学習処理）
Q16
j＝j＋1

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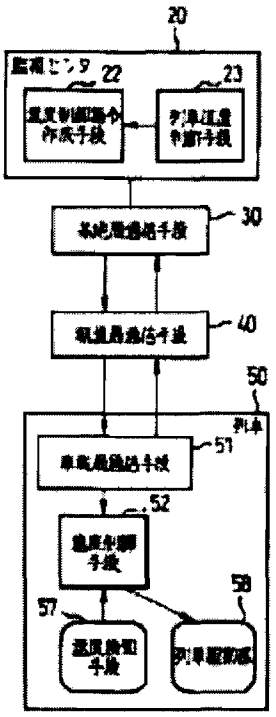
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(54) RAILWAY CONTROL DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a railway control device whereby investment in equipment of various facilities and a running cost related to train operation can be reduced.

SOLUTION: Information giving/receiving between a monitoring center 20 monitor controlling a train and a train 50 are performed by a base station communication means 30 and an on-vehicle station communication means 51 through a track station communication means 40 provided in a track. In the monitoring center 20, when passing of the train 50 is detected in the track station communication means 40, a train position is judged by a train position judging means 23, in a train control command forming means 22, a speed control command value of the following train is formed from train position information caught by the train position judging means 23. On the other hand, in the train 50, in a speed control means 57, speed control of the train 50 is performed by a speed control command value formed in the speed control command forming means 22 and a train speed detected in the speed control means 57.



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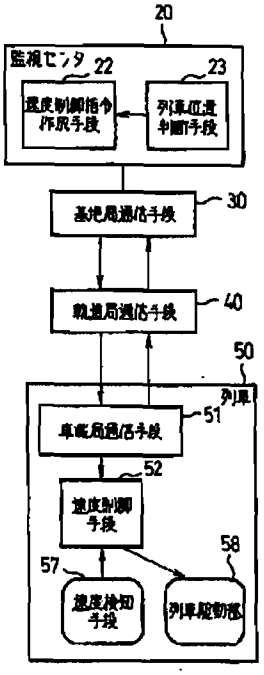
(74)代理人　弁理士　紋田　誠

(54)【発明の名称】　鉄道制御装置

(57)【要約】

【課題】　列車運行に関わる諸設備の設備投資やランニングコストを低減できる鉄道制御装置を提供することである。

【解決手段】　列車を監視制御する監視センタ２０と列車５０との間の情報授受は、軌道１に設けられた軌道局通信手段４０を介して基地局通信手段３０と車載局通信手段５１とで行われる。監視センタ２０では、軌道局通信手段４０が列車５０の通過を検知したときは列車位置判断手段２３により列車位置を判断し、列車制御指令作成手段２２は列車位置判断手段２３により把握した列車位置情報から後続列車の速度制御指令値を作成する。一方、列車５０では、速度制御手段５７は、速度制御指令作成手段２２で作成された速度制御指令値と速度検知手段５７で検知した列車速度により列車５０の速度制御を行なう。



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【特許請求の範囲】

【請求項１】　軌道上を運行する列車を監視制御する監視センタと、前記軌道に設置され列車との情報授受を行なうための軌道局通信手段と、前記軌道局通信手段を経由して前記監視センタからの制御情報を前記列車に送信したり前記列車からの情報を受信する基地局通信手段と、前記監視センタに設けられ前記軌道局通信手段により列車の通過を検知して列車の位置を判断する列車位置判断手段と、前記監視センタに設けられ前記列車位置判断手段により把握した列車位置情報から後続列車の速度制御指令値を作成する速度制御指令作成手段と、前記列車に設けられ前記軌道局通信手段と情報授受を行う車載局通信手段と、前記列車に設けられ列車の速度を検知する速度検知手段と、前記速度制御指令作成手段で作成された速度制御指令値と前記速度検知手段で検知した列車速度により列車の速度制御を行なう速度制御手段とを備えたことを特徴とする鉄道制御装置。

【請求項２】　請求項１の発明において、前記速度制御手段の代わりに前記速度制御指令作成手段で作成された速度制御指令値を表示するための速度制御指令値表示手段を設け、列車の運転は前記速度制御指令値表示手段により表示される速度制御指令値を参照して運転士が行なうことを特徴とする鉄道制御装置。

【請求項３】　請求項１の発明において、前記列車内に、次駅への到着時刻を予測する到着時刻予測手段と、前記到着時刻予測手段で予測した到着予測時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段とを設けたことを特徴とする鉄道制御装置。

【請求項４】　請求項１の発明において、前記監視センタに設けられ前記列車の通過時刻からその列車の次駅への到着時刻を作成する到着時刻作成手段と、駅に設けられ前記監視センタからの列車の到着時刻情報を受けて案内情報を作成する情報提供内容作成手段と、駅に設けられ前記情報提供内容作成手段で作成された列車の到着時刻の案内情報を旅客に音声出力もしくは文字図形の表示出力で提供する駅案内情報出力手段とを備えたことを特徴とする鉄道制御装置。

【請求項５】　請求項４の発明において、前記列車に設けられ前記列車の乗車人数を検知する乗車人数検知手段と、前記監視センタに設けられ前記乗車人数検知手段で検知し収集した各列車の乗車人数に基づいて営業管理を行なう営業管理手段とを備え、前記駅案内情報出力手段には列車の混雑度も出力するようにしたことを特徴とする鉄道制御装置。

【請求項６】　請求項４の発明において、前記監視センタに設けられ前記到着時刻作成手段により作成された各列車の到着時刻に基づき各列車の運行間隔を算出し運行間隔を調整する運行間隔調整手段と、前記列車に設けられ前記運行間隔調整手段で調整された運行間隔に基づいて各列車の出発時刻を制御する出発時刻制御手段と、前

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記列車に設けられ前記出発時刻制御手段により設定された出発時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段とを備えたことを特徴とする鉄道制御装置。

【請求項７】　請求項１の発明において、列車に設けられその列車の走行したキロ数を積算する走行キロ積算手段と、前記監視センタに設けられ前記走行キロ積算手段により算出した列車の走行キロ数を前記軌道局通信手段を経由して入力し列車の保守スケジュールを作成する保守スケジュール作成手段と、車両基地に設けられ前記保守スケジュール作成手段からの列車の保守スケジュールに基づいて保守作業を管理する保守作業管理手段とを備えたことを特徴とする鉄道制御装置。

【請求項８】　請求項７の発明において、列車の故障情報を作成する故障情報作成手段を列車に設け、故障情報作成手段で作成された列車の故障情報を前記軌道局通信手段を経由して監視センタの保守スケジュール作成手段に送信し、保守スケジュール作成手段は故障情報も加味して保守スケジュールを作成することを特徴とする鉄道制御装置。

【請求項９】　請求項１の発明において、前記軌道上に前記列車の速度を検出する軌道上速度検知手段を設け、前記列車に設けられた速度検知手段により検知された列車速度に代えて、前記軌道上速度検知手段により検知された列車速度を前記軌道局通信手段を経由して前記監視センタに送信することを特徴とする鉄道制御装置。

【請求項１０】　請求項１の発明において、前記監視センタに、前記列車の駆動用電源を供給する変電所の積算電力量を監視する電力管理手段を設け、前記速度制御指令作成手段は前記電力管理手段の出力に基づいて速度制御指令値を作成することを特徴とする鉄道制御装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、軌道上を複数の列車が運行する鉄道の各列車の運行を監視制御する鉄道制御装置に関する。

【０００２】

【従来の技術】例えば、鉄道においては軌道上を複数の列車が運行し、その運行する各列車が安全に運行できるように監視制御している。鉄道は停止距離が長いので、安全面と効率面とから列車群の運行を制御する。その運行の制御方式としては閉塞方式が採用されている。この閉塞方式は、線路をいくつかの区間に分けて、一つの区間には１台の列車しか入れないという方法で、列車同士の衝突を防止するものである。

【０００３】図１２は、従来の軌道回路を用いた列車制御方式の説明図である。軌道１上を列車５０は走行し、軌道１には信号機１０１が設けられると共に、列車５０の有無を検知する軌道回路１０２と呼ばれる列車検知装置が設けられている。すなわち、閉塞方式では、軌道１

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を分割して複数の軌道回路１０２を設け、どの区間に列車がいるかを軌道回路１０２により常時検知するようにしている。そして、その軌道回路１０２の両端部には信号機１０１が設けられ、列車同士の衝突を防止するようにしている。この場合、列車の運転間隔を縮めることができるようにするためには、軌道回路１０２の区間を短くして、列車５０に速度制限を与えることにより、列車５０は、より高密度に運行できるようになる。

【０００４】また、列車制御方式としては、列車の位置を軌道回路１０２を用いないで把握し制御するようにしたものもある。この列車制御方式は、列車の速度検出装置で検出した速度を積分することによって列車の位置を列車内で把握し、列車対地上局の無線通信で列車制御システムに伝達する。そして、列車制御システムでは各列車の制限速度信号を作成し、各列車に伝達するようにしている。このような列車制御方式では、列車の位置は軌道回路１０２を用いないので、連続的に列車位置を列車から地上局に送信している。

【０００５】一方、軌道回路１０２による列車検知方式は、軌道１に電流を流し、列車が存在する場合にはその軌道電流が短絡することで列車の有無を判断するものであるが、列車の識別まではできない。従って、列車群の運行管理を行なうためには、別に列車識別装置を設置する必要がある。

【０００６】図１３は、その列車識別装置の説明図である。列車識別装置は、軌道１の地上側に設置される地上子１０３と、列車５０の車上側に設置される車上子１０４とを有している。列車５０が列車識別装置地上子１０３を通過した時に列車識別装置車上子１０４との間で、電磁誘導により列車の識別番号を授受する。このほか、列車識別装置としては、駅ホームで列車に設けられたバーコードを読み取る方式もある。

【０００７】また、列車は走行したキロ数などに応じて点検保守を行なうことが義務づけられているが、従来は、列車の運行計画と並行して列車の運用計画とならべて保守スケジュールを作成し保守してきた。

【０００８】

【発明が解決しようとする課題】ところが、フルオートマティックな列車運行を実現するためには、列車運行に関わる諸設備を統合することが望まれるが、鉄道業界では今後の乗客数の大きな伸びも見込めず、設備費や保守費の削減が重要である。

【０００９】軌道回路を用いた列車制御方式では路線全線にわたっての保守が必要でありコストがかかるといった課題があり、列車の位置を軌道回路１０２を用いないで把握する列車制御方式では連続的に列車位置を列車から地上局に送信する必要がある。また、それぞれの列車制御方式が並列の形で採用され、それぞれに必要な設備が個々に設置されているために独立分散の意味では利点があるが、設備投資、維持や保守の面で無駄があるといった課題がある。

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【００１０】本発明の目的は、列車運行に関わる諸設備の設備投資やランニングコストを低減できる鉄道制御装置を提供することである。

【００１１】

【課題を解決するための手段】請求項１の発明に係わる鉄道制御装置は、軌道上を運行する列車を監視制御する監視センタと、軌道に設置され列車との情報授受を行なうための軌道局通信手段と、軌道局通信手段を経由して監視センタからの制御情報を列車に送信したり列車からの情報を受信する基地局通信手段と、監視センタに設けられ軌道局通信手段により列車の通過を検知して列車の位置を判断する列車位置判断手段と、監視センタに設けられ列車位置判断手段により把握した列車位置情報から後続列車の速度制御指令値を作成する速度制御指令作成手段と、列車に設けられ軌道局通信手段と情報授受を行う車載局通信手段と、列車に設けられ列車の速度を検知する速度検知手段と、速度制御指令作成手段で作成された速度制御指令値と速度検知手段で検知した列車速度により列車の速度制御を行なう速度制御手段とを備えたことを特徴とする。

【００１２】請求項１の発明に係わる鉄道制御装置では、列車を監視制御する監視センタと列車との間の情報授受は、軌道に設けられた軌道局通信手段を介して基地局通信手段と車載局通信手段とで行われる。そして、監視センタでは、軌道局通信手段が列車の通過を検知したときは列車位置判断手段により列車の位置を判断し、列車制御指令作成手段は列車位置判断手段により把握した列車位置情報から後続列車の速度制御指令値を作成する。一方、列車では、速度制御手段は、監視センタの速度制御指令作成手段で作成された速度制御指令値と列車の速度検知手段で検知した列車速度により列車の速度制御を行なう。

【００１３】請求項２の発明に係わる鉄道制御装置は、請求項１の発明において、速度制御手段の代わりに速度制御指令作成手段で作成された速度制御指令値を表示するための速度制御指令値表示手段を設け、列車の運転は速度制御指令値表示手段により表示される速度制御指令値を参照して運転士が行なうことを特徴とする。

【００１４】請求項２の発明に係わる鉄道制御装置では、請求項１の発明での自動運転に代えて、列車の運転は、運転士により手動で行われる。その際、運転士は速度制御指令値表示手段により表示される速度制御指令値を参照して列車の運転を行う。

【００１５】請求項３の発明に係わる鉄道制御装置は、請求項１の発明において、列車内に、次駅への到着時刻を予測する到着時刻予測手段と、到着時刻予測手段で予測した到着予測時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段とを設けたことを特徴とする。

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【００１６】請求項３の発明に係わる鉄道制御装置では、請求項１の発明の作用に加え、列車内の到着時刻予測手段で次駅への到着時刻を予測し、案内情報出力手段により予測した到着予測時刻を列車内に音声出力もしくは文字図形で表示出力する。

【００１７】請求項４の発明に係わる鉄道制御装置は、請求項１の発明において、監視センタに設けられ列車の通過時刻からその列車の次駅への到着時刻を作成する到着時刻作成手段と、駅に設けられ監視センタからの列車の到着時刻情報を受けて案内情報を作成する情報提供内容作成手段と、駅に設けられ情報提供内容作成手段で作成された列車の到着時刻の案内情報を旅客に音声出力もしくは文字図形の表示出力で提供する駅案内情報出力手段とを備えたことを特徴とする。

【００１８】請求項４の発明に係わる鉄道制御装置では、請求項１の発明の作用に加え、監視センタの到着時刻作成手段は列車の通過時刻からその列車の次駅への到着時刻を作成し、駅の情報提供内容作成手段によりその列車の到着時刻の案内情報を作成する。作成された列車の到着時刻の案内情報は、駅案内情報出力手段により旅客に音声出力もしくは文字図形の表示出力で提供される。

【００１９】請求項５の発明に係わる鉄道制御装置は、請求項４の発明において、列車に設けられ列車の乗車人数を検知する乗車人数検知手段と、監視センタに設けられ乗車人数検知手段で検知し収集した各列車の乗車人数に基づいて営業管理を行なう営業管理手段とを備え、駅案内情報出力手段には列車の混雑度も出力するようにしたことを特徴とする。

【００２０】請求項５の発明に係わる鉄道制御装置では、請求項４の発明の作用に加え、列車の乗車人数検知手段で検知し収集した各列車の乗車人数に基づいて、監視センタの営業管理手段は営業管理を行い、駅案内情報出力手段に列車の混雑度も出力する。

【００２１】請求項６の発明に係わる鉄道制御装置は、請求項４の発明において、監視センタに設けられ到着時刻作成手段により作成された各列車の到着時刻に基づき各列車の運行間隔を算出し運行間隔を調整する運行間隔調整手段と、列車に設けられ運行間隔調整手段で調整された運行間隔に基づいて各列車の出発時刻を制御する出発時刻制御手段と、列車に設けられ出発時刻制御手段により設定された出発時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段とを備えたことを特徴とする。

【００２２】請求項６の発明に係わる鉄道制御装置では、請求項４の発明の作用に加え、監視センタの運行間隔調整手段は、到着時刻作成手段により作成された各列車の到着時刻に基づき各列車の運行間隔を算出し運行間隔を調整する。列車の出発時刻制御手段は、運行間隔調整手段で調整された運行間隔に基づいて各列車の出発時

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刻を制御し、列車の案内情報出力手段に出発時刻制御手段により設定された出発時刻を列車内に音声出力もしくは文字図形で表示出力する。

【００２３】請求項７の発明に係わる鉄道制御装置は、請求項１の発明において、列車に設けられその列車の走行したキロ数を積算する走行キロ積算手段と、監視センタに設けられ走行キロ積算手段により算出した列車の走行キロ数を軌道局通信手段を経由して入力し列車の保守スケジュールを作成する保守スケジュール作成手段と、車両基地に設けられ保守スケジュール作成手段からの列車の保守スケジュールに基づいて保守作業を管理する保守作業管理手段とを備えたことを特徴とする。

【００２４】請求項７の発明に係わる鉄道制御装置では、請求項１の発明の作用に加え、監視センタの保守スケジュール作成手段は、列車の走行キロ積算手段により算出した列車の走行キロ数を軌道局通信手段を経由して入力し列車の保守スケジュールを作成する。車両基地の保守作業管理手段は保守スケジュール作成手段からの列車の保守スケジュールに基づいて保守作業を管理する。

【００２５】請求項８の発明に係わる鉄道制御装置は、請求項７の発明において、列車の故障情報を作成する故障情報作成手段を列車に設け、故障情報作成手段で作成された列車の故障情報を軌道局通信手段を経由して監視センタの保守スケジュール作成手段に送信し、保守スケジュール作成手段は故障情報も加味して保守スケジュールを作成することを特徴とする。

【００２６】請求項８の発明に係わる鉄道制御装置では、請求項７の発明の作用に加え、保守スケジュール作成手段は故障情報も加味して保守スケジュールを作成する。

【００２７】請求項９の発明に係わる鉄道制御装置は、請求項１の発明において、軌道上に列車の速度を検出する軌道上速度検知手段を設け、列車に設けられた速度検知手段により検知された列車速度に代えて、軌道上速度検知手段により検知された列車速度を軌道局通信手段を経由して監視センタに送信することを特徴とする。

【００２８】請求項９の発明に係わる鉄道制御装置では、請求項１の発明の作用に代えて、軌道上速度検知手段により検知された列車速度を軌道局通信手段を経由して監視センタに送信し、列車の車載局通信手段の負荷を軽減する。

【００２９】請求項１０の発明に係わる鉄道制御装置は、請求項１の発明において、監視センタに、列車の駆動用電源を供給する変電所の積算電力量を監視する電力管理手段を設け、速度制御指令作成手段は電力管理手段の出力に基づいて速度制御指令値を作成することを特徴とする。

【００３０】請求項１０の発明に係わる鉄道制御装置では、請求項１の発明の作用に加え、列車の駆動用電源を供給する変電所の積算電力量が所定値を越えたときは、

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電力管理手段は速度制御指令作成手段に対し速度を減速し電力消費を軽減させる指令を出力する。

【００３１】

【発明の実施の形態】以下、本発明の実施の形態を説明する。図１１は本発明の鉄道制御装置を鉄道システムに適用した場合の構成図である。図１１に示す鉄道システムは、都市内を走行する延長１０ｋｍ～２０ｋｍ程度の規模のレール式交通システムであり、列車５０は軌道１上を走行し駅７０で停車する運転を行っている。監視センタ２０は路線の近傍に設置され、軌道１に設けられた軌道局通信手段４０とデータの送受信を行う基地局通信手段３０を有する。

【００３２】軌道上には複数個の軌道局通信手段４０が設置され、列車５０の情報は軌道局通信手段４０を経て基地局通信手段３０に通信され、監視センタ２０に送られる。列車５０と軌道局通信手段４０との間は、電磁誘導や空間波を用いた無線伝送を行い、データの送受信を行う。また、基地局通信手段３０と軌道局通信手段４０との間は、空間波を用いた無線伝送でデータ伝送を行う。軌道局通信手段４０は、ここでは駅７０間に１個乃至数個設置されたものを示している。また、軌道１には分岐装置７が設けられ、を介して列車５０を車両基地８０に導くようになっている。

【００３３】次に、図１は本発明の第１の実施の形態に係わる鉄道制御装置のブロック構成図である。監視センタ２０は軌道上を運行する列車を監視制御するものであり、基地局通信手段３０および軌道局通信手段４０を介して列車５０とデータの送受信を行う。監視センタ２０は基地局通信手段３０と有線で結合し、基地局通信手段３０と軌道局通信手段４０との間、および軌道局通信手段４０と車載局通信手段５１との間は無線で結合している。なお、基地局通信手段３０と軌道局通信手段４０の間は通信ケーブルを用いて結合しても良いことは言うまでもない。

【００３４】監視センタ２０は速度制御指令作成手段２２と列車位置判断手段２３とを有しており、列車位置判断手段２３は、列車５０が軌道局通信手段４０を通過した情報に基づいて列車の位置を判断するものである。一方、速度制御指令手段２２は列車位置判断手段２３により把握した列車位置情報から後続列車の速度制御指令値を作成するものである。

【００３５】列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８とが設けられている。速度制御手段５２は、車載局通信手段５１を介して入力した監視センタ２０の速度制御指令作成手段２２で作成された速度制御指令値と、速度検知手段５７で検知した列車速度とを比較し、列車の速度制御を行なう。すなわち、列車速度が速度制御指令になるように列車駆動部５８に列車の駆動指令を出力する。これにより、後続列車の速度を自動制御する。

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【００３６】軌道局通信手段４０は、列車５０が軌道局通信手段４０を通過する時に列車５０から送信された列車識別番号を識別すると共に通過時刻を検出する。また、列車の速度検知手段５７で検知した列車速度は車載局通信手段５１を介して軌道局通信手段４０に伝送される。軌道局通信手段４０では、列車識別番号、列車速度および列車通過時刻に加え、軌道局通信手段４０の識別番号を基地局通信手段３０に伝送する。

【００３７】監視センタ２０内の列車位置判断手段２３では、列車５０の突入した路線上の区間を判断し通過時刻とともに記憶する。例えば、図１１の列車５０ａの場合、軌道局通信手段４０ｄの通過の情報より、列車５０ａの突入した路線上の区間（４０ｄ－４０ｅ）を判断し、軌道局通信手段４０ｄの列車通過時刻とともに記憶する。そして、速度制御指令作成手段２２により、接続する後ろの区間（４０ｃ－４０ｄ）に他の列車が入る場合の目標速度である速度制御指令値を次式で作成する。

【００３８】

【数１】

$$Vref(nk) = \min(V(nk), V^*(nk))$$

$$V^*(nk) = \sqrt{((Xp - xp - X) \times 2 \times a(nk) \times 3600/1000)}$$

ただし、

Vref(nk)　：列車 nk の速度指令値[km/h]

V(nk)　：列車 nk の現在速度[km/h]

V*(nk)　：列車 nk の減速目標値[km/h]

Xp　：軌道局通信手段 p の位置[m]

X　：列車現在位置[m]

xp　：余裕距離[m]

a(nk)　：列車 nk の設定減速度[(km/h)/s]

【００３９】軌道局通信手段４０の設置間隔の短い場合には、軌道局通信手段４０をまたがって速度指令値を算出することになる。この速度制御指令値の作成動作は、いずれかの列車がいずれかの軌道局通信手段４０を通過したタイミングで実施する。

【００４０】一方、列車５０ａは、軌道局通信手段４０ｄ通過時に、速度制御指令作成手段２２により同様に算出されていた区間４０ｄ－４０ｅの速度制御指令値を軌道局通信手段４０ｄより車載局通信手段５１を介して受け取り、速度制御手段５２により速度検知手段５７で検知した自列車の速度と照合させ、検知速度が速度制御指令値を上回る時は列車駆動部５８に対してブレーキ操作を指示し、下回る時は力行を指示することにより自列車の速度を制御する。

【００４１】この第１の実施の形態によれば、後続の列車の速度指令値を先行する列車の位置に基づいて算出し、後続の列車の速度を自動制御するので安全性が向上する。また、どの区間にどの列車が存在するかを軌道局通信手段４０で検知するので設備が合理化できる。ま

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た、列車の運転間隔に応じて軌道局通信手段４０の設置個数を少なくすることができ、しかも駅構内に設置することにより、保守を簡単化できる。

【００４２】次に、本発明の第２の実施の形態を説明する。図２は本発明の第２の実施の形態に係わる鉄道制御装置のブロック構成図である。この第２の実施の形態は、図１に示した第１の実施の形態に対し、速度制御手段５２の代わりに速度制御指令作成手段２２で作成された速度制御指令値を表示するための速度制御指令値表示手段６３を設け、列車の運転は速度制御指令値表示手段６３により表示される速度制御指令値を参照して運転士が行なうようにしたものである。

【００４３】監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３とが設けられ、列車５０内には、車載局通信手段５１と速度制御指令値表示手段６３と速度検知手段５７と列車駆動部５８とが設けられている。

【００４４】第１の実施の形態では列車５０は自動運転されるが、この第２の実施の形態では列車５０の操縦は運転士が行なう。そのために速度制御手段５２の代わりに速度制御指令値表示手段６３が設けられ、運転士は速度制御指令値表示手段６３により表示される速度制御指令値を参照して運転を行なうことになる。

【００４５】この第２の実施の形態では、システムダウン時などの特殊運転状況下においても、速度制御指令値表示手段６３により、運転士による目視運転が実施でき列車を走行させることができる。

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【００４６】次に、本発明の第３の実施の形態を説明する。図３は本発明の第３の実施の形態に係わる鉄道制御装置のブロック構成図である。この第３の実施の形態は、図１に示した第１の実施の形態に対し、列車５０内に、次駅への到着時刻を予測する到着時刻予測手段５３と、到着時刻予測手段５３で予測した到着予測時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段５９とを追加して設けたものである。

【００４７】監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３とが設けられ、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７に加え、到着時刻予測手段５３と案内情報出力手段５９とが設けられている。

【００４８】列車５０内では、監視センタ２０から指示された列車５０の速度制御指令値に基づき、次駅への到着時刻を次のように予測する。まず、軌道局通信手段４０の各ポイントについて、標準速度で走行した場合の次駅までの走行時間を記憶しておく。次駅到着予測時刻T(m,k,nk)は、次式で算出する。

【００４９】

【数２】

$$T(m,k,nk) = T0 + t^*(m,k,nk) \times V^*(m,k) / V(nk) \quad \cdots(1)$$

ただし、

T(m,k,nk)：m駅へのk時間帯のnk番目の列車の次駅到着予測時刻

T0　　：現在時刻

t*(m,k,nk)：m駅へのk時間帯の次駅までの標準走行時間[秒]

V(nk)　：列車nkの速度制御指令値[km/h]

V*(m,k)　：m駅k時間帯の標準速度[km/h]

【００５０】そして、上式で算出した次駅到着予測時刻T(m,k,nk)を、列車内の案内情報出力手段５９に表示する。

【００５１】この第３の実施の形態によれば、列車遅延発生時にも旅客に対して的確に列車運転状況をアナウンスすることができ、乗務員なしの運転が可能となる。

【００５２】次に、本発明の第４の実施の形態を説明する。図４は本発明の第４の実施の形態に係わる鉄道制御装置のブロック構成図である。この第４の実施の形態は、図１に示した第１の実施の形態に対し、列車５０の通過時刻からその列車５０の次駅への到着時刻を作成する到着時刻作成手段２４を監視センタ２０に追加して設け、基地局通信手段３０とデータの授受を行う軌道局通信手段４０と、監視センタ２０からの列車の到着時刻情報を受けて案内情報を作成する情報提供内容作成手段７２と、情報提供内容作成手段７２で作成された列車の到着時刻の案内情報を旅客に音声出力もしくは文字図形の表示出力で提供する駅案内情報出力手段７３とを駅に追加して設けたものである。

【００５３】図４において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と到着時刻作成手段２４とが設けられ、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８が設けられている。また、駅７０には、軌道局通信手段４０と情報提供内容作成手段７２と駅案内情報出力手段７３が設けられている。

【００５４】監視センタ２０の到着時刻作成手段２４は、列車５０の通過時刻からその列車の次駅への到着時刻を作成し、駅７０の情報提供内容作成手段７２によりその列車５０の到着時刻の案内情報を作成する。作成された列車５０の到着時刻の案内情報は、駅案内情報出力手段７３により旅客に音声出力もしくは文字図形の表示出力で提供される。

【００５５】すなわち、監視センタ２０では、速度制御

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指令作成手段２２で作成した速度制御指令に基づき到着時刻作成手段２４により全列車の到着時刻を作成し、駅７０に設置してある軌道局通信手段４０を介して情報提供内容作成手段７２に伝送し、駅案内情報出力手段７３に表示する。

【００５６】この第４の実施の形態によれば、駅５０において次の列車の到着予測時刻を表示するので、駅７０で列車５０を待つ乗客に列車運行に関する適切なアナウンスを行なうことができ、駅員の無人化を図ることができる。

【００５７】次に、本発明の第５の実施の形態を説明する。図５は本発明の第５の実施の形態に係わる鉄道制御装置のブロック構成図である。この第５の実施の形態は、図４に示した第４の実施の形態に対し、列車の乗車人数を検知する乗車人数検知手段５６を列車５０内に追加して設け、乗車人数検知手段５６で検知し収集した各列車５０の乗車人数に基づいて営業管理を行なう営業管理手段２７を監視センタ２０内に設け、駅７０内の駅案内情報出力手段７３には列車５０の混雑度も出力するようにしたものである。

【００５８】図５において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と到着時刻作成手段２４と営業管理手段２７とが設けられている。列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８と乗車人数検知手段５６が設けられている。また、駅７０には、軌道局通信手段４０と情報提供内容作成手段７２と駅案内情報出力手段７３とが設けられている。

【００５９】監視センタ２０では、速度制御指令作成手段２２で作成した速度制御指令に基づき到着時刻作成手段２４により到着時刻を作成し、駅７０に設置してある軌道局通信手段４０を介して情報提供内容作成手段７２に伝送し、駅案内情報出力手段７３に表示する。

【００６０】この際、乗車人数検知手段５６により列車内で測定した各列車の荷重測定装置の出力を乗客の平均体重設定値（例えば５５ｋｇ）で割ることにより乗客数を算出し、乗客数を車載局通信手段５１により軌道局通信手段４０を介して監視センタ２０に送信する。監視センタ２０では、営業管理手段２７により乗客数データの

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帳票出力、旅客流動解析、運転計画等の営業管理を行なうとともに軌道局通信手段４０を介して駅７０に送信し、駅案内情報として到着する列車の混雑度を表示する。

【００６１】この第５の実施の形態では、列車５０の混雑度を駅７０に表示するので、各区間ごとの乗客数の計数ができ、よりきめ細やかな運転計画、旅客サービスができる。また、乗客数に基づいて列車の運行管理から営業管理までの一元管理が可能となり省力化が図れる。

【００６２】次に、本発明の第６の実施の形態を説明する。図６は本発明の第６の実施の形態に係わる鉄道制御装置のブロック構成図である。この第６の実施の形態は、図４に示した第４の実施の形態に対し、到着時刻作成手段２４により作成された各列車の到着時刻に基づき各列車の運行間隔を算出し運行間隔を調整する運行間隔調整手段を監視センタ２０に追加して設け、この運行間隔調整手段２５で調整された運行間隔に基づいて各列車の出発時刻を制御する出発時刻制御手段５４と、出発時刻制御手段５４により設定された出発時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段５９とを列車５０に追加して設けたものである。

【００６３】図６において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と到着時刻作成手段２４と運行間隔調整手段２５とが設けられる。列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と出発時刻制御手段５４と案内情報出力手段５９とドア開閉操作部６１とが設けられる。また、駅７０には、軌道局通信手段４０と情報提供内容作成手段７２と駅案内情報出力手段７３とが設けられる。

【００６４】到着時刻作成手段２４で作成した到着時刻を用いて、運行間隔調整手段２５では、各列車の運行間隔がある一定幅になるよう各列車の出発時刻を作成する。この第６の実施の形態では、環状線のように、一日中列車がぐるぐる回っているような路線で運行ダイヤとして運転間隔が設定されているような場合に有効である。各列車の計画出発時刻は次のように決定する。

【００６５】

【数３】

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$TS0(m,k,nk) > T0k + nk \times td(k)$ の場合

$TS(m,k,nk) = TT(m,k,nk) + en(m,k)$

$TS0(m,k,nk) < T0k + nk \times td(k)$ の場合

$TS(m,k,nk) = T0k + nk \times td(k)$

ただし、

$TS0(m,k,nk) = TT(m,k,nk) + eh(m,k)$

$TT(m,k,nk)$ ： m駅のk時間帯のnk列車の到着予測時刻時刻

$TS(m,k,nk)$ ： m駅のk時間帯のnk列車の計画出発時刻

$T0k$ ： k時間帯の初期時刻

$td(k)$ ： k時間帯の運行間隔[秒]

$en(m,k)$ ： 最小停車時間[秒]

$eh(m,k)$ ： 標準停車時間[秒]

【００６６】運行間隔調整手段２５で決定した計画出発時刻は、基地局通信手段３０および軌道局通信手段４０を経由して車載局通信手段５１により列車５０内に伝送される。列車５０内では、出発時刻制御手段５４により受信した計画出発時刻に基づき案内情報出力手段５９に計画出発時刻が表示されるとともに、出発のためのドア開閉操作指令がドア開閉操作部６１に入力され、ドア閉め後力行指令が列車駆動部５８に入力される。また、計画出発時刻は駅７０にも伝送され、駅案内情報出力手段７３に表示される。

【００６７】この第６の実施の形態では、列車５０の運行間隔のバラツキを調整できるので、列車の運行を円滑に行うことができる。すなわち、列車５０の運行間隔のバラツキは、駅７０における乗り降りの混雑などで時間帯ごとにさまざまに発生するが、この第６の実施の形態によれば運行間隔の適正化が自動で行なえる。

【００６８】次に、本発明の第７の実施の形態を説明する。図７は本発明の第７の実施の形態に係わる鉄道制御装置のブロック構成図である。この第７の実施の形態は、図１に示した第１の実施の形態に対し、列車５０の走行したキロ数を積算する走行キロ積算手段５５を列車５０に設け、走行キロ積算手段５５により算出した列車５０の走行キロ数を軌道局通信手段４０を経由して入力し列車５０の保守スケジュールを作成する保守スケジュール作成手段２６を監視センタ２０に設け、保守スケジュール作成手段２６からの列車５０の保守スケジュールに基づいて保守作業を管理する保守作業管理手段８２を車両基地８０に設けたものである。

【００６９】図７において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と保守スケジュール作成手段２６が設けられて、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と走行キロ積算手段５５と列車駆動部５８とが設けられている。また、車両基地８０には、軌道局通信手段４０と保守作業管理手段８２とが設けられている。

【００７０】監視センタ２０の保守スケジュール作成手段２６は、列車５０の走行キロ積算手段５５により算出した列車５０の走行キロ数を軌道局通信手段５１を経由して入力し列車５０の保守スケジュールを作成する。車両基地８０の保守作業管理手段８２は保守スケジュール作成手段２６からの列車５０の保守スケジュールに基づいて保守作業を管理する。

【００７１】すなわち、列車５０は走行キロ数に応じた点検保守作業を実施するために、走行キロ積算手段５５において速度検知手段５７の出力を積分することとにより走行した延べキロ数を算出する。そして、車載局通信手段５１は、列車識別番号、列車速度に加え、走行キロ数を軌道局通信手段４０および基地局通信手段３０を経由して監視センタ２０内の保守スケジュール作成手段２６に送信する。保守スケジュール作成手段２６では、各列車５０の走行キロ数を監視し、保守スケジュール表を埋める形で走行キロ数がしきい値を越えた列車を割り当てていく。一方、保守を行なう列車については、軌道１の分岐制御により車両基地８０へ配送する。

【００７２】この第７の実施の形態によれば、列車５０の位置検知と同時に、監視センタ２０で各列車５０の走行キロ数をオンラインで監視するので、列車５０の統合的な管理が可能となり、システムのコスト削減が図れる。

【００７３】次に、本発明の第８の実施の形態を説明する。図８は本発明の第８の実施の形態に係わる鉄道制御装置のブロック構成図である。この第８の実施の形態は、図７に示した第７の実施の形態に対し、列車の故障情報を作成する故障情報作成手段６２を列車５０に設け、故障情報作成手段６２で作成された列車５０の故障情報を軌道局通信手段４０を経由して監視センタ２０の保守スケジュール作成手段２６に送信し、保守スケジュール作成手段２６は故障情報も加味して保守スケジュールを作成するようにしたものである。

【００７４】図８において、監視センタ２０内には速度

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制御指令作成手段２２と列車位置判断手段２３と保守スケジュール作成手段２６が設けられ、列車５０内には、車載局通信手段５１と速度制御手段６２と速度検知手段５７と走行キロ積算手段５５と列車駆動部５８と故障情報作成手段６２とが設けられている。また、車両基地８０には、軌道局通信手段４０と保守作業管理手段８２とが設けられている。

【００７５】列車５０に故障が発生した場合に、故障情報作成手段６２により故障の程度、内容などを識別して符号化し、車載局通信手段５１により軌道局通信手段４０および基地局通信手段３を経由して監視センタ２０に送信する。必要に応じて保守スケジュール作成手段２６により保守スケジュールに組み込み、保守スケジュールを基地局通信手段３０を介して車両基地８０に送信する。

【００７６】この第８の実施の形態によれば、列車の位置検知と同時に、監視センタ２０で各列車の故障情報をオンラインで監視し、保守スケジュール作成手段２６により故障情報も加味して保守スケジュールを作成するので、列車５０の統合的な管理が可能となる。また、システムのコスト削減が図れる。

【００７７】次に、本発明の第９の実施の形態を説明する。図９は本発明の第９の実施の形態に係わる鉄道制御装置のブロック構成図である。この第９の実施の形態は、図１に示した第１の実施の形態に対し、軌道上に列車の速度を検出する軌道上速度検知手段４５を設け、列車５０に設けられた速度検知手段５２により検知された列車速度に代えて、軌道上速度検知手段４５により検知された列車速度を軌道局通信手段４０を経由して監視センタ２０に送信するようにしたものである。

【００７８】図９において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３とが設けられ、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８とが設けられている。また、軌道１上には軌道上速度検知手段４５が設けられている。

【００７９】車載局通信手段５１では、列車情報として列車識別番号を軌道局通信手段４０に送信する。列車速度は、軌道上の速度検知手段４５により検知した速度を軌道局通信手段４０から基地局通信手段３０を介して監視センタ２０に送信する。

【００８０】請求項９の発明に係わる鉄道制御装置では、請求項１の発明の作用に代えて、軌道上速度検知手段により検知された列車速度を軌道局通信手段を経由して監視センタに送信し、列車の車載局通信手段の負荷を軽減する。

【００８１】この第９の実施の形態では、車載局通信手段５１と軌道局通信手段４０との間の伝送項目を減らすことができ、その分、列車５０内でしか収集できない情報に充てることができる。

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【００８２】次に、本発明の第１０の実施の形態を説明する。図１０は本発明の第１０の実施の形態に係わる鉄道制御装置のブロック構成図である。この第１０の実施の形態は、図１に示した第１の実施の形態に対し、監視センタ２０に、列車５０の駆動用電源を供給する変電所の積算電力量を監視する電力管理手段２１を設け、速度制御指令作成手段２２は電力管理手段２１の出力に基づいて速度制御指令値を作成するようにしたものである。

【００８３】図１０において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と電力管理手段２１が設けられ、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８とが設けられている。

【００８４】電力管理手段２１においては、常時各変電所の積算電力量を監視し、契約量を超えることが予想される時には、一時的に省電力モードとし、省電力指令を速度制御指令作成手段２２に出力する。速度制御指令作成手段２２では、省電力指令を受けた場合には最高速度を２０％減少として速度制御指令値を決定する。このように、列車５０の駆動用電源を供給する変電所の積算電力量が所定値を越えたときは、電力管理手段２１は速度制御指令作成手段２２に対し速度を減速し電力消費を軽減させる指令を出力する。これにより、各列車の力行時間が短縮され、積算電力量の増加が抑制できる。

【００８５】

【発明の効果】以上述べたように、本発明によれば、軌道上の拠点に地上子を設け、車上子との間を非接触式で情報通信を行い、列車の通過とその列車の識別番号、混雑情報、保守情報などの列車情報を一括して伝送し、それらの情報を使用して列車の自動運行ダイヤ管理、保守作業の自動スケジューリングを行なうので、設備投資ならびに省力化を含むランニングコストを抑制した鉄道制御装置を得ることができる。

【図面の簡単な説明】

【図１】図１は、本発明の第１の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図２】図２は、本発明の第２の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図３】図３は、本発明の第３の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図４】図４は、本発明の第４の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図５】図５は、本発明の第５の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図６】図６は、本発明の第６の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図７】図７は、本発明の第７の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図８】図８は、本発明の第８の実施の形態に係わる鉄道制御装置のブロック構成図である。

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【図９】図９は、本発明の第９の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図１０】図１０は、本発明の第１０の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図１１】図１１は、本発明の鉄道制御装置を鉄道システムに適用した場合の構成図である。

【図１２】図１２は、従来の軌道回路を用いた列車制御方式の説明図である。

【図１３】図１３は、従来の列車識別装置の説明図である。

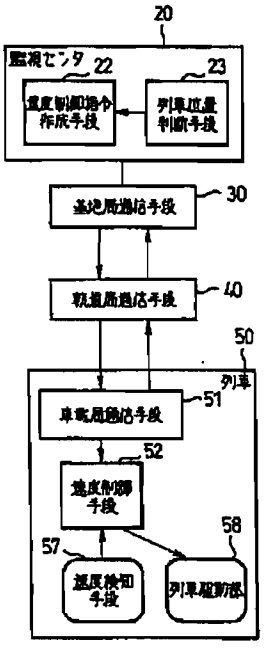
【符号の説明】

１　軌道
２０　監視センタ
２１　電力管理手段
２２　速度制御指令作成手段
２３　列車位置判断手段
２４　到着時刻作成手段
２５　運行間隔調整手段
２６　保守スケジュール作成手段
２７　営業管理手段
３０　基地局通信手段
４０　軌道局通信手段

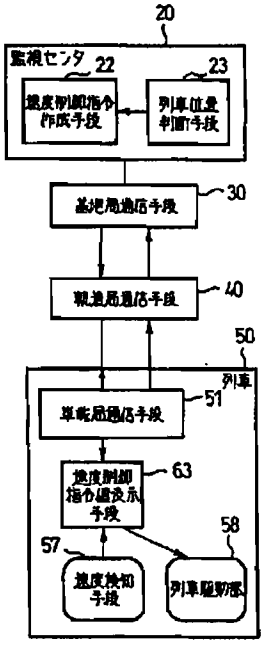
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４５　軌道上速度検知手段
５０　列車
５１　車載局通信手段
５２　速度制御手段
５３　到着時刻予測手段
５６　乗車人数検知手段
５７　速度検知手段
５８　列車駆動部
５９　案内情報表示手段
６１　ドア開閉操作部
６２　故障情報作成手段
６３　速度制御指令値表示手段
７０　駅
７２　情報提供内容作成手段
７３　駅案内情報出力手段
８０　車両基地
８２　保守作業管理手段
１０１　信号機
１０２　軌道回路
１０３　地上子
１０４　車上子

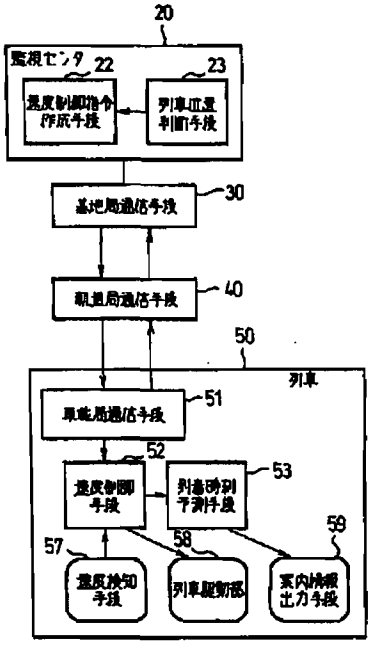
【図１】



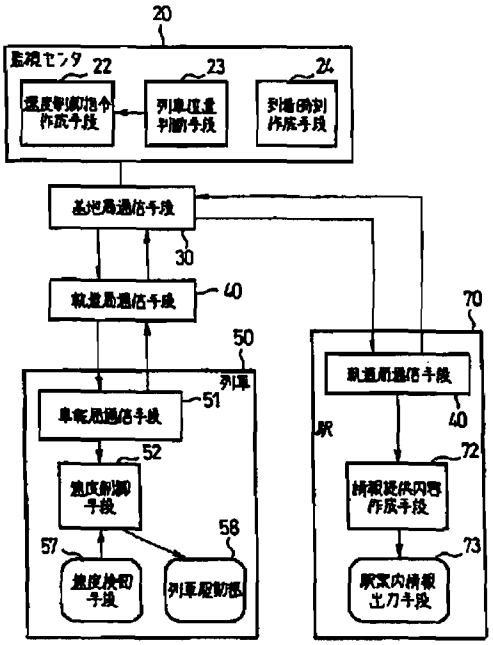
【図２】



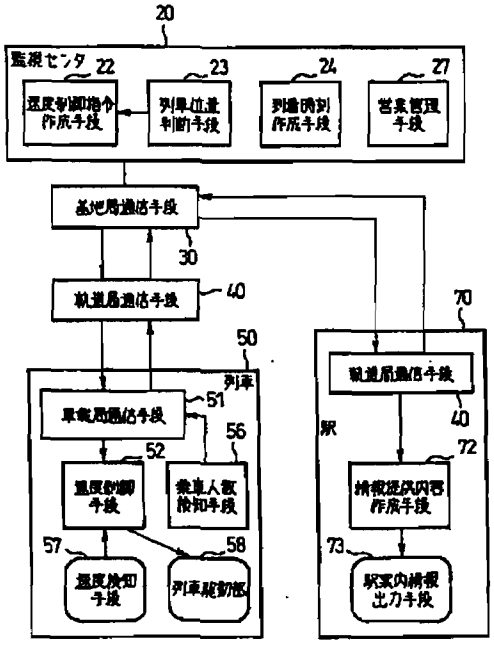
【図３】



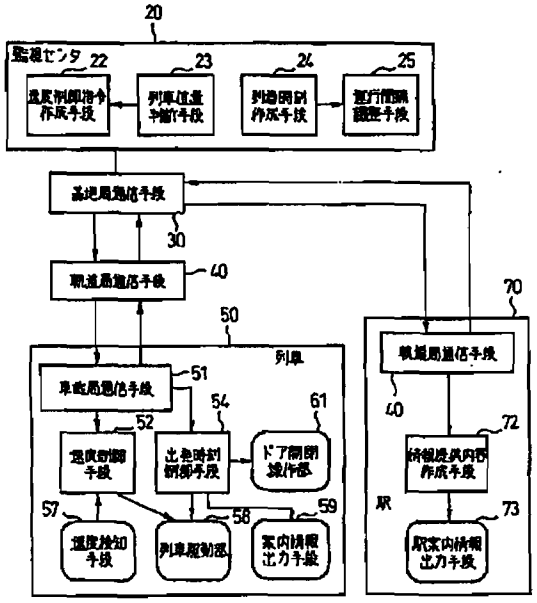
【図４】


20
監視センタ
22
23
24
速度制御指令作成手段
列車位置判断手段
到着時刻作成手段
基地局通信手段
30
軌道局通信手段
40
50
列車
車載局通信手段
51
52
速度制御手段
57
速度検知手段
58
列車制御部
70
軌道局通信手段
40
駅
72
情報提供内容作成手段
73
駅案内情報出力手段

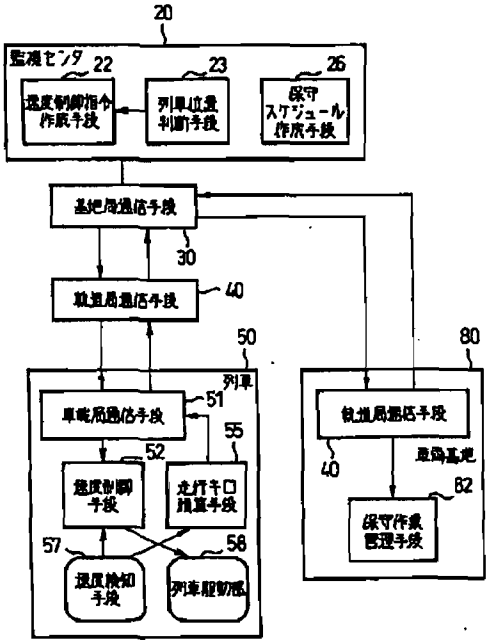
【図５】


20
監視センタ
22
23
24
27
速度制御指令作成手段
列車位置判断手段
到着時刻作成手段
営業管理手段
基地局通信手段
30
軌道局通信手段
40
50
列車
車載局通信手段
51
52
56
速度制御手段
乗車人数検知手段
57
58
速度検知手段
列車制御部
70
軌道局通信手段
40
駅
72
情報提供内容作成手段
73
駅案内情報出力手段

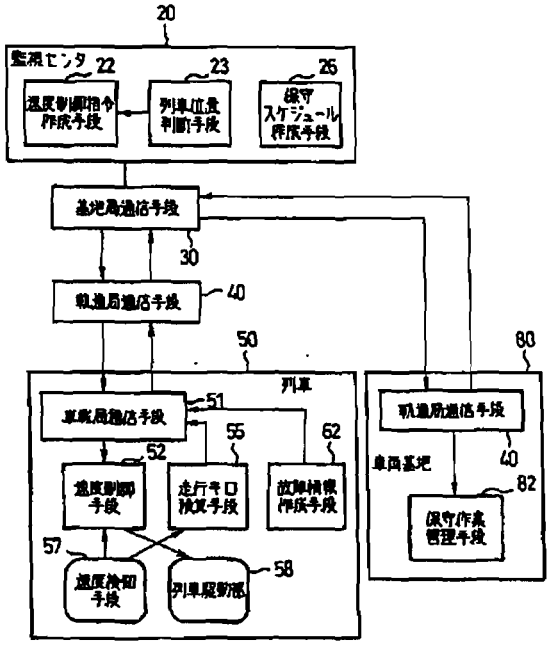
【図６】


20
監視センタ
22
23
24
25
速度制御指令作成手段
列車位置判断手段
到着時刻作成手段
運行管理調整手段
基地局通信手段
30
軌道局通信手段
40
50
列車
車載局通信手段
51
52
54
61
速度制御手段
出発時刻制御手段
ドア開閉操作部
57
58
59
速度検知手段
列車制御部
案内情報出力手段
70
軌道局通信手段
40
72
情報提供内容作成手段
駅
73
駅案内情報出力手段

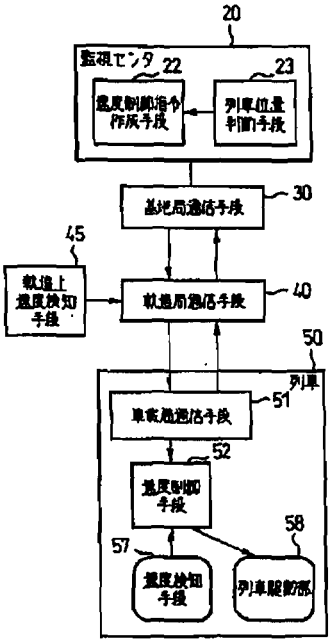
【図７】


20
監視センタ
22
23
26
速度制御指令作成手段
列車位置判断手段
保守スケジュール作成手段
基地局通信手段
30
軌道局通信手段
40
50
列車
車載局通信手段
51
52
55
速度制御手段
走行キロ積算手段
57
58
速度検知手段
列車制御部
80
軌道局通信手段
40
車両基地
82
保守作業管理手段

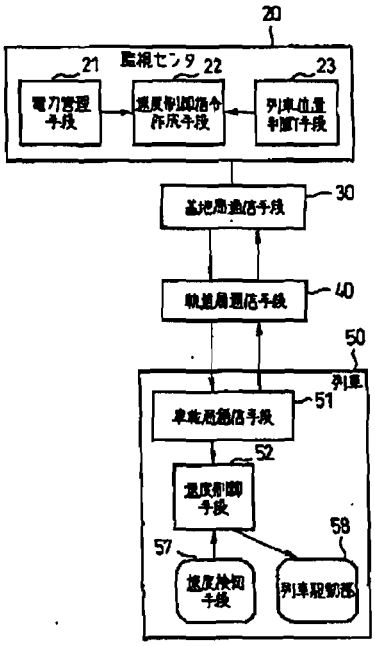
【図８】



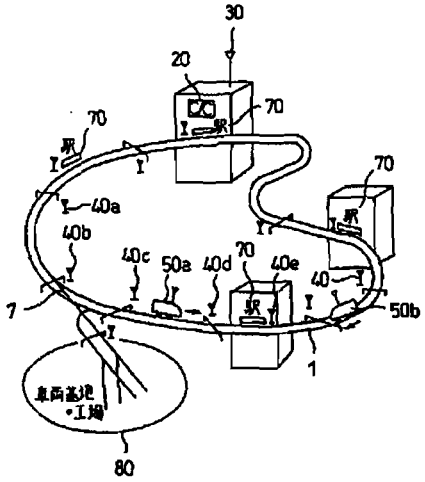
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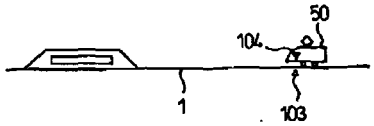
【図１０】



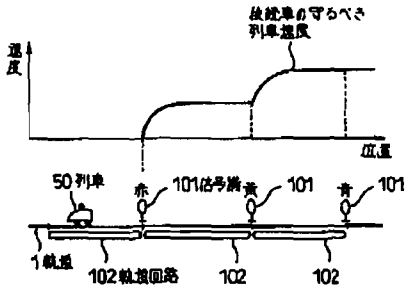
【図１１】



【図１３】



【図１２】


故経車の守るべき
列車速度
速度
位置
50 列車
赤
101 信号機
黄
101
青
101
1 軌道
102 軌道回路
102
102

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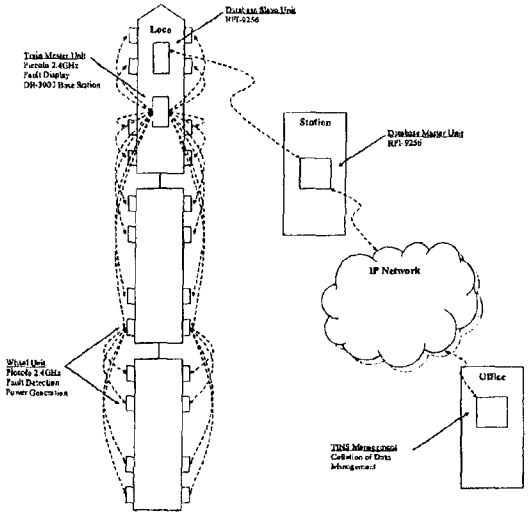
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(54) Title: TRAIN INTEGRITY NETWORK SYSTEM



(57) **Abstract:** A train integrity network system comprises bogie units which monitor critical parameters relating to the condition of bogie components and the rail track they are travelling on, an onboard server which controls the bogie units and a wireless network which enables communication between the server and the bogie units. Each bogie unit is powered by an electrical generator which utilises the rotation of the bogie wheels and has a processor which compares the critical parameters against defined standards in order to issue alerts to the train driver. The wireless network utilises master/slave base band role switching, has store-and-forward nodes which convey quasi real time data to the server and utilises frequency hopping modes.

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TRAIN INTEGRITY NETWORK SYSTEM

FIELD OF THE INVENTION

This invention relates to computerised real time wireless network communication systems for monitoring rail and other vehicular transport for component failure and other safety aspects.

BACKGROUND OF THE INVENTION

The prior art in the field of rail transport safety discloses a number of devices designed to monitor the failure of critical components such as wheels, bearings, axles and the rail itself. For example US 6,672,681 teaches a railway axle hub sensor unit for detecting vibrations in vertical and horizontal axial directions and signalling an impending failure and/or a damaged condition whereas US 5,381,692 also uses temperature sensors to signal abnormal bearing temperatures.

US 5,433,111 discloses apparatus and a method for detecting defective conditions in both the train wheels and the rail tracks using a mobile tracking unit to record the location of the latter. Similarly, US 6,435,027, US 6,471,407, US 5,631,426, US6,378,373 and US 5,022,267 all teach various combinations of motion and temperature sensors to signal component failure and US 6,474,832 teaches a self regulating axle mounted device for generating electrical energy to power such apparatus.

However there are a number of major issues involved in monitoring all the critical components of a train at the same time, especially in long freight trains, and combining the output of many sensors to warn of developing problems before a critical failure. For example running cables throughout trains is not practical as carriages and wagons are regularly shunted into and out of different trains to make up an operating consist. Cabling plugs and sockets, compatibility from operator to operator, age of wagons and access is difficult and labour intensive. Accordingly there is a need for a wireless network which sends data processed at an axle end to a server located in the prime mover where the information is processed against set rules and automatic or manual intervention commands issued.

Further the wireless communications system must have the ability to operate in an ad-hoc environment where the sensor units on the wagon wheels have no prior

knowledge of each other but must be automatically configured to cooperate with each other in a particular train consist. Also the system must have built in redundancy, that is, the monitoring system of the server in the locomotive must be ready to act in the case of a critical situation even if signalling from specific units has failed; the failed axle units must be identified and the network automatically re-established to maintain monitoring.

Another major issue is the requirement for a reliable stable power supply for the wheel monitoring and radio networking system, since freight rolling stock do not have power on board. Each wheel unit must have a small generator powered by utilising the rotation of the wheel hub and since the power generated varies with the speed of rotation of the wheel, stable regulation of the electrical energy generated is a critical issue. Finally the system must be able to interact with a range of sensor systems which gather data for transfer to the wheel processing units.

It is also desirable for a train integrity network system (TINS) to perform the following functions:

- measuring coupling tension between wagons to enable more efficient loading and train management
- monitoring pack components such as sandwich packs, yokes and air supply.
- detecting coupling failure between wagons
- monitoring wheel slip and braking malfunction
- detecting wheel damage, failure and derailment
- detecting axle fatigue
- monitoring the security of unloading and discharge doors
- monitoring wear surfaces
- monitoring wheel wear and profile
- tracing the cause of steering defects
- lighting the side of trains to ensure visibility at rail crossings
- tracking location of individual wagons
- tracking the consignment of mixed goods
- electronic monitoring of interactions with wayside operation systems
- warning rail crossing users of train proximity
- provision of warning and prevention of train to train and other collision dangers

- provision of real time monitoring of railway crossings and rail station crossovers to prevent vehicular and pedestrian accidents
- provision of an alternative to conventional signalling methods based on global information systems
- detecting and locating track failure using global information systems.

Although developed for use in trains, such integrity network systems have a wide range of potential application in a variety of vehicles such as trams, mining machinery and road trains. The network can also be used to monitor and relay structural integrity and to collect data and security information in a range of applications such as buildings, bridges, engineering infrastructure and public places.

OBJECT OF THE INVENTION

It is therefore an object of the present invention to provide a train integrity network system (TINS) which has some of the above functions or at least provides a useful alternative to prior art systems.

STATEMENT OF THE INVENTION

According to the present invention a train integrity network system comprises two or more bogie units which monitor critical parameters relating to the condition of bogie components and the rail track they are travelling on, an onboard server which controls the bogie units and a wireless network which enables communication between the server and the bogie units.

Preferably the bogie units have sensors to monitor the temperature of the wheel hubs of the bogie.

Preferably the bogie units have sensors to monitor the temperature of the wheel perimeters of the bogie.

Preferably the bogie units have motion detectors to monitor movement of the bogie axle in vertical and horizontal directions.

Preferably the bogie units have accelerometers to monitor acceleration of the bogie axle.

Preferably the bogie units have means to measure the speed of rotation of the bogie wheels.

Preferably the bogie units are powered by an electrical generator which utilises the rotation of the bogie wheels.

Preferably the bogie units have a processor which compares the critical parameters against defined standards.

Preferably the bogie units have a wireless transceiver which enables communication with other bogie units and the server.

Preferably the bogie units have a source of illumination.

Preferably the wireless network utilises master/slave base band role switching.

Preferably the wireless network has store-and-forward nodes which convey quasi real time data to the server.

Preferably the wireless network has frequency hopping modes.

Preferably the server can download data to a wayside database.

Preferably the system has a GPS unit to record the location of the train at any time.

Preferably the system has an end-of-train monitoring function.

Preferably the system has a collision avoidance function.

Preferably the system has a level crossing warning function.

Preferably the system transmits a warning signal to vehicles approaching a level crossing which are equipped to receive said signal.

Preferably the system monitors tension and compression in the train wagon couplings.

BRIEF DESCRIPTION OF THE DRAWINGS

A particular embodiment of the invention is now described by way of example only with reference to the accompanying drawings in which:

Figure 1 illustrates the general arrangement of the store and forward function of individual bogie units and their master/slave automatic configuration,

Figure 2 illustrates the overall network architecture of the system,

Figure 3 illustrates the architecture of a bogie unit ,

Figure 4 shows the sensor circuit board layout of a bogie unit,

Figure 5 illustrates the server architecture,

Figure 6 illustrates a TINS network of 4 unit depth and 3 unit width,

Figure 7 illustrates the TINS network of Figure 6 during the establishment phase,

Figure 8 illustrates the basic establishment methodology of the TINS network,

Figure 9 illustrates the network discovery messaging of the TINS network,

Figure 10 illustrates the RSSI and wheel number division of time during network discovery,

Figure 11 illustrates the extension of the network,

Figure 12 is the network establishment flowchart,

Figure 13 shows the network establishment frequency use,

Figure 14 shows the progression of hopping channel with each control frame,

Figure 15 shows an ideal coverage map for a network of 5 unit depth and 2 unit width,

Figure 16 is a transmit data flowchart,

Figure 17 is a receive data flowchart,

Figure 18 shows the RF section of a bogie unit,

Figure 19 is a schematic of a bogie unit,

Figure 20 is a photograph of a bogie unit,

Figure 21 shows the layout of a bogie unit with remote infrared censor and

Figure 22 is a schematic of the bogie unit software architecture.

DETAILED DESCRIPTION OF THE INVENTION

The TINS has two main components, namely, the bogie units which incorporate the wireless communication system, and the onboard server unit. The bogie units monitor in real time various wheel and track factors including rotation, vibration, g-force acceleration and bearing temperature, as well as the causes of differential temperature effects. The information is analysed in a processor in the bogie unit by means of algorithms which have been developed to recognise a range of specific component conditions. If a monitored condition exceeds a predetermined threshold or parameter the processor will generate an alarm which is transmitted via a RF network to the server. The server then notifies the driver via a control console, of the specific exception, including the condition, the position of the bogie in the train consist, the last ten minutes of trend information and a menu of corrective actions to be taken.

The bogie units comprise:

- various temperature, motion and acceleration sensors

- a microprocessor to analyse signals from the sensors
- non volatile memory for data storage
- a radio modem for communicating with the on board server and other bogie units
- a power generation and regulation system
- an external housing
- programming software
- an antenna and
- strobe lighting

The server comprises:

- a laptop or other personal computer
- three radios and related modems
- antennas
- a GPS transponder
- programming software
- a data storage device
- and a video compression engine

The bogie units can detect:

- a hot axle box
- flat and broken wheels
- wheel slip and wheel derailment
- end-of-train and train handling
- brake failure and hot wheels
- hunting wheel sets and
- track conditions such as corrugations, cracked and broken rails and horizontal and vertical defects.

The core of the TINS is a RF/Digital wireless communications backbone which links the monitoring and processing hardware and software of the bogie units with the server and each other. The units are installed on each end of a bogie and monitor a range of parameters which detect the above conditions. This information is then relayed through the wireless backbone to alert the driver to intervene manually or to trigger an automatic response in critical situations. There is a "heart beat" protocol

within the TINS which establishes that the bogie units are on-line and fully operational and reports any that have failed. Accordingly the TINS not only guards against derailments but improves performance and efficiency thus reducing operational costs.

A critical aspect of the TINS is the ability of the bogie units to self-configure, that is when wagons are coupled into a train consist there is no shared information between the units and the server. However, once the consist is assembled and the units power up , they can be either manually or automatically booted so that they start to communicate with each other and within several minutes become united in the one network with the sever to provide whole train integrity. If one of the units fails the adjacent units leap-frog to the next operating unit to maintain the train's "heart beat" which is essential for operational redundancy. Since it has an open architecture, the TINS can also host a range of additional "smart" monitoring and warning systems such as collision avoidance.

Figures 1 and 2 illustrate the overall network architecture between the units, the server, a database slave unit, both located in the loco, a database located in a station and a remote management server. When the train powers up, the server establishes a fully connected network of master, repeater, and slave units. This network then transmits signals generated by the sensors to the server where the data is collated. As the train passes through a station, a radio modem is used to download the data to a wayside database which is connected to a remote management server via an IP network. The station databases provide the statistics for final collation and analysis by the management server.

Figures 19 and 20 show a schematic and a photographic view respectively of the bogie units while Figures 3 and 4 illustrate their architecture and sensor circuit board layout respectively. The power required for each unit is generated by a multiphase AC alternator in which the stator is the coil assembly and the magnets are fixed to a circular disc that spins at wheel velocity. The multiphase AC output is proportional to wheel velocity (within certain constraints) and is rectified, regulated and processed by a regulator module.

The power regulator supplies power to a single Piccolo radio module PCB shown in Figure 18, the sensor circuit board as shown in Figure 4, and the sensors; the Piccolo module is powered directly but the other components are only supplied with power when the Piccolo has become active and enables the sensor power switch. The sensor power switch is only activated when the Piccolo has determined that there is sufficient power from the bogie units to supply the sensor sub-system; this is done my monitoring the raw voltage output of the power supply regulator circuit.

There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in Figure 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.

Vibrations in the vertical and horizontal planes of the wheel are measured by two orthogonally mounted accelerometers. The accelerometer outputs are analog DC proportional to acceleration between defined limits. These outputs are converted to digital via an ADC, converted from ADC units (voltage) into real-world units (G's), low-pass filtered, and compared against an alarm level. If the filtered acceleration exceeds the prescribed alarm level, then an alarm is generated. Approximate wheel velocity is derived from the power generator supply voltage which is divided down and converted to digital via an ADC. The result is then converted into a voltage which is proportional to rate of rotation. However precise wheel velocity is determined by a Hall Effect device attached to the rotating magnet assembly which produces a pulse output for each completed wheel revolution.

The microprocessor module of the bogie units uses high speed programmable logic arrays to process the incoming data from the sensors described above so that it is not overloaded with tasks which reduce its response time and limit its ability to control the RF section. A flow diagram of the programming software for the units is given in

Figure 22. Communication between the processing module and the microprocessor module is via a parallel bus which enables the fastest communications possible. This module performs the following functions:

- Processing alarms generated by the module and activating the data radio.
- Providing instructions to the processing module.
- Providing non-volatile storage of temperature and vibration data for continuous transmission in the event of a valid alarm condition.
- Managing a serial data protocol for external communications and programming.
- Establishing routines for "heartbeat" responses
- Managing the data radio background functions.
- Managing store and forward functionality and redundancy.

A high speed digital radio which has its power and antenna outputs controlled by the microprocessor module is used to transmit to and receive from other bogie units and the server. The radio performs dual roles of a network repeater or an end point station depending on the network configuration and its position in the train consist. The antenna system is designed to focus the RF energy forward and backward along the axis of the train so that other units will be radiated by the RF lobe maxima. The range of the signal is controlled by the power output of the transmitter which is in turn controlled by the microprocessor. Spectrum reuse is paramount in a very long consist and so the range of the units' data radio has to be controlled.

Figure 5 is a schematic of the six components of the server namely a network protocol parser and generator, a service layer, an automatic network control and data gathering, real time trending, data storage and trending and a user interface. The protocol generator and parser generates request packets for the data radio and parses response packets for the service layer to interpret. The service layer provides individual status of the wheel with alarm reporting, individual status of the wheel without alarm reporting, and network status and alarm reporting on the entire network.

The automatic network control and data gathering performs automatic status retrieval from bogie units on the network, alarm generation from status retrieved, individual

monitoring of units and interface to real-time graphical trending. The latter also displays data graphically as it arrives in the automatic network control and data gathering component and visually indicates alarm conditions. The data storage and trending includes a database with the option to graph the time stamped data stored and to apply algorithms to it. Connection from the server to the bogie units is via a data radio and the server can be connected to an external wireless network such as a satellite data modem or a WLAN or any standard data radio in order to report to a remote management centre.

The TINS wireless network architecture is shown in Figure 6 as a series of interconnected units arranged in layers having a depth of four units and a width of three units. The depth of a network is the maximum number of units that a message must travel through in order for it to move between the master and the furthest unit and the width is the maximum number of units in each layer.

The network can be in one of two modes, an establishment mode or an operational mode. In the former one unit from each layer is designated as the primary and only that unit can transmit messages to or receive messages from units below it in the network as shown in Figure 6. In the latter mode any units in layer *n* can communicate with units in layers *n+1* and *n-1*. In this scenario each unit communicates with a single unit in the lower layer, and a single unit the upper layer, effectively creating a number of different networks equal to the network width. A unit may communicate with more than one unit in the layer above or below it and in the network establishment mode shown in Figure 7, only M_{00}, U_{10}, U_{21}, and U_{30} can transmit messages to units in lower layers or receive messages from units in lower layers. A maximum of 6 units per layer is supported within the network.

The TINS wireless network also uses a time division store and forward communications architecture with multiple redundant communication paths while in full operation. All data is transmitted in fixed width slots and any one slot may contain one or two frames depending on the format of the slot. There are three types of slots downlink, uplink and connect. A downlink slot contains data to be transmitted from the master to a single unit or to all units. Data transmitted in a downlink slot is not acknowledged by receiving units within the same downlink slot. Downlink slots are used to transmit data down the communications network. An uplink slot contains data to be transmitted from a single unit to the master. Data transmitted in an uplink slot is

acknowledged by the receiving unit within the slot. Uplink slots are used to transmit data up the communications network. A connect slot allows unconnected units to announce themselves and permit connection to the network.

Accordingly there are two distinct communications behaviours in the TINS wireless network. When the network establishment mode is entered during start-up the set of available units is discovered, and the role of each unit in normal operation is allocated. While undertaking network establishment, there is no redundancy and a unit failure will result in the restarting of network establishment. Once the network has been established, the operational mode is entered and the network supports multiple redundant communication paths. In this mode the network performs the following functions. The units asynchronously report alarm conditions to the master; the alarms are propagated from the generating unit to the master via the communications network. The stati of the sensors on a single unit are reported to the master in real-time; the last ten minutes of data for the internal sensors is also transmitted to the master when this function is operating. The units also pass on debugging information.

In the following description of the TINS network, when a unit A is above unit B there are fewer hops between the master and unit A than between the master and unit B. And when unit A is below unit B, then there are more hops between the master and unit A, than between the master and unit B. Each unit in the TINS network has three pre-configured addresses, and one dynamically allocated address. The three pre-configured addresses are:

- Globally Unique Identifier (GUID): A 32-bit factory configured address.
- Carriage Identifier (CID): A 25-bit user configured address. All wheel units on the same carriage must have the same carriage address.
- Wheel Number: A 3-bit user configured address. This indicates which wheel on the carriage a particular unit relates to. The wheel numbering can be found in the PRS.

The wheel number of carriage identifier go together to form a 32-bit Carriage Unique Identifier (CUID). The dynamically assigned address is the Dynamically Allocated

Hopping Pattern (DAHP). The DAHP sets the frequencies that the unit transmits and receives on, and uniquely identifies the unit in the network.

In the following sections a number of symbols are used to represent various network configuration and timing parameters. These are shown below.

d The depth of the network.

w The maximum width of the network.

b_m The number of bytes in a monitoring upload slot.

m The amount of bandwidth (in bits per second) available for monitoring.

n_c The number of channels.

n_u The number of uplink slots per downlink slot used in normal operation.

$t_e(x)$ The amount of time (in seconds) required to complete a request or response cycle during network establishment for a network of depth x.

$t_d(x)$ The amount of time (in seconds) required to complete a single discovery cycle on a network of depth x.

$t_{down}(x)$ The amount of time (in seconds) required for a message to propagate from the master to a unit at depth x. This is only applicable in normal operation.

$t_{up}(x)$ The amount of time (in seconds) required for a message to propagate from a unit at depth x to the master. This is only applicable in normal operation.

$t_x(x)$ The amount of time (in seconds) required to complete a single network extension on a network of depth x.

t_l The total time taken to achieve lock.

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t_n The total amount of time (in seconds) required to complete network establishment.

t_s The slot time in seconds.

r The number of transmissions required to successfully receive a data frame. For example, $r = 1$ implies that 100% of packets get through on the first attempt, with $r = 1.5$ implies that 50% of packets get through on the first attempt.

s_d The number of slots to spend performing network discovery.

When a unit first powers up in network establishment mode it enters the unconnected state and behaves as follows. It listens on a single channel for $(n_c+1)t_s$ ms, where n_c is the number of channels and t_s is the maximum slot time. After this time it moves to the next channel and continue listening. If a downlink frame is detected it checks the child address list for this unit's GUID. If it is found it then locks and hops with that unit. If a connect frame is detected, it locks and hops with that unit until the connect frames stop being transmitted and generates connect responses occasionally until acknowledged.

Network establishment is controlled by the master unit in the locomotive and the TINS network operates in a simple request / response mode as shown in Figure 8. Requests are generated by the master, and each unit continually re-transmits the same request until the master changes the request it is transmitting. Each request is directed to a single unit. Once the unit has completed the request, it passes a response back to the master via the network.

In Figure 8 a request is inserted in slot 0 and propagated down to U_{30}, where a response is generated which returns to the master in slot 9. The master spends half of its time talking to one side of the train as shown and the other half of its slots are used to communicate with the other side of the train. Lost requests are handled by the downlink constantly sending the same message until the master changes it. This will not happen until a response is received or a timeout occurs. Lost responses are handled by retries within the uplink frame.

When using this scheme, the amount of time required to transmit a request from the master to its destination, or from a unit to the master is given by:

$$t_e(x) = t_s[2r(x-1)]$$

where x is the depth of the unit. All master generated requests have an associated timeout period. If a response is not received before the timeout expires then the transmitted request is considered lost. This causes the restart of network establishment which has two basic operations, network discovery where a single unit is instructed by the master to discover what other to discover what other unconnected units are available for communications and network extension where a single unit is instructed to extend the communications network.

The messages used to perform network discovery are shown in Figure 9 where a DISCOVER-REQ message is transmitted from the master, and propagated down to a single destination. When the destination of the DISCOVER-REQ message receives it, the unit enters discovery mode and allows all unconnected units to transmit CONNECT messages. The connect message contains the following information: the GUID and the CUID of the transmitter, the RSSI between the connected and unconnected units and the number of failed connect attempts. Each CONNECT message is acknowledged by the connected unit. Once an unconnected unit has been acknowledged, it no longer attempts to transmit. The number of slots available for unconnected units to transmit is broadcast by the connected unit. The time taken for an unlocked unit to achieve lock with a unit that is transmitting CONNECT messages is given by:

$$t_l = r(n_c + 1)t_s$$

Thus, the number of slots allocated to locking must take into account this period of potential dead-time at the start.

The parameters for received signal strength intensity (RSSI) and wheel number are available for controlling unconnected unit transmissions to minimise the possibility of collision. During the first phase of connection there is no restriction, however during the second phase the air time is divided such that RSSI and wheel number select the slots that unconnected units may transmit as shown in Figure 10

Network extension occurs after network discovery and is used to extend the network by adding an additional layer. The messages used for network extension are shown in Figure 11 If network discovery is performed by U_{30}, then the network extension command will be passed to U_{20}. It is then the responsibility of U_{20} to pass the network extension command to all its children (U_{30} through U_{33}) and verify that each one received the command. The network extension request contains the following information: the DAHP for each unit in the layer below the destination, the children of each unit the layer below the destination and the primary for each child of the layer below the destination. When using this scheme, the amount of time required to perform network extension for a single layer at depth x is given by:

$$t_x(x) = 2t_e(x) + 4r.w.t_s$$

The flowchart for network establishment is shown in Figure 12as a repetitive two step process. In the first step the available units are discovered, while in the second step the network is extended to accept these new units. This process is repeated until no new units are discovered. Network establishment is $O(d^2)$ in complexity. The total time required to perform network establishment is given by:

$$\begin{aligned}
t_n &= \sum_{x=1}^{d} \left(t_d(x) + t_x(x)\right) \\
&= \sum_{x=1}^{d} \left(2t_e(x) + t_s s_d + 2t_e(x) + 4t_s rw\right) \\
&= \sum_{x=1}^{d} 4t_e(x) + \left(ds_d + 4drw\right)t_s \\
&= \sum_{x=1}^{d} 4t_s[2r(x-1)] + \left(ds_d + 4drw\right)t_s \\
&= 8t_s r\sum_{x=1}^{d} x - 8t_s r + \left(ds_d + 4drw\right)t_s \\
&= 4t_s r\left(d^2 + d\right) - 8t_s r + \left(ds_d + 4drw\right)t_s \\
&= t_s\left(4rd^2 + 4rd - 8r + ds_d + 4drw\right)
\end{aligned}$$

The US Federal Communications Commission's regulations (Part 15.247) for frequency hopping systems in 2.4GHz state:

> *(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. The*

system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

And:

(ii) Frequency hopping systems operating in the 2400–2483.5 MHz and 5725–5850 MHz bands shall use at least 75 hopping frequencies. The maximum 20 dB bandwidth of the hopping channel is 1 MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

The major feature of these requirements is that on average, each frequency must be used with the same regularity and the occupancy of any frequency must not be greater than 0.4 seconds in any 30 second period. The wheel units use a set of 256 unique hopping patterns. All hopping patterns are of a fixed length equal to the number of available channels, where each channel is visited exactly once. Hopping pattern position is derived from the master, thus each unit in the network visits the first channel in its hopping pattern at the same time. Based on these properties, hopping patterns can be selected that minimize interference.

The allocation of frequencies during network establishment shown in Figure 13 is unbiased ie no favour is given to any particular frequency, nor is any particular frequency used for a particular purpose. Each transmitter effectively uses two hopping patterns equally, its own and the hopping pattern of the unit above. Thus, on average each frequency is used with the same regularity by each transmitter as both hopping patterns contain all frequencies. The hopping pattern progresses by 1 each time the master transmits a downlink slot. The connect slots use the hopping patterns by progressing the hopping pattern index by one on each slot. When in operational mode as shown in Figure 14, a change in frequency (progression through

the hopping pattern) occurs with each control frame the hopping channel index increases by 1 for each control frame.

The downlink frame contains two parameters used to control hopping pattern progression: the offset number which is the number of slots that the transmitters downlink frame transmission is offset from the master's downlink frame transmission and the current hopping pattern index number which gives the transmit frequency.

Hopping patterns can be calculated for minimum interference by using the following properties of the network:

- Units are arranged in layers, where any unit in layer n can hear units in layer *n+1* and *n-1*. We will also assume that it is possible to hear units in layers *n+p* and *n-p*, where *p* is the RF propagation factor.
- Units on either side of the train cannot hear each other.
- Each unit visits the same index in a hopping pattern at the same time.

Thus, the following rules apply to the hopping patterns: 256 hopping patterns must be generated and no set of *w(2p+1)* sequential hopping patterns have a collision in any channel. The TINS hopping pattern sequences are calculated using a linear congruent generator (LCG) of the form:

$$y_{n+1} = (ay_n + b) \bmod m$$

The minimum standard (MINSTD) generator is used, having constants:

$$m = 2^{31} - 1 = 2147483647$$
$$a = 7^5 = 16807$$
$$b = 0$$

The result of the LCG is to pick one of the remaining frequencies for each hopping pattern, where frequencies that would interfere are not allowed to be selected.

Accordingly the TINS provides real time monitoring of critical factors and impact risk assessment of failure immediately and not at some future time or distant monitoring wayside station. There exists an immediate option for the driver to decide whether to stop the train, reduce speed till the defective wagon can be removed form the consist

or take other action. All the while real time monitoring of the alarm condition is displayed to the driver including the last ten minutes of operation since the condition occurred . A decision can be made on the validity of the alarm, the event that may have caused the alarm and therefore the expected risk of continuing.

The TINS system also provides an end-of-train monitoring system via the bogie units of the last wagon without the need for additional equipment and is independent of the length of the train or the effect of tunnels or terrain, unlike existing wireless end-of-train systems. By installing train simulation software (TSS) into the TINS server the compressive or tension condition across each coupling along the length of the train can also be monitored. This feature enables the driver to better manage train dynamics as well as run in and run out. By integrating a GPS unit the TINS network offers additional anti-collision features between the end of the train and a following locomotive entering a proximity envelope.

By installing ACS data common protocol (DCPS) transponders, interface and software in the server, the TINS system also provides an effective low cost anti-collision system. When any two trains fall within the ACS footprint operating range, which will depend on terrain but is generally a five kilometre separation, the server will draw the driver's attention to the interaction of the approaching trains. This range can be extended as required at specific locations by the installation of permanent wayside repeaters.

The display on the locomotive server will show the relative velocity of each train, the distance of separation to a one metre resolution, a spatial map showing the position of and proximity to track infrastructure, including which track each trains occupies, which determines the risk of collision. This information will give drivers sufficient warning to react immediately or to contact a traffic controller for instructions. Accordingly, following train movements can be kept at a minimum separation regardless of visibility and cruise control options with locomotive throttle mechanisms also become possible.

By installing a database of GPS positions of all road/rail crossings on the rail system and installing a transponder at each crossing, a crossing warning system can also be incorporated into the TINS. A radio broadcast is made continuously identifying the

crossing with its code name with the broadcast range varied by the power of the radio system. With optimum antenna configuration and design, a range at maximum power of 2.5 kilometres is achievable. When the proximity switching system installed at a road crossing senses that the crossing is, or is about to be obstructed by a vehicle or person, or in the case of an actively protected crossing the boom gates or bells are functioning, but fouled by traffic or people, the video system is activated. A real time video capture of the crossing is broadcast over the 2.5 kilometre range of the system.

When a train enters the 2.5 km crossing footprint or greater footprint if repeaters are installed, the crossing ID is recognised, tested for functionality and logged as such in the server database. Crossings not functioning are reported at specific reporting points along the route or can be reported online with satellite communications separately installed. The video capture of the crossing is stored in the server until the train has cleared the crossing. Accordingly, the driver is able to ascertain any risk prior to reaching the crossing and to take appropriate action. In the event that the time to stop the train is inadequate the system provides the train operator with a clear record of the responsible party to the accident.

If no proximity switches are activated, the crossing is logged in the database as being functional but no image is displayed to the locomotive driver. A record of events is collected and stored whilst the train itself intercepts the crossing. In the case of multiple crossings, the imagery is stacked sequentially based on the closest first. Where an accident occurs, the video capture will record the events creating the accident, whether the cause of the track being fouled was before the arrival of the locomotive or after, in the case of a crash into the side of the train. The video capture is terminated once the train clears the crossing and if no interjection is made by the driver as a vigilance procedure the record is removed from the storage device for the particular crossing. This system is also able to transmit a warning signal to vehicles approaching a level crossing which are equipped to receive the signal and so reduces the train whistle objections raised by local residents.

The surplus power generated by the bogie units whilst the train is in motion is used to operate strobe lighting on units thus illuminating the full length of the train and

improving its visibility side on. When the train is stationary the strobe lighting ceases and the bogie units go into hibernation mode.

VARIATIONS

It will be realized that the foregoing has been given by way of illustrative example only and that all other modifications and variations as would be apparent to persons skilled in the art are deemed to fall within the broad scope and ambit of the invention as herein set forth. In particular it will be apparent that the TINS could be applied to vehicular systems other than trains and systems which have characteristics similar to trains such as security monitoring systems.

Throughout the description and claims to this specification the word "comprise" and variations of that word such as "comprises " and "comprising" are not intended to exclude other additives, components, integers or steps.

CLAIMS

1. A train integrity network system comprising two or more bogie units which monitor critical parameters relating to the condition of bogie components and the rail track they are travelling on, an onboard server which controls the bogie units and a wireless network which enables communication between the server and the bogie units.
2. The system of claim 1 wherein the bogie units have sensors to monitor the temperature of the hub of a bogie wheel.
3. The system of claim 1 wherein the bogie units have sensors to monitor the temperature of the periphery of a bogie wheel.
4. The system of claim 1 wherein the bogie units have motion detectors to monitor movement of the bogie axle in vertical and horizontal directions.
5. The system of claim 1 wherein the bogie units have accelerometers to monitor acceleration of the bogie axle.
6. The system of claim 1 wherein the bogie units have means to measure the speed of rotation of a bogie wheel.
7. The system of claim 1 wherein the bogie units are powered by an electrical generator which utilises the rotation of the bogie wheels.
8. The system of claim 1 wherein the bogie units have a processor which compares the critical parameters against defined standards.
9. The system of claim 1 wherein the bogie units have a wireless transceiver which enables communication with other bogie units and the server.
10. The system of claim 1 wherein the bogie units have a source of illumination.
11. The system of claim 1 wherein the wireless network utilises master/slave base band role switching.
12. The system of claim 1 wherein the wireless network has store-and-forward nodes which convey quasi real time data to the server.
13. The system of claim 1 wherein the wireless network utilises frequency hopping modes.
14. The system of claim 1 wherein the server can download data to a wayside database.
15. The system of claim 1 which also has a GPS unit to record the location of the train at any time.
16. The system of claim 1 which has an end-of-train monitoring function.

BNSDOCID: <WO_____2005105536A1_I_>

17. The system of claim 1 which has a collision avoidance function.

18. The system of claim 1 which has a level crossing warning function.

19. The system of claim 1 which transmits a warning signal to vehicles approaching a level crossing which are equipped to receive said signal.

20. The system of claim 1 which monitors tension and compression in the train wagon couplings.

DATED THIS THIRD DAY OF MAY 2005

STI RAIL PTY LTD

BY THEIR PATENT ATTORNEY

IPFIRST

BNSDOCID: <WO_____2005105536A1_I_>

Figure 1

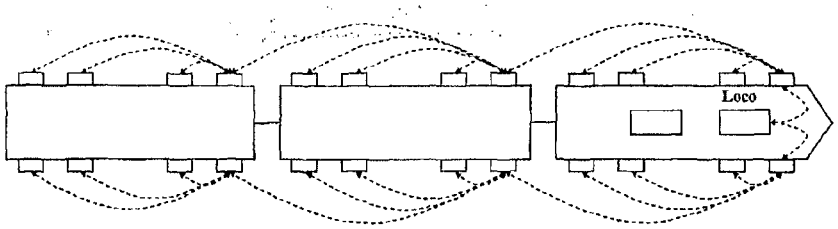
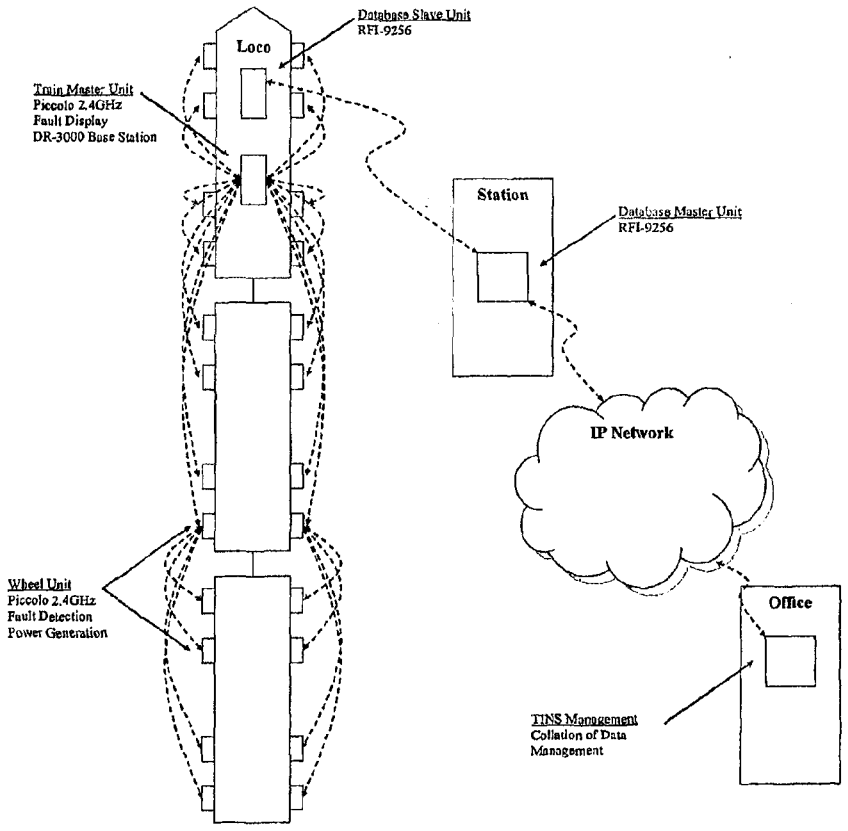


Figure 2



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Figure 3

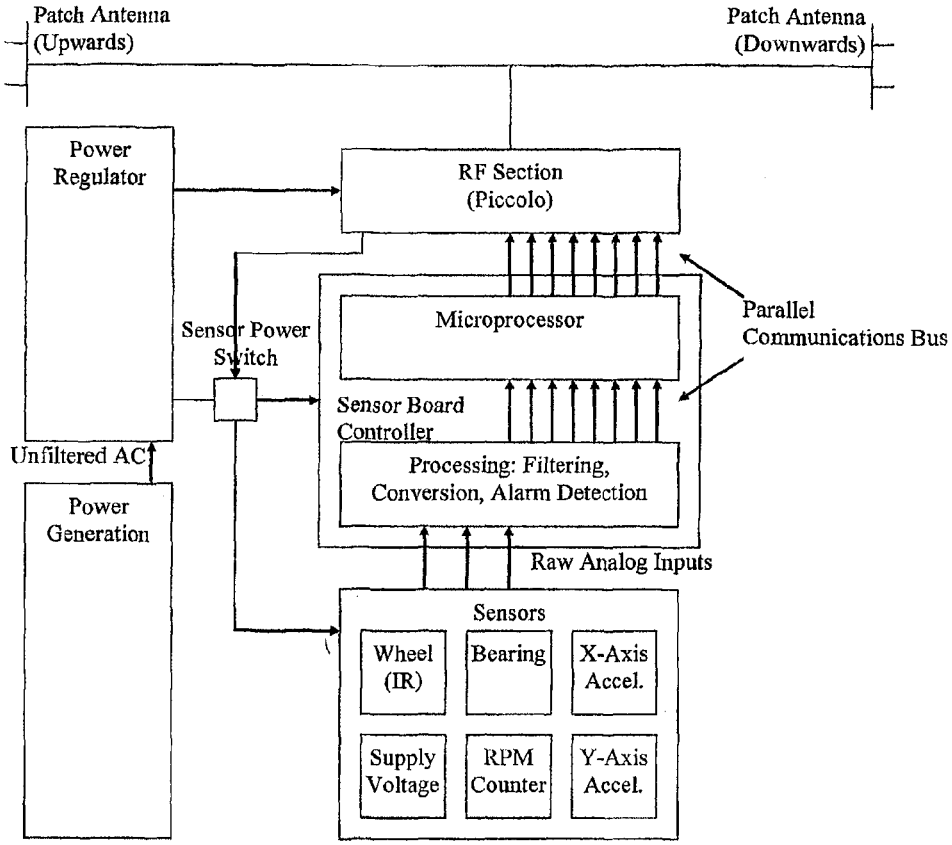
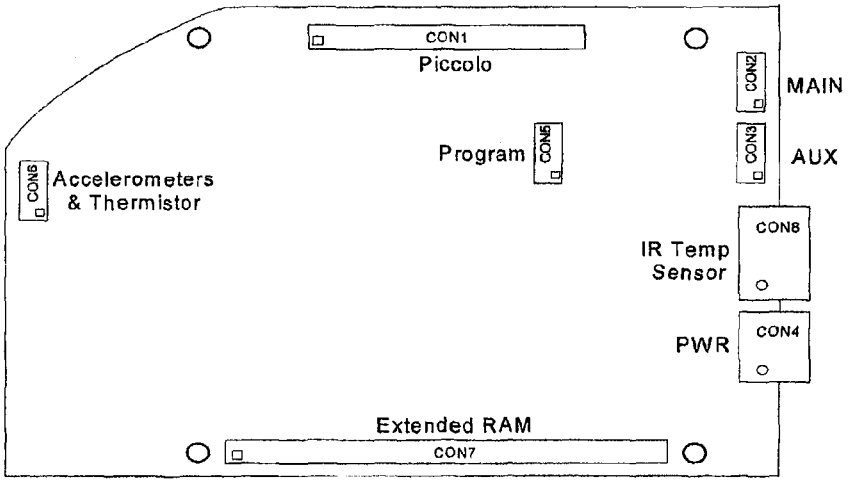


Figure 4



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Figure 5

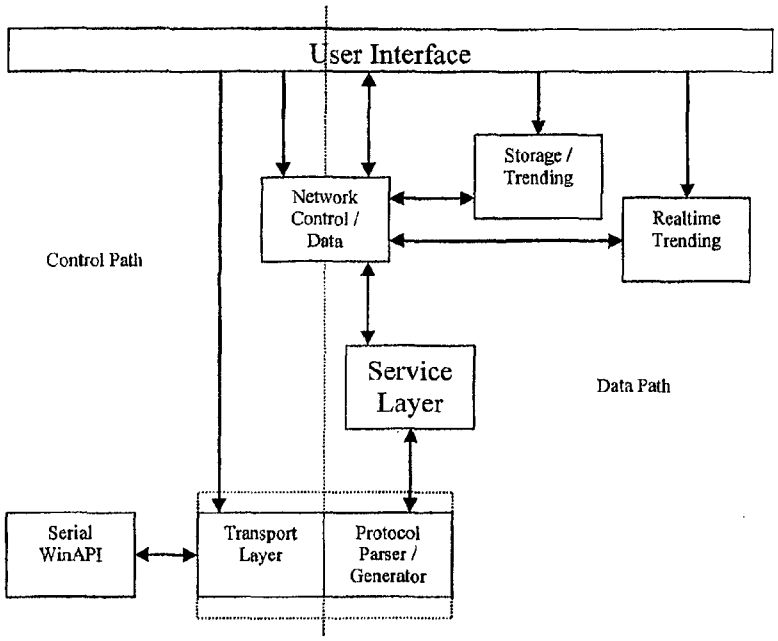


Figure 6

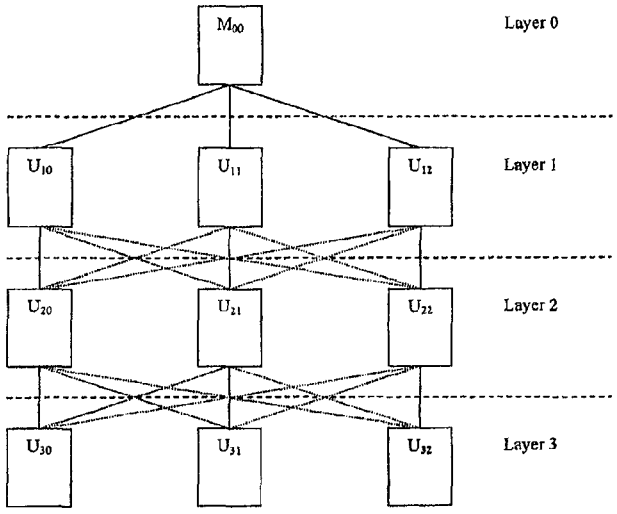


Figure 7

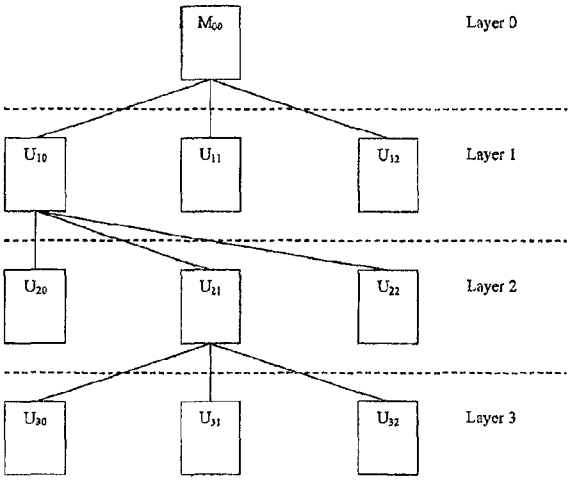
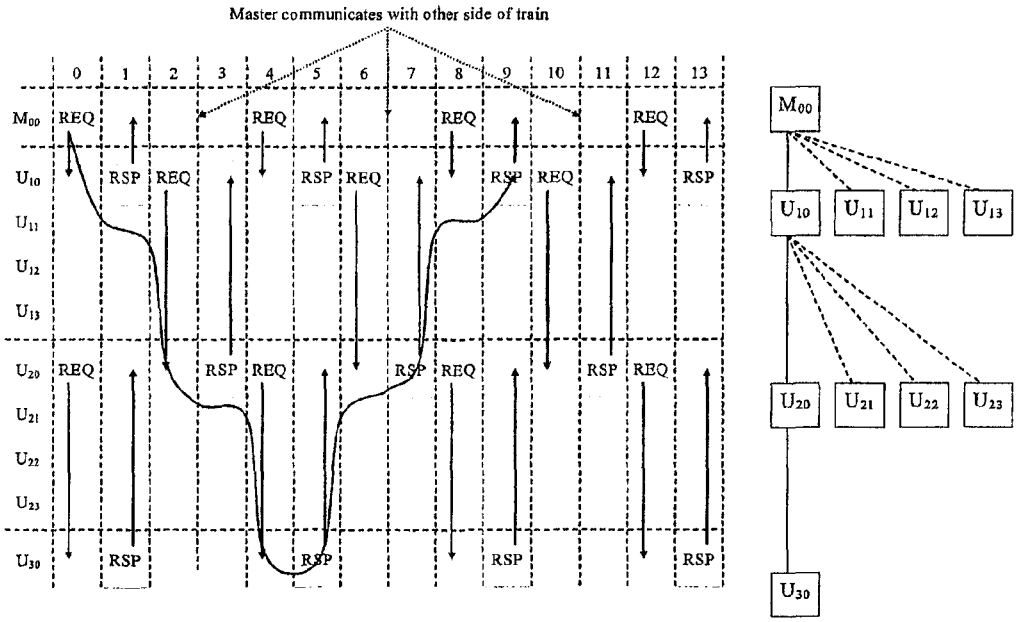
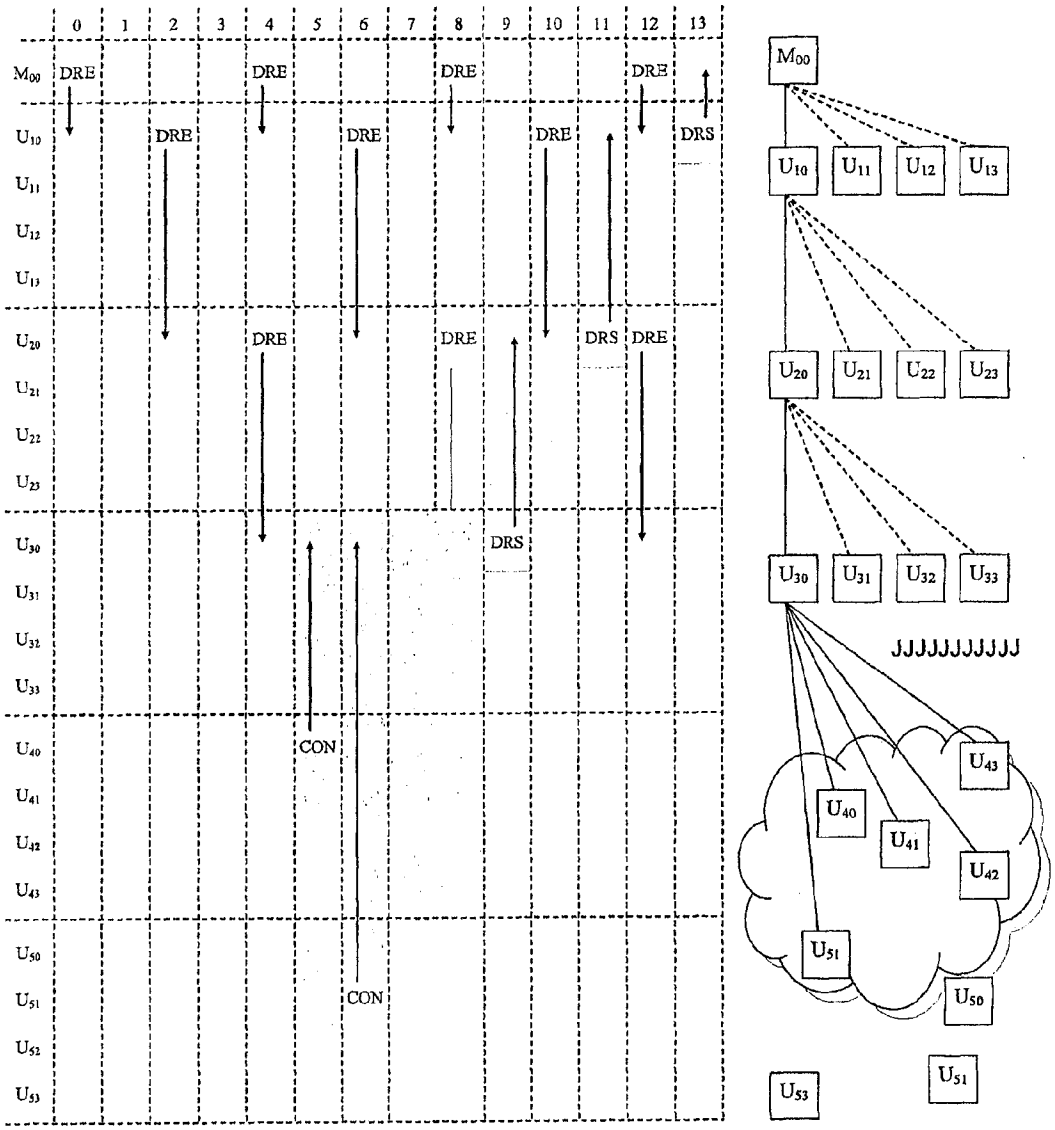


Figure 8



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Figure 9



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Figure 10

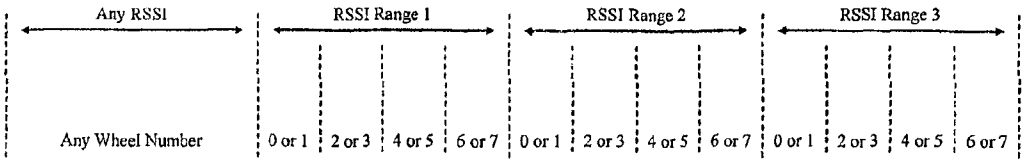
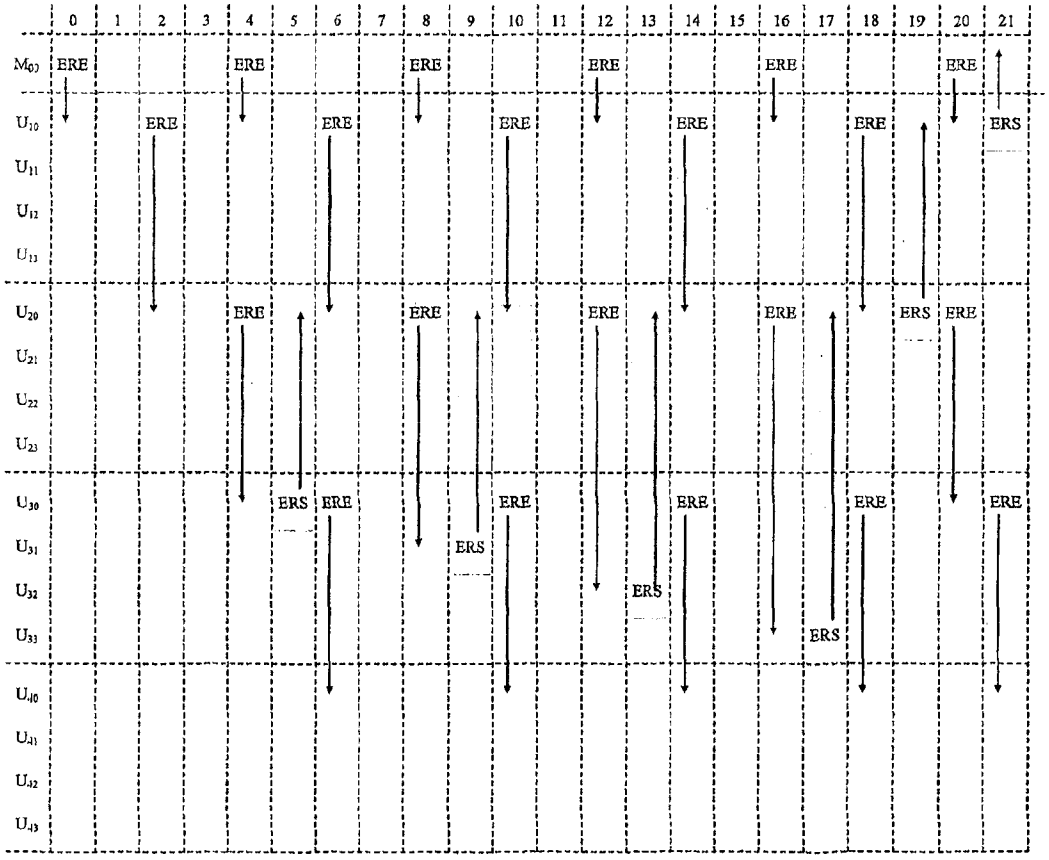
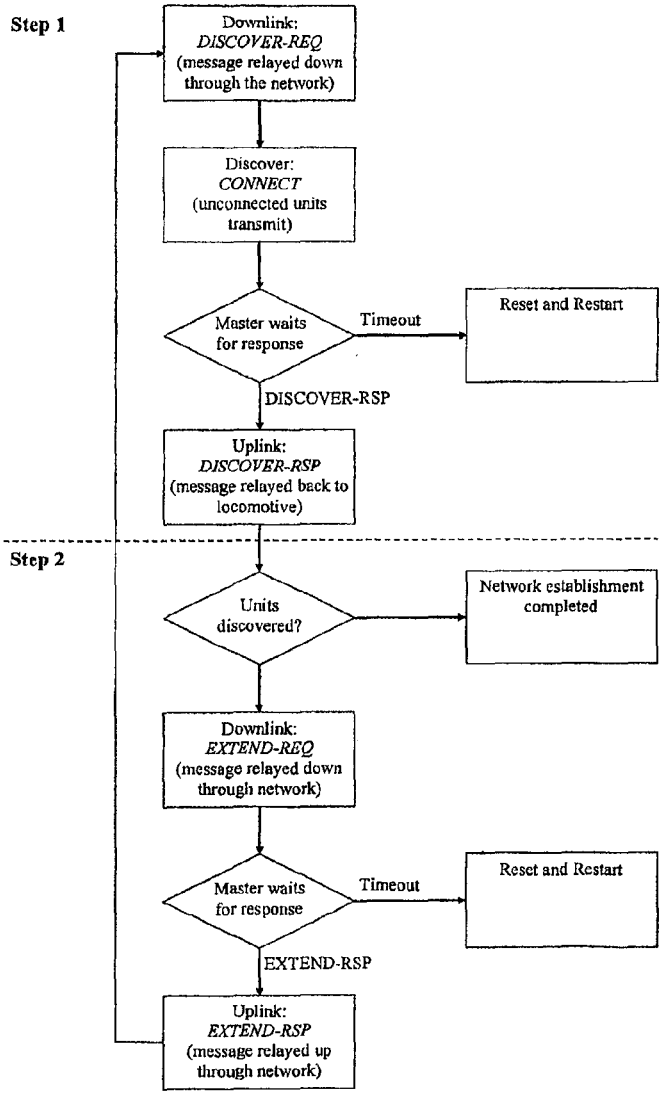


Figure 11



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Figure 12



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Figure 13

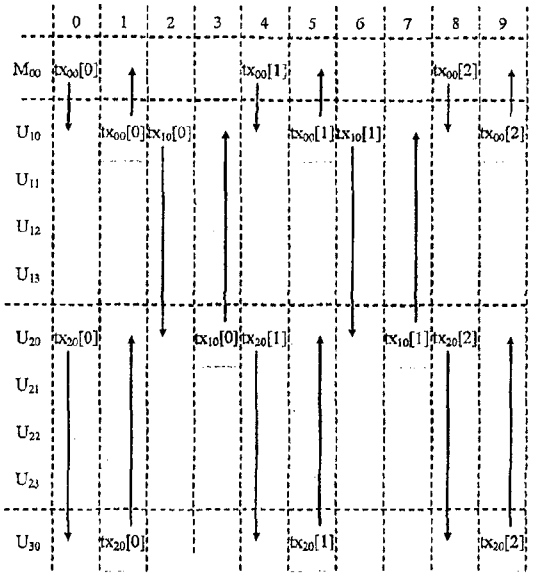
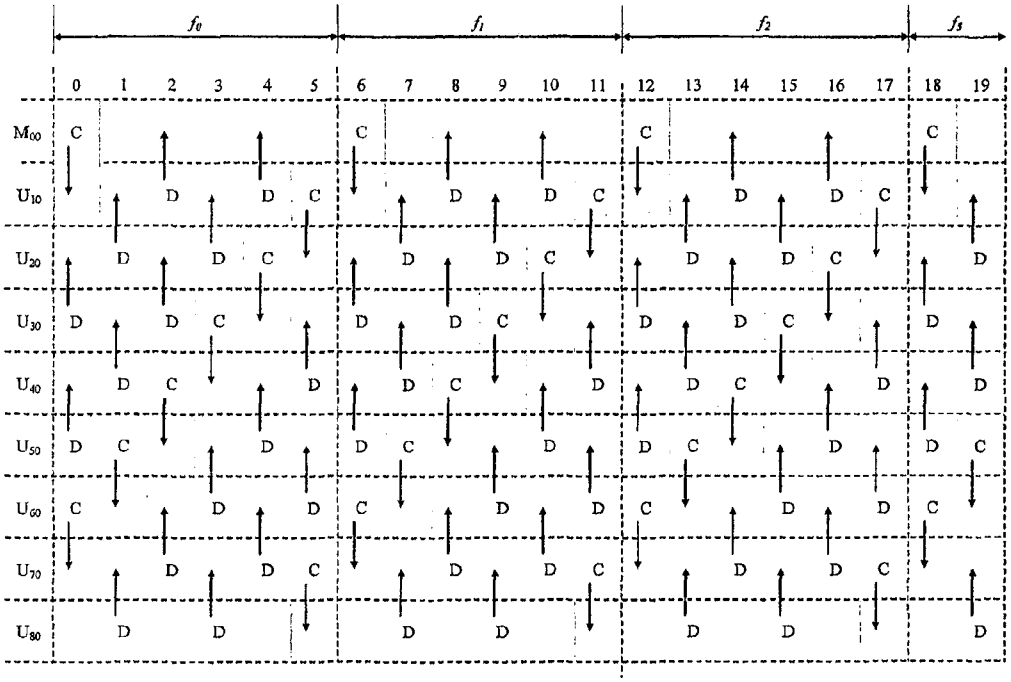
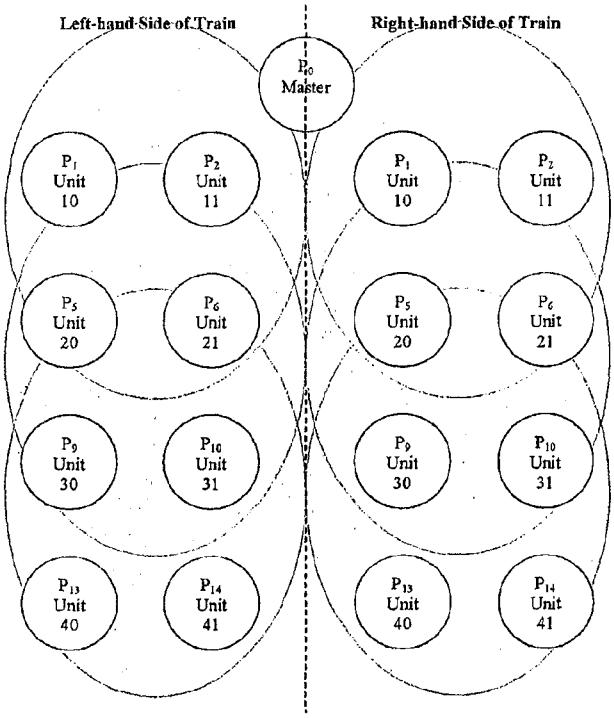


Figure 14



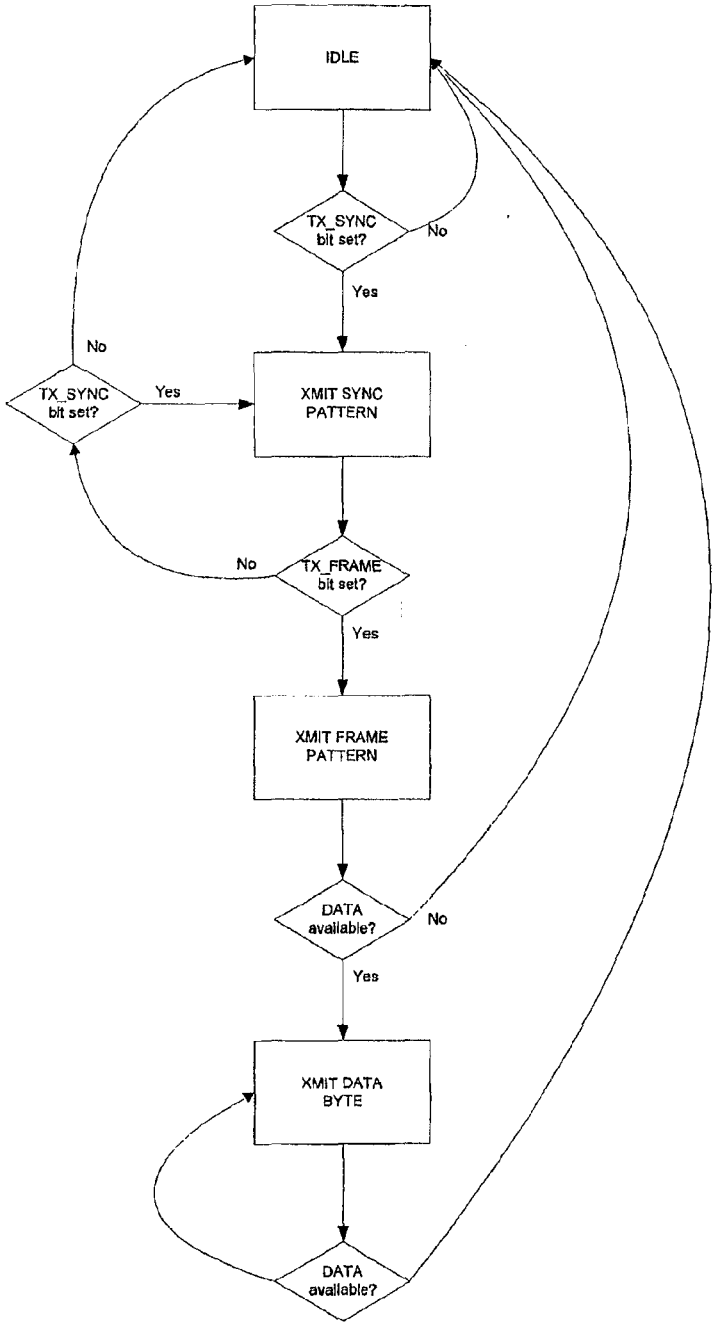
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Figure 15



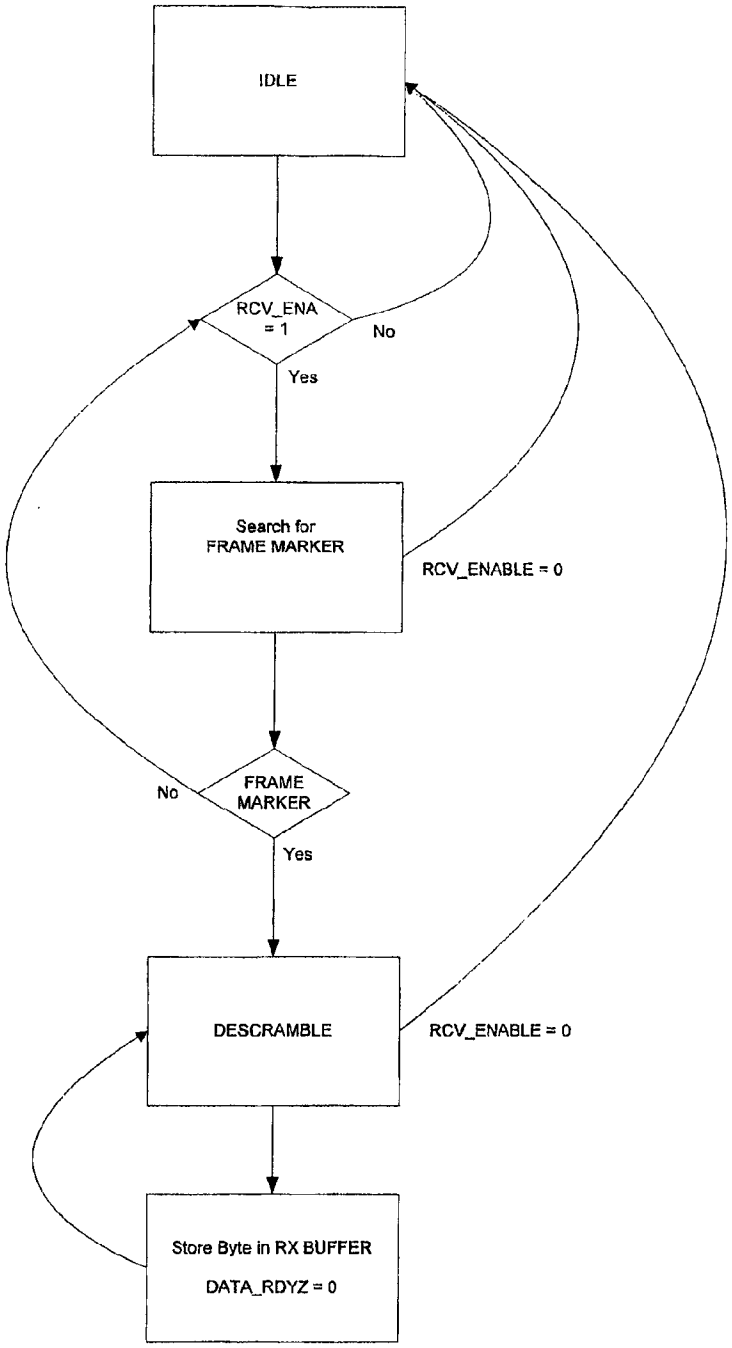
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Figure 16



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Figure 17



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Figure 18

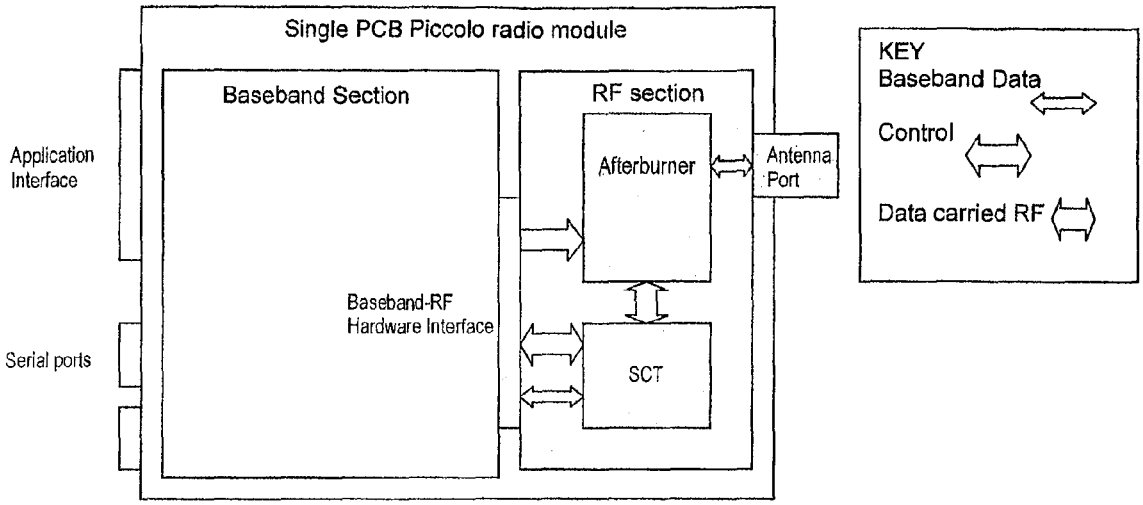
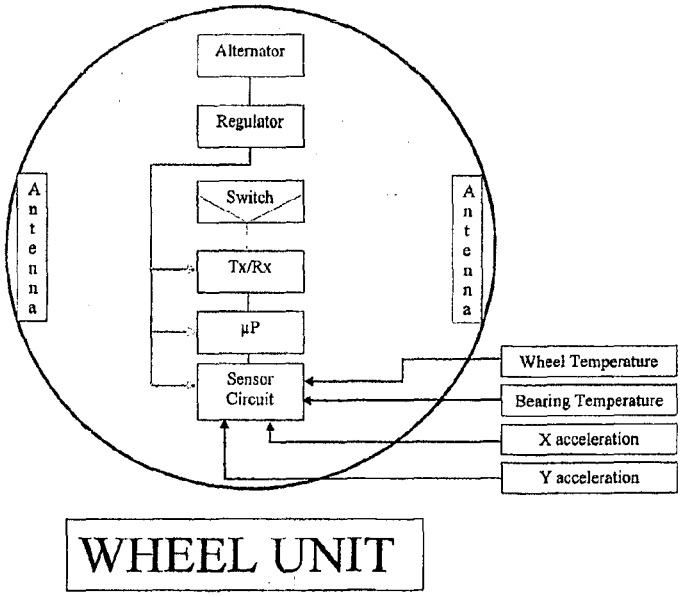


Figure 19



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Figure 20

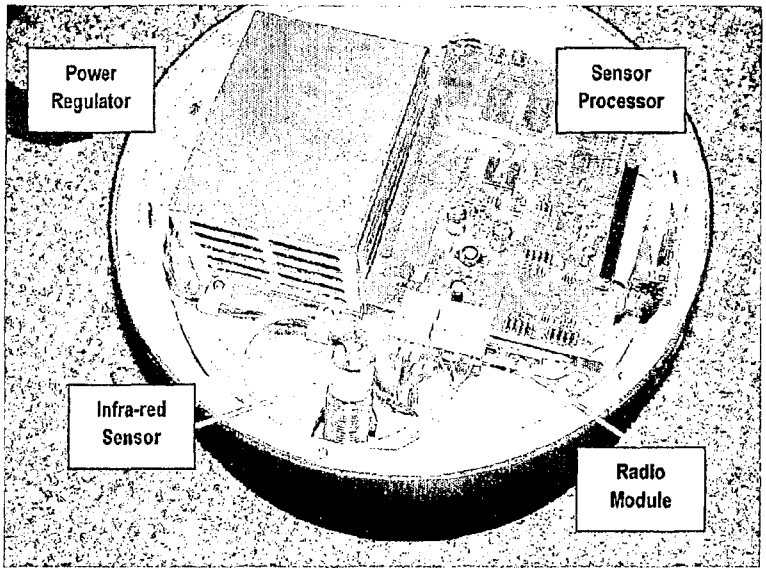
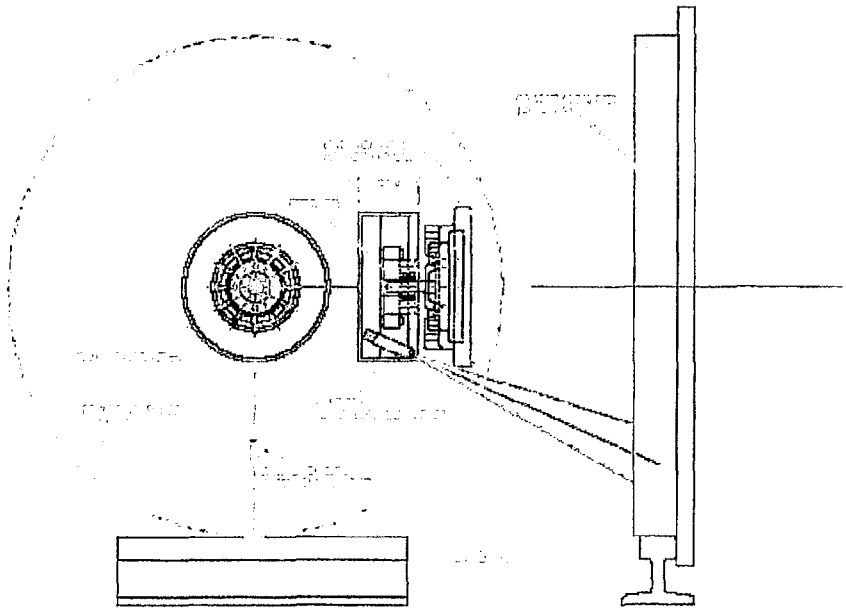
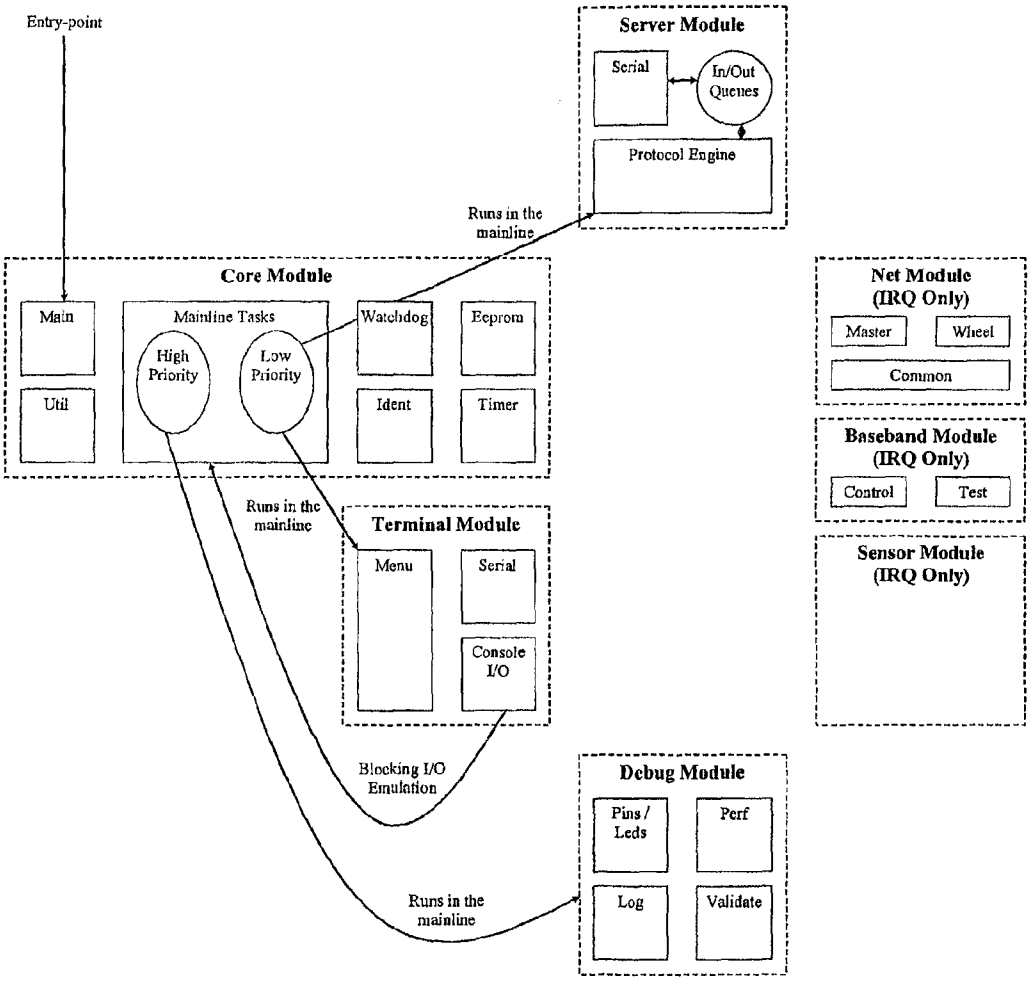


Figure 21



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Figure 22



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PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
Hecht, Gary
FOX ROTHSCHILD LLP
P.O. Box 5231
Princeton NJ 08543-5231
ETATS-UNIS D'AMERIQUE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference P36736A2	Date of mailing *(day/month/year)* 23 April 2015 (23-04-2015) **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/IB2013/003267	International filing date *(day/month/year)* 14 June 2013 (14-06-2013)
Applicant AMSTED RAIL COMPANY, INC.	

1. [X] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

   How? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Fascimile No.: (41-22) 338.82.70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 - 9.011.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with any applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **19 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the International Searching Authority European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040 Fax: (+31-70) 340-3016	Authorized officer VOYé-PICCOLI, Alexandra Tel: +49 (0)89 2399-8003

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
P36736A2		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/IB2013/003267	14 June 2013 (14-06-2013)	19 June 2012 (19-06-2012)
Applicant		
AMSTED RAIL COMPANY, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 6 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language,** the international search was carried out on the basis of:
      [X] the international application in the language in which it was filed
      [ ] a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. [ ] This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. [X] **Certain claims were found unsearchable** (See Box No. II)

3. [ ] **Unity of invention is lacking** (see Box No III)

4. With regard to the **title,**
   [X] the text is approved as submitted by the applicant
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**
   [X] the text is approved as submitted by the applicant
   [ ] the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings,**
   a. the figure of the **drawings** to be published with the abstract is Figure No. 3A
      [ ] as suggested by the applicant
      [X] as selected by this Authority, because the applicant failed to suggest a figure
      [ ] as selected by this Authority, because this figure better characterizes the invention
   b. [ ] none of the figures is to be published with the abstract

Form PCT/ISA/210 (first sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2013/003267

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 5-46, 50
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/003267

A. CLASSIFICATION OF SUBJECT MATTER
INV. B61L15/00 B61L27/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B61L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/105536 A1 (STI RAIL PTY LTD [AU]; SEARLE DONALD STEPHEN [AU]; WINKINS CHARLES RIC) 10 November 2005 (2005-11-10) page 1, line 4 - line 6 page 3, line 19 - line 27 page 5, line 17 - page 8, line 17 page 8, line 31 - page 9, line 22 figures 2,19-22 ----- -/--	1-4, 47-49

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 April 2015	23/04/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Janhsen, Axel

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	EP 2 650 191 A1 (PROGRESS RAIL SERVICES CORP [US]) 16 October 2013 (2013-10-16) paragraph [0001] paragraph [0011] - paragraph [0012] paragraph [0016] - paragraph [0017] paragraph [0024] - paragraph [0025] paragraph [0033] - paragraph [0034] paragraph [0041] paragraph [0045] paragraph [0049] figures 1,2 -----	1-4, 47-49

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2013/003267

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2005105536 A1	10-11-2005	EP 1747135 A1	31-01-2007
		US 2008195265 A1	14-08-2008
		WO 2005105536 A1	10-11-2005
EP 2650191 A1	16-10-2013	EP 2650191 A1	16-10-2013
		US 2013270396 A1	17-10-2013

Form PCT/ISA/210 (patent family annex) (April 2005)

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 5-46, 50

1 The international search Authority hereby confirms that the preliminary search made by this Authority, pursuant to Art. 15 PCT, has revealed that the description, claims or drawings fail to comply with the PCT requirements to such an extent that a meaningful search cannot be carried out in relation to this international application (Art. 17(2)(a)(ii) PCT). Pursuant to paragraph 9.34 and 9.35 of the PCT international search and examination guidelines, this authority required some further clarification.

2 The set of claims does comprise four independent apparatus claims 1, 5, 10 and 17 as well as two independent method claims 37 and 47 with different scope. This creates doubt about the invention to be claimed, rendering all claims unclear according to Art. 6 PCT. The set of claims should only comprise one single independent claim per category of claims for reasons of conciseness.

3 The applicant was invited to should indicate, which one of the above mentioned groups of claims should be search and examined. However, he did not respond to the invitation.

Accordingly, only the first set of system claims 1-4 and the corresponding method claims 47-49 were searched and examined.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) declaration be overcome.

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PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: GARY A. HECHT
FOX ROTHSCHILD LLP
997 LENOX DRIVE, BUILDING 3
LAWRENCEVILLE, NJ 08648-2311

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 27 APR 2015
Applicant's or agent's file reference 037659.00056	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US2014/072380	International filing date *(day/month/year)* 24 December 2014
Applicant AMSTED RAIL COMPANY, INC.	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **19 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 Telephone No. PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 037659.00056	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2014/072380	International filing date *(day/month/year)* 24 December 2014	(Earliest) Priority Date *(day/month/year)* 24 December 2013
Applicant AMSTED RAIL COMPANY, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☒ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

   a. the figure of the **drawings** to be published with the abstract is Figure No. 1

   ☐ as suggested by the applicant.

   ☒ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

Form PCT/ISA/210 (first sheet) (July 2009)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 037659.00056	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2014/072380	International filing date *(day/month/year)* 24 December 2014	(Earliest) Priority Date *(day/month/year)* 24 December 2013
Applicant AMSTED RAIL COMPANY, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☒ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

   a. the figure of the **drawings** to be published with the abstract is Figure No. 1

   ☐ as suggested by the applicant.

   ☒ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

Form PCT/ISA/210 (first sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/072380

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

SEE CONTINUATION SHEET ATTACHED

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-55, 60-65

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/072380

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B61L 15/00 (2015.01)
CPC - B61L 15/0072 (2015.04)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B60T 17/22; B61L 15/00; G01K 7/02; G06F 19/00; G08B 21/18 (2015.01)
USPC - 246/169; 340/438, 870.16, 870.17; 374/152; 701/19, 20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - B60T 17/22, 17/228; B61K 9/04; B61L 15/0018, 15/0027, 15/0054, 15/0072, 15/0081, 2205/04 (2015.04) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar.
Search terms used: train, railcar, sensor, communication, wireless, management, analyze, operational, anomalies, remote, receiver, node, collect, thermo, temperature, data, parameter, network

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7,688,218 B2 (LEFEBVRE et al) 30 March 2010 (30.03.2010) entire document	1-30, 33-44, 46, 48-50, 54, 60-65
--		----------
Y		31, 32, 45, 47
Y	US 2009/0173840 A1 (BROWN et al) 09 July 2009 (09.07.2009) entire document	31, 32, 45, 47
A	US 8,370,006 B2 (KUMAR et al) 05 February 2013 (05.02.2013) entire document	1-55, 60-65
A	US 7,336,156 B2 (ARITA et al) 26 February 2008 (26.02.2008) entire document	1-55, 60-65
A	US 2007/0241610 A1 (SMITH) 18 October 2007 (18.10.2007) entire document	1-55, 60-65

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 April 2015	27 APR 2015

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

CONTINUATION OF BOX III

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees need to be paid.

Group I, claims 1-55, 60-65 are drawn to a remote receiver.
Group II, claim 56 is drawn to mesh networks.
Group III, claims 57-59 are drawn to a wireless sensor node.

The inventions listed in Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1, because under PCT Rule 13.2 they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I, detecting operational anomalies on a train comprising communicating a message to a remote receiver when an anomaly is detected, are not present in Groups II or III; the special technical features of Group II, a system detecting operational anomalies on a train comprising, train-based mesh network, railcar-based mesh networks, a distributed complex event processing engine, are not present in Groups I or III; and the special technical features of Group III, wireless sensor node comprising a protective housing, a power source, an accelerometer, and an electrical circuitry, are not present in Groups I or II.

Groups I-III share the technical features of sensors located on railcars. However, these shared technical features do not represent a contribution over the prior art. Specifically, US 2012/0046811 A1 to Murphy et al., is in the field of railcar handbrake monitor (Abstract) and teaches of sensors located on railcars (Para. [0032], railcar 10 provided with a motion detection device 72 which can include motion sensors, tilt sensors).

Groups I and II share the technical features of communication management units mounted railcars and sensors located on railcars. Specifically, US 2012/0046811 A1 to Murphy et al., is in the field of railcar handbrake monitor (Abstract) and teaches of communication management units mounted railcars, and sensors located on railcars (Para. [0032], railcar 10 provided with a motion detection device 72 located in the CMU 70 [communication management unit] which can include motion sensors, tilt sensors).

Since none of the special technical features of the Groups I-III inventions are found in more than one of the inventions, unity is lacking.

Electronic Acknowledgement Receipt

EFS ID:	29699800
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht/Patricia Frisoli
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	037659.00062 (P36736B US)
Receipt Date:	06-JUL-2017
Filing Date:	18-MAY-2016
Time Stamp:	11:34:18
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	IDS_FINAL__.pdf	1118463 b3e0e3bf8c324a36fb139f5da4198c0205ac9ed2	no	12

Warnings:

Information:					
A U.S. Patent Number Citation is required in the Information Disclosure Statement (IDS) form. You may remove the form to add the required data in order to correct the Informational Message or if you chose not to, the image of the form will be processed and be made available within the Image File Wrapper (IFW) system. However, no data will be extracted from this form. Any additional data such as Foreign Patent Documents or Non Patent Literature will be manually reviewed and keyed into USPTO systems.					
2	Foreign Reference	P36736B_US_EP_1548419.pdf	4373950 ddcd7e3526725346f8c4d4e2bf05eb7f4c2d2b37	no	103
Warnings:					
Information:					
3	Foreign Reference	P36736B_US_EP_2650191.pdf	365876 02fca8fe8598e6dc08c16025fca0caaa47bb6484	no	8
Warnings:					
Information:					
4	Foreign Reference	P36736B_US_GB_2295207.pdf	394156 89ec5858869a209801898d98d3f9649e670dc4d1	no	15
Warnings:					
Information:					
5	Foreign Reference	P36736B_US_JP_05213195.pdf	301238 b2e1e6537537c44bd72399bb8d0c9d5b6d9734df	no	9
Warnings:					
Information:					
6	Foreign Reference	P36736B_US_JP_05343294.pdf	1223677 5bb02f184427b5b4f808fc437a5fbb7a1652092b	no	22
Warnings:					
Information:					
7	Foreign Reference	P36736B_US_JP-0815099.pdf	359915 cd948f8107b2252d8a8cba1df8c0610ca1d3cb4a	no	8
Warnings:					
Information:					
8	Foreign Reference	P36736B_US_JP_10217968.pdf	524880 c5d1cac6105891f6fd7597849bfde4517ccd8ea9	no	9

Warnings:					
Information:					
9	Foreign Reference	P36736B_US_JP_11192948.pdf	876766 9a69c5387468553f2512338791ec0a98d0a3bd0d	no	14
Warnings:					
Information:					
10	Foreign Reference	WO_2005105536.pdf	2619218 a250b3dfc32a717e44357c5dc48eab7f343396b9	no	38
Warnings:					
Information:					
11	Non Patent Literature	P36736B_US_Topolev_publication.pdf	129953 9b8ccc127ea972478efbcfd81225d3c31dcebd9e	no	3
Warnings:					
Information:					
12	Non Patent Literature	P36736_B_US_Balkov_et_al_publication.pdf	236980 ee42169e1d3785d9227e25a1b80453974897fd29	no	4
Warnings:					
Information:					
13	Non Patent Literature	P36736_B_US_MSI_9300_Series_publication.pdf	2508418 0ebdce3c1409c8b0d1f097074d004ca10c21685f	no	35
Warnings:					
Information:					
14	Non Patent Literature	P36736B_US_Dillon_Extreme_Dynamometer_publication.pdf	1433191 0ea5cfadf7bf80b3ddbb8ce718bab58fb4e70ea5	no	44
Warnings:					
Information:					
15	Non Patent Literature	24448639_1_web_pages_lat_lon_com.pdf	7483475 98054982dcebdc05b2c7deec66708b6188e52594	no	13
Warnings:					
Information:					

16	Non Patent Literature	24448705_1_Transcore_web_pages.pdf	624890 97b7e1c6cde1a4f73df3c00a4d6d41c982e41959	no	3
Warnings:					
Information:					
17	Non Patent Literature	24448657_1_ID_Systems_web_pages.pdf	4123613 d18b603da935239122d7e8825d891a56ba424a52	no	6
Warnings:					
Information:					
18	Non Patent Literature	24448693_1_Microstrain_web_pages.pdf	9944877 ef8b3fff307549dd038fbd47cd4154d79e7be0a6	no	17
Warnings:					
Information:					
19	Non Patent Literature	P36736B_US_InternationalSearchReport_4_23_2015.pdf	240210 a4e065f1dcc49374e18c243fa92cbadbf13ada22	no	7
Warnings:					
Information:					
20	Non Patent Literature	P36736B_US_PCT_Intl_Search_Rept_Intl_App_PCT_US2014_072380_dated4_27_15.pdf	418323 6e042cb5f2cd1ca7a836d4a7c883c2802e54a07d	no	6
Warnings:					
Information:					
		Total Files Size (in bytes):	39302069		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

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Electronic Acknowledgement Receipt

EFS ID:	29700901
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht/Patricia Frisoli
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	037659.00062 (P36736B US)
Receipt Date:	06-JUL-2017
Filing Date:	18-MAY-2016
Time Stamp:	12:29:06
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Non Patent Literature	Part_1_IDS_for_Salco_Tech.pdf	11535705 39e1a6bce4aa383f07d0b055f5f5209b27715b68	no	10

Warnings:

Information:					
2	Non Patent Literature	Part_2_IDS_for_Salco_Tech.pdf	14009964 714a606421f36b09b96e72c5c6e2bdeb3c0f2c97	no	9
Warnings:					
Information:					
3	Non Patent Literature	Part_3_IDS_for_Salco_Tech.pdf	6982169 99773ebda89850b4a583e081eab5a7d92c69ec0d	no	6
Warnings:					
Information:					
4	Non Patent Literature	Part_4_IDS_for_Salco_Tech.pdf	8412064 2927b9ee6b76d941cb57a1cb4a492af93dac5fa6	no	7
Warnings:					
Information:					
5	Non Patent Literature	Lat_Lon_Printout_of_Web_pages.pdf	10086077 7111bbf7cd63e7d5666479c7bd908df0e4e69838	no	13
Warnings:					
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6	Non Patent Literature	SkyBitz_Printout_of_Web_pages.pdf	16746992 9c9b620f4ec909f70467500142c0a07093bc47ba	no	24
Warnings:					
Information:					
			Total Files Size (in bytes):	67772971	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

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If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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Courtesy Reminder for
Application Serial No: 15/158,018

Attorney Docket No: 037659.00062 (P36736B US)
Customer Number: 29880
Date of Electronic Notification: 06/29/2017

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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15158018
Filing Date	2016-05-18
First Named Inventor	MARTIN ET AL.
Art Unit	3744
Examiner Name	
Attorney Docket Number	037659.00062(P36736B US)

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3854417		1974-12-17	MacDonnell et al.	
	2	4134464		1979-01-16	Johnson et al.	
	3	4296707		1981-10-27	Kennedy	
	4	4368927		1983-01-18	Billingsley et al	
	5	4801288		1989-01-31	Schmitt et al.	
	6	4905795		1990-03-06	Rains	
	7	5038605		1991-08-13	Tews et al.	
	8	5394137		1995-02-28	Orschek	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	9	5410911		1995-05-02	Severinsson	
	10	5603556		1997-02-18	Klink	
	11	5701974		1997-12-30	Kanjo et al.	
	12	6006868		1999-12-28	Klink	
	13	6014600		2000-01-11	Ferri et al.	
	14	6170619	B1	2001-01-09	Sheriff et al.	
	15	6175784	B1	2001-01-16	Jicha et al.	
	16	6237722	B1	2001-05-29	Hammond et al.	
	17	6397978	B1	2002-06-04	Jackson et al.	
	18	6474450	B1	2002-11-05	Ring et al.	
	19	6739675	B1	2004-05-25	Scharpf et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15158018
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	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	20	6823242	B1	2004-11-23	Ralph	
	21	7114596	B2	2006-10-03	Borugian	
	22	7180019	B1	2007-02-20	Chiou et al.	
	23	RE40099	E	2008-02-26	Stephens et al.	
	24	8033236	B2	2011-10-11	Michel et al.	
	25	8060264	B2	2011-11-15	Oestermeyer et al.	
	26	6474451	B1	2002-11-05	O'Brien, Jr.	
	27	3718040		1973-02-27	Freeman et al.	
	28	4812826		1989-03-14	Kaufman et al.	
	29	5381090		1995-01-10	Adler et al.	
	30	5440184		1995-08-08	Samy et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15158018
	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	31	5446451		1995-08-29	Grosskopf, Jr.	
	32	5503030		1996-04-02	Bankestrom	
	33	5682139		1997-10-28	Pradeep et al.	
	34	5691980		1997-11-25	Welles, II et al.	
	35	5810485		1998-09-22	Dublin, Jr. et al.	
	36	6161962		2000-12-19	French et al.	
	37	6179471	B1	2001-01-30	Moretti et al.	
	38	6184798	B1	2001-02-06	Egri	
	39	6301531	B1	2001-10-09	Pierro et al.	
	40	6324899	B1	2001-12-04	Discenzo	
	41	6339397	B1	2002-01-15	Baker	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	42	6441324	B1	2002-08-27	Stimpson	
	43	6487478	B1	2002-11-26	Azzaro et al.	
	44	6535135	B1	2003-03-18	French et al.	
	45	6668216	B2	2003-12-23	Mays	
	46	7336156	B2	2008-02-26	Arita et al.	
	47	7688218	B2	2010-03-30	LeFebvre et al.	
	48	7698962	B2	2010-04-20	LeFebvre et al.	
	49	8212685	B2	2012-07-03	LeFebvre et al.	
	50	8244411	B2	2012-08-14	Baker	
	51	8370006	B2	2013-02-05	Kumar et al.	
	52	8672273	B2	2014-03-18	Brown et al.	

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	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	53	8751290	B2	2014-06-10	Schullian et al.	
	54					

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U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020111726	A1	2002-08-15	Dougherty et al.	
	2	20030058091	A1	2003-03-27	Petersen et al.	
	3	20030097885	A1	2003-05-29	Kell	
	4	20070062765	A1	2007-03-22	Michel et al.	
	5	20070084676	A1	2007-04-19	Vithani et al.	
	6	20070151812	A1	2007-07-05	Michel et al.	
	7	20080179269	A1	2008-07-31	Bachman	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15158018
	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	8	20080252515	A1	2008-10-16	Oestermeyer et al.	
	9	20090001226	A1	2009-01-01	Haygood	
	10	20100200307	A1	2010-08-12	Toms	
	11	20120037435	A1	2012-02-16	Duehring	
	12	20120046811	A1	2012-02-23	Murphy et al.	
	13	20020017439	A1	2002-02-14	Hill et al.	
	14	20050259619	A1	2005-11-24	Boettle et al.	
	15	20060264221	A1	2006-11-23	Koike et al.	
	16	20070241610	A1	2007-10-18	Smith	
	17	20080195265	A1	2008-08-14	Searle et al.	
	18	20090173840	A1	2009-07-09	Brown et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15158018
	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	19	20110270475	A1	2011-11-03	Brand et al.	
	20	20110282540	A1	2011-11-17	Armitage et al.	
	21	20120051643	A1	2012-03-01	Ha et al.	
	22	20150083869	A1	2015-03-26	LeFebvre et al.	

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FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	1548419	EP	A1	2005-06-00	NSK Ltd.		☐
	2	2650191	EP	A1	2013-10-00	Progress Rail Services Corporation		☐
	3	2295207	GB	A	1996-05-00	The Torrington Company		☐
	4	05213195	JP	A	1993-08-00	Sumitomo Metal Ind Ltd		☐
	5	05343294	JP		1993-12-00	NEC Corp		☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15158018
	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	6	0815099	JP		1996-01-00	Sumitomo Metal Ind Ltd		☐
	7	10217968	JP		1998-08-00	Toshiba Corp		☐
	8	11192948	JP		1999-07-00	Toshiba Corp		☐
	9	2005105536	WO	A1	2005-11-00	Sti Rail Pty Ltd		☐

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T5
	1	Topolev, V.P.; Automation of Strain-gauge Crane Scales; Feb. 1966; Translated from Izmeritel'naya Tekhnika, No. 2, pp. 81-82	☐
	2	Balkov, P.O. et al; Electrical Strain-guage Scales; Oct. 1961; Tanslated from Izmeritel'naya Tekhnika, No. 10, pp. 17-20	☐
	3	MSI-9300 Series User Guide, Rev 1 Jul. 27, 2002 for SW Ver 1-1	☐
	4	Dillon EDxtreme Dynamometer and Crane Scale User's Manual, Dec. 2008 EDX_U.P65 PN 29808-0011 Issue AC	☐
	5	See attached Information Disclosure Statement for Salco Technologies, LLC Handbrake Sensor - Brochure dated Mar. 30, 2007	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	6	http://web.archive.org/web/20130206222004/http://lat-lon.com/gps-products/locomotive-monitoring unit, http://web.archive.org/web/20130206221020/http://lat-lon.com/gps-products/solar-tracking-unit http://web.archive.org/web/20130205074831/http://lat-lon.com/gps-products-sensors Available on the Internet at least as early as Feb. 6, 2013	☐
	7	Printout of web pages found at http:/lat-lon.com/Available on the Internet at least as early as Sep. 23, 2013	☐
	8	Printout of web pages found at http://www.skybitz.com/Available on the Internet at least as early as Sep. 23, 2013	☐
	9	Printout of web pages found at http://www.transcore.com/Available on the Internet at least as early as Sep. 23, 2013	☐
	10	Printout of web pages found at http://www.id-systems.com/Available on the Internet at least as early as early Sep. 23, 2013	☐
	11	Printout of web pages found at http://www.microstrain.com/wireless sensors Available on the Internet at least as early as Sep. 23, 2013	☐
	12	International Search Report in related WO Application No. PCT/IB2013/03267, dated Apr. 23, 2015	☐
	13	International Search Report in WO Application No. PCT/US2014/072380, dated Apr. 27, 2015	☐

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[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

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	Application Number	15158018
	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2017-06-26
Name/Print	Gary A. Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Electronic Acknowledgement Receipt

EFS ID:	30318356
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht/Deborah Fowler
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	037659.00062 (P36736B US)
Receipt Date:	11-SEP-2017
Filing Date:	18-MAY-2016
Time Stamp:	09:52:02
Application Type:	Utility under 35 USC 111(a)

Payment information:

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	P36736B_US_IDS_transmittal_9_11_17.pdf	21583 54611bef5afb76bbe7ffa7d30374cc65190b264b	no	2

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New Applications Under 35 U.S.C. 111

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If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: **A. Martin**	Group Art Unit: **3668**
Application No: **15/158,018**	Examiner: **Yazan A Soofi**
Filing Date: **5/18/2016**	Attorney Docket: **P36736B US**
For: **System and Method for Monitoring Railcar Performance**	Customer No. **29880**
	Confirmation No: **1036**

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

SUBMISSION OF CORRECTED INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sir:

This communication is supplemental to the Information Disclosure Statement, electronically filed on July 6, 2017. Applicant notes that, in the "Foreign Patent Documents" section of the Information Disclosure Statement filed on July 6, 2017, the names of the respective applicants for the foreign patent documents listed therein were omitted. Accordingly, Applicant encloses herewith a corrected Information Disclosure Statement by Applicant (Form PTO/SB/08a (03-15)) which has been updated to include the names of the respective applicants for the listed foreign patent documents.

Applicant does not believe that any fee is required in connection with this submission. However, if the U.S. Patent and Trademark Office determines that a fee is required in connection with this submission, we hereby authorize the U.S. Patent and Trademark Office to charge the applicable fee to our Deposit Account, No. 50-1943.

Favorable action in connection with this submission is respectfully solicited.

Respectfully submitted,

September 11, 2017 /gah/

Gary Hecht
Reg. No. 36, 826
Attorney for Applicant

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Electronic Patent Application Fee Transmittal

Application Number:	15158018
Filing Date:	18-May-2016
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Filer:	Gary A. Hecht/Deborah Fowler
Attorney Docket Number:	037659.00062 (P36736B US)

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
		Total in USD ($)		**180**

Electronic Acknowledgement Receipt

EFS ID:	30611651
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht/Deborah Fowler
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	037659.00062 (P36736B US)
Receipt Date:	10-OCT-2017
Filing Date:	18-MAY-2016
Time Stamp:	14:41:50
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$180
RAM confirmation Number	101117INTEFSW14425600
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Fee Worksheet (SB06)	fee-info.pdf	30846 5363d7775bbefe408ffe57f65aa54e4fe261f0f4	no	2

Warnings:	
Information:	
Total Files Size (in bytes):	30846

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Andrew H. Martin	:	Confirmation No.: 1036
Application No.: 15/158,018	:	Group Art Unit: 3668
Filed: May 18, 2016	:	Examiner: Yazan A. Soofi

Title: SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

RESPONSE TO OFFICE ACTION

This Response to Office Action and one-month extension of time is in reply to the Office Action dated June 29, 2017 in this patent application.

Claims begin on page 2.

Remarks begin on page 6.

CLAIMS

Claims 1-36 (canceled)

Claim 37 (original): A method of monitoring operational characteristics of a railcar comprising the steps of:

a. receiving data or processed information regarding said operational characteristic from one or more sensing units on said railcar, said sensing units monitoring an operational characteristic of said railcar;

b. applying a heuristic to said received data to determine deviations from nominal operating conditions;

c. assigning a severity level to said deviations from nominal operating conditions; and

d. determining an alarm condition based on said assigned severity level.

Claim 38 (original): The method of claim 37 further comprising the initial step of establishing wireless communication with said one or more remote sensing units.

Claim 39 (original): The method of claim 38 wherein said one or more remote sensing units form a mesh network.

Claim 40 (original): The method of claim 38 wherein steps a-d are executed by a processing unit located on said railcar.

Claim 41 (original): The method of claim 40 wherein said processing unit located on said railcar is a part of said mesh network.

Claim 42 (original): The method of claim 38 further comprising the step of transmitting said alarm condition to a location remote from said railcar.

Claim 43 (original): The method of claim 38 further comprising the step of transmitting said data received from said one or more sensing units to a location remote from said railcar.

Claim 44 (original): The method of claim 38 further comprising the steps of:

a. receiving data from a plurality of railcars;

b. applying a heuristic to said received data to determine deviations from nominal operating conditions;

c. assigning a severity level to said deviations from nominal operating conditions;

d. determining an alarm condition based on said assigned severity level;

e. transmitting said raised alarm to a display unit on a train of which said plurality of railcars are a part.

Claim 45 (original): The method of claim 42 further comprising the steps of

a. determining a recommended course of action based on said alarm condition;

and

b. transmitting said recommended course of action to a display unit on a train of which said railcar is a part.

Claim 46 (canceled)

Claim 47 (original): A method of monitoring a temperature of a desired part of a railcar, comprising:

(a) sensing the temperature of a part of the railcar other than the desired part by use of a temperature sensor in thermal communication with said other part;

(b) determining the temperature of the desired part by use of the temperature sensed in step (a);

(c) determining if said temperature of the desired part is outside an acceptable range of temperatures; and

(d) transmitting an alarm if in step (c) it is determined that the temperature of the desired part is outside an acceptable range.

Claim 48 (original): A method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, further comprising the step of determining the temperature of the ambient air, which temperature is used in the determination of step (b).

Claim 49 (original): A method of monitoring a temperature of a desired part of a railcar in accordance with claim 47, wherein steps (a) through (d) are carried out by a single unit attached to said railcar.

Claim 50 (currently amended): The method of claim 37 wherein steps (a) through (d) can be carried out at different event engines distributed among at least two of said sensor [[unit]] units, a communication management unit, and a mobile or land base station.

Claim 51 (previously presented): A method for monitoring the operation of a railcar performed by a communication management unit disposed on said railcar comprising the steps of:

a. wirelessly receiving data from one or more sensing units which periodically collect readings from one or more sensors disposed on said railcar;

b. heuristically analyzing said received data to determine if an actual failure exists on said railcar or to predict potential or imminent failures based on a statistical analysis of said received data; and

c. communicating the results of said analysis to an off-railcar location.

Claim 52 (previously presented): The method of claim 51 wherein each of said sensing units can make a determination of an alarm condition based on data collected by the sensing unit, said method further comprising the step of:

a. wirelessly receiving notice of said alarm condition from said sensing unit; and

b. communicating said alarm condition to an off-railcar location.

Claim 53 (previously presented): The method of claim 51 further comprising the steps of:

a. making a determination of an alarm condition based on data received from two or more of said sensing units; and

b. communicating said alarm condition to an off-railcar location.

Claim 54 (previously presented): The method of claim 51 further comprising the step of placing said one or more sensing units in a stand-by state when said one or more sensing units is not reading data from any of said sensors or transmitting data.

Claim 55 (previously presented): The method of claim 51 further comprising the step of joining a mesh network consisting of one or more sensing units located on said railcar.

Claim 56 (previously presented): The method of claim 51 further comprising the step of joining a mesh network consisting of communication management units located on other railcars.

Claim 57 (previously presented): The system of claim 51 further comprising the steps of:

a. saving data received from said one or more sensing units in memory; and

b. comparing data received with said saved data to identify trends or deviations from normal readings of said data stored in memory.

Claim 58 (previously presented): A method for monitoring the operation of a railcar comprising:

a. collecting data at periodic intervals about one or more operating parameters of said railcar using one or more sensor units provided on said railcar;

b. communicating said collected data to a communication management unit;

c. analyzing said collected data by applying heuristics thereto to (i) determine if an actual failure exists and (ii) to predict potential or imminent failures based on a statistical analysis of said collected data.

Claim 59 (previously presented): The method of claim 58 further comprising the steps of: assessing the collected data to determine if an alarm condition exists; and wirelessly communicating said alarm condition to an off railcar location.

REMARKS

In the Office Action, the Office rejected claims 37-45 and 47-59. More specifically:

- The Office rejected claims 37-45 and 47-59 under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent Application Publication No. 20080195265 to Searle et al. ("Searle") in view of U.S. Patent No. 6,339,397 to Baker ("Baker").

Upon entry of these remarks, claims 37-45 and 47-59 will remain pending. Claim 50 has been amended to make "units" plural to correct the grammar. For the reasons discussed below, Applicant respectfully requests the Office to withdraw all rejections in this case.

IDS

An Information Disclosure Statement was filed on July 6, 2017, supplemented on September 11, 2017, without a fee for filing after the issuance of the Office Action dated June 29, 2017. A fee for the IDS was subsequently filed on October 10, 2017.

Rejections Under 35 U.S.C. §103(a)

Independent Claim 37

Independent claim 37 is nonobvious over Searle in view of Baker and in further view of Official Notice because the cited references, whether considered alone or in combination, fail to teach or suggest each and every limitation of independent claim 37. Specifically, the combination of Searle, Baker and Official Notice fails to teach or suggest at least the following limitations of claim 37:

- assigning a severity level to said deviations from nominal operating conditions; and
- determining an alarm condition based on said assigned severity level.

Searle is directed to a "train integrity network system" having "bogie units which monitor critical parameters relating to the condition of bogie components and the rail track they are travelling on." Searle at Abstract. As explained by Searle, the "bogie units monitor in real time various wheel and track factors…" and if "a monitored condition exceeds a predetermined threshold or parameter the processor will generate an alarm which is transmitted via a RF network to the server." *Id.* at [0072].

In contrast, claim 1 requires "applying a heuristic to said received data to determine deviations from nominal operating conditions", "assigning a severity level to said deviations from nominal operating conditions", and "determining an alarm condition based on said assigned severity level" (emphasis added). As explained in at least paragraph [0042] of the Specification of the present application, determining an alarm condition based on the assigned severity level avoids an excess of stoppages and delays that could result if an alarm was generated for every deviation that is detected.

Baker fails to resolve the deficiencies of Searle. Baker is directed to a portable self-contained tracking unit that includes a GPS receiver, a microprocessor and a transmitter. Baker at Abstract. Baker explains that a "GPS receiver 86…receives tracking information from various satellites of the GPS, via GPS antenna 88…This data is transmitted in digital form from the receiver to the microprocessor 84. This information includes latitude, longitude, heading, velocity, time, and elevation. Other defined data inputs such as multiple alarm states, high and low priority alarm alerts, and miscellaneous external measurements may be programmed into micro controller 84 through the user defined status inputs designated generally at 90." *Id* at 5:1-10.

As such, Baker sends both high and low priority alarm alerts as part of the data that is transmitted from a receiver to a microprocessor. In contrast, claim 37 requires "assigning a

severity level to said deviations from nominal operating conditions" and "determining an alarm condition based on said assigned severity level." Baker does not teach or suggest assigning a severity level or determining an alarm condition based on that severity level.

On page 3 of the Office Action, the Office states "Searle does not explicitly disclose wherein determining high level alarms based on data and alarms collected from said communication management unit. Searle in view of official notice does disclose collecting data and alarm from said communication management unit and displaying alarm condition. However Baker teaches determining high level alarms based on data and alarms collected from said communication management unit." The Office further provides on page 4 of the Office Action that "Baker is introduced to teach determining high level alarms based on data and alarms collected from said communication management unit."

Applicant notes that claim 1 does not include the limitation of "wherein determining high level alarms based on data and alarms collected from said communication management unit." As such, it is unclear whether this part of the rejection is applicable to claim 37 or not.

In addition, it is unclear as to what the Office is taking Official Notice of. The Office provides no explanation or justification for the use of Official Notice with respect to claim 37. However, Applicant traverses the application of Official Notice because it is not in compliance with the Office's own procedures.

Proper use of Official Notice requires compliance with several obligations expressly set forth in at least MPEP § 2144.03. The Office has failed to meet these obligations. MPEP § 2144.03(B), for example, expressly requires the Office to provide specific factual findings predicated on sound technical and scientific reasoning to support taking Official Notice. The Office should present an Applicant with the explicit basis on which Official Notice is based so that the Applicant is able to challenge the assertion in the next reply after the Office

action. MPEP § 2144.03(B). Naked assertions about what is allegedly known in the art, like those made at page 3 of the Office Action, cannot satisfy these requirements. Applicant respectfully requests that the Office provide a rationale and explanation of the Official Notice that is being taken that is based on sound and scientific reasoning.

Accordingly, for at least these reasons, claim 37 is are nonobvious over the cited references. In addition, because claims 38-45 depend from and incorporate all of the limitations of claim 37, these dependent claims are also non-obvious over the cited references. See MPEP § 2143.03. Accordingly, Applicant respectfully asks the Office to withdraw the §103(a) rejections associated with claims 37-45.

Dependent Claim 44

On pages 2-3 of the Office Action, the Office rejects dependent claim 44 as being obvious over Searle, Baker and Official Notice. As explained above, it is unclear as to what the Office is taking Official Notice of. The Office provides no explanation or justification for the use of Official Notice with respect to claim 44. However, Applicant traverses the application of Official Notice because it does not comply with the Office's own procedures.

Proper use of Official Notice requires compliance with several obligations expressly set forth in at least MPEP § 2144.03. The Office has failed to meet these obligations. MPEP § 2144.03(B), for example, expressly requires the Office to provide specific factual findings predicated on sound technical and scientific reasoning to support taking Official Notice. The Office should present an Applicant with the explicit basis on which Official Notice is based so that the Applicant is able to challenge the assertion in the next reply after the Office action. MPEP § 2144.03(B). Naked assertions about what is allegedly known in the art, like those made at page 3 of the Office Action, cannot satisfy these requirements. Applicant

respectfully requests that the Office provide a rationale and explanation of the Official Notice that is being taken that is based on sound and scientific reasoning.

Independent Claim 47

Independent claim 47 is nonobvious over Searle in view of Baker because the cited references, whether considered alone or in combination, fail to teach or suggest each and every limitation of independent claim 47. Specifically, the combination of Searle and Baker fails to teach or suggest at least the following limitations of claim 47:

- sensing the temperature of a part of the railcar other than the desired part by use of a temperature sensor in thermal communication with said other part; and
- determining the temperature of the desired part by use of the temperature sensed in step (a).

On page 7 of the Office Action, the Office asserts that paragraph [0104] of Searle discloses the above limitations. This paragraph explains that "there are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in FIG. 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis."

Claim 47, however, requires determining the temperature of a desired part of a railcar by use of the temperature that is sensed by a temperature sensor in thermal communication with a part of the railcar other than the desired part. Searle describes using two temperature

sensors for sensing the temperature of the hub of the wheel and one for measuring the temperature at the periphery of the wheel. But Searle does not teach or suggest determining one of those temperatures by use of the other temperature.

The Office Action indicates that claim 47 is rejected under 35 U.S.C. §103(a) as being unpatentable over Searle in view of Baker. However, the Office Action does not explain the relevance of Baker to claim 47. Regardless, Baker fails to resolve the deficiencies of Searle.

Accordingly, for at least these reasons, claim 47 is are nonobvious over the cited references. In addition, because claims 48-50, depend from and incorporate all of the limitations of claim 47, these dependent claims are also non-obvious over the cited references. See MPEP § 2143.03. Accordingly, Applicant respectfully asks the Office to withdraw the §103(a) rejections associated with claims 47-50.

Independent Claim 51

Independent claim 51 is nonobvious over Searle in view of Baker and in further view of Official Notice because the cited references, whether considered alone or in combination, fail to teach or suggest each and every limitation of independent claim 51. Specifically, the combination of Searle, Baker and Official Notice fails to teach or suggest at least the following limitations of claim 51:

- heuristically analyzing said received data to determine if an actual failure exists on said railcar or to predict potential or imminent failures based on a statistical analysis of said received data

The Office rejected claim 51 on the same grounds as it used to reject claim 37. However, claim 51 includes different limitations from claim 37 that are not addressed by the Office. For example, the limitation of "heuristically analyzing said received data to determine if an actual failure exists on said railcar or to predict potential or imminent failures based on a

statistical analysis of said received data" was not addressed by the Office. As such, Applicant is unsure of the applicability of Searle and Baker to claim 51.

On page 3 of the Office Action, the Office states "Searle does not explicitly disclose wherein determining high level alarms based on data and alarms collected from said communication management unit. Searle in view of official notice does disclose collecting data and alarm from said communication management unit and displaying alarm condition. However Baker teaches determining high level alarms based on data and alarms collected from said communication management unit." The Office further provides on page 4 of the Office Action that "Baker is introduced to teach determining high level alarms based on data and alarms collected from said communication management unit."

Applicant notes that claim 51 does not include a limitation of "wherein determining high level alarms based on data and alarms collected from said communication management unit." As such, it is unclear whether this part of the rejection is applicable to claim 51 or not.

In addition, it is unclear as to what the Office is taking Official Notice of. The Office provides no explanation or justification for the use of Official Notice with respect to claim 51. However, Applicant traverses the application of Official Notice because it does not comply with the Office's own procedures.

Proper use of Official Notice requires compliance with several obligations expressly set forth in at least MPEP § 2144.03. The Office has failed to meet these obligations. MPEP § 2144.03(B), for example, expressly requires the Office to provide specific factual findings predicated on sound technical and scientific reasoning to support taking Official Notice. The Office should present an Applicant with the explicit basis on which Official Notice is based so that the Applicant is able to challenge the assertion in the next reply after the Office action. MPEP § 2144.03(B). Naked assertions about what is allegedly known in the art, like

those made at page 3 of the Office Action, cannot satisfy these requirements. Applicant respectfully requests that the Office provide a rationale and explanation of the Official Notice that is being taken that is based on sound and scientific reasoning.

For the sake of completeness, though, Applicant traverses the rejection to the best of its ability. As explained above, Searle provides that "bogie units monitor in real time various wheel and track factors…" and if "a monitored condition exceeds a predetermined threshold or parameter the processor will generate an alarm which is transmitted via a RF network to the server." Searle at [0072]. Similarly, Baker provides that "data is transmitted in digital form from the receiver to the microprocessor 84. This information includes latitude, longitude, heading, velocity, time, and elevation. Other defined data inputs such as multiple alarm states, high and low priority alarm alerts, and miscellaneous external measurements may be programmed into micro controller 84 through the user defined status inputs designated generally at 90." Baker at 5:1-10. However, neither Searle nor Baker teach or suggest "heuristically analyzing said received data to determine if an actual failure exists on said railcar or to predict potential or imminent failures based on a statistical analysis of said received data" (emphasis added).

Accordingly, for at least these reasons, claim 51 is are nonobvious over the cited references. In addition, because claims 52-57 depend from and incorporate all of the limitations of claim 51, these dependent claims are also non-obvious over the cited references. See MPEP § 2143.03. Accordingly, Applicant respectfully asks the Office to withdraw the §103(a) rejections associated with claims 51-57.

Independent Claim 58

Independent claim 58 is nonobvious over Searle in view of Baker because the cited references, whether considered alone or in combination, fail to teach or suggest each and every limitation of independent claim 58. Specifically, the combination of Searle and Baker fails to teach or suggest at least the following limitations of claim 58:

- analyzing said collected data by applying heuristics thereto to (i) determine if an actual failure exists and (ii) to predict potential or imminent failures based on a statistical analysis of said collected data.

On page 12 of the Office Action, the Office acknowledges that Baker fails to teach or suggest the above-identified limitation, but asserts that Searle does. Applicant respectfully disagrees. As discussed above with respect to claim, Searle teaches the use of two sensors to sense the temperature of a wheel hub and the periphery of the wheel. According to Searle, "the outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis." Searle at [0104].

While Searle teaches comparing data against alarm triggering levels, it does not teach or suggest applying heuristics to determine if an actual failure exists **and** to predict potential or imminent failures based on a statistical analysis of the collected data as required by claim 58.

Accordingly, for at least these reasons, claim 58 is are nonobvious over the cited references. In addition, because claim 59 depends from and incorporates all of the limitations of claim 58, this dependent claim is also non-obvious over the cited references. See MPEP §

2143.03. Accordingly, Applicant respectfully asks the Office to withdraw the §103(a) rejections associated with claims 58 and 59.

CONCLUSION AND REQUEST FOR INTERVIEW

For the reasons stated in this document, Applicant respectfully asks the Office to reconsider and withdraw all rejections in this case.

If the next Office Action will not result in allowance of the claims, Applicant respectfully requests an interview to discuss any remaining issues. Applicant invites the Examiner to contact the undersigned attorney to schedule a time that is convenient for the Examiner.

The Commissioner is hereby authorized to charge any additional fees which may be required for this Response, or credit any overpayment, to Deposit Account No. 50-1943

Respectfully submitted,

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Date: October 13, 2017

Electronic Patent Application Fee Transmittal

Application Number:	15158018
Filing Date:	18-May-2016
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Filer:	Gary A. Hecht/Natalie Ward
Attorney Docket Number:	037659.00062 (P36736B US)

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension - 1 month with $0 paid	1251	1	200	200
Miscellaneous:				
			Total in USD ($)	**200**

Electronic Acknowledgement Receipt

EFS ID:	30655285
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht/Natalie Ward
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	037659.00062 (P36736B US)
Receipt Date:	13-OCT-2017
Filing Date:	18-MAY-2016
Time Stamp:	16:58:32
Application Type:	Utility under 35 USC 111(a)

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Payment Type	CARD
Payment was successfully received in RAM	$200
RAM confirmation Number	101617INTEFSW16585200
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Response_to_Office_Action_Amendment_00062.pdf	85138 e98014ff094091976d91e3aff7b3e9659ffa8302	yes	16

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	5
	Applicant Arguments/Remarks Made in an Amendment	6	16

Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	31011 b22851c457ab4fd84ea5c550bf456ca6e38b3bf8	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	116149	

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

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PTO/SB/06 (09-11)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 15/158,018	Filing Date 05/18/2016	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT **10/13/2017**

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 22	Minus	** 50	= 0	X $80 =	0
Independent (37 CFR 1.16(h))	* 4	Minus	***5	= 0	X $420 =	0
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	0

AMENDMENT

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
KIMBERLY PANNELL

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15158018
Filing Date	2016-05-18
First Named Inventor	MARTIN ET AL.
Art Unit	3744
Examiner Name	
Attorney Docket Number	037659.00062(P36736B US)

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3854417		1974-12-17	MacDonnell et al.	
	2	4134464		1979-01-16	Johnson et al.	
	3	4296707		1981-10-27	Kennedy	
	4	4368927		1983-01-18	Billingsley et al	
	5	4801288		1989-01-31	Schmitt et al.	
	6	4905795		1990-03-06	Rains	
	7	5038605		1991-08-13	Tews et al.	
	8	5394137		1995-02-28	Orschek	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /Y.A.S/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15158018
	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	9	5410911		1995-05-02	Severinsson	
	10	5603556		1997-02-18	Klink	
	11	5701974		1997-12-30	Kanjo et al.	
	12	6006868		1999-12-28	Klink	
	13	6014600		2000-01-11	Ferri et al.	
	14	6170619	B1	2001-01-09	Sheriff et al.	
	15	6175784	B1	2001-01-16	Jicha et al.	
	16	6237722	B1	2001-05-29	Hammond et al.	
	17	6397978	B1	2002-06-04	Jackson et al.	
	18	6474450	B1	2002-11-05	Ring et al.	
	19	6739675	B1	2004-05-25	Scharpf et al.	

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	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	20	6823242	B1	2004-11-23	Ralph	
	21	7114596	B2	2006-10-03	Borugian	
	22	7180019	B1	2007-02-20	Chiou et al.	
	23	RE40099	E	2008-02-26	Stephens et al.	
	24	8033236	B2	2011-10-11	Michel et al.	
	25	8060264	B2	2011-11-15	Oestermeyer et al.	
	26	6474451	B1	2002-11-05	O'Brien, Jr.	
	27	3718040		1973-02-27	Freeman et al.	
	28	4812826		1989-03-14	Kaufman et al.	
	29	5381090		1995-01-10	Adler et al.	
	30	5440184		1995-08-08	Samy et al.	

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	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	31	5446451		1995-08-29	Grosskopf, Jr.	
	32	5503030		1996-04-02	Bankestrom	
	33	5682139		1997-10-28	Pradeep et al.	
	34	5691980		1997-11-25	Welles, II et al.	
	35	5810485		1998-09-22	Dublin, Jr. et al.	
	36	6161962		2000-12-19	French et al.	
	37	6179471	B1	2001-01-30	Moretti et al.	
	38	6184798	B1	2001-02-06	Egri	
	39	6301531	B1	2001-10-09	Pierro et al.	
	40	6324899	B1	2001-12-04	Discenzo	
	41	6339397	B1	2002-01-15	Baker	

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	First Named Inventor	MARTIN ET AL.
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	Attorney Docket Number	037659.00062(P36736B US)

	42	6441324	B1	2002-08-27	Stimpson	
	43	6487478	B1	2002-11-26	Azzaro et al.	
	44	6535135	B1	2003-03-18	French et al.	
	45	6668216	B2	2003-12-23	Mays	
	46	7336156	B2	2008-02-26	Arita et al.	
	47	7688218	B2	2010-03-30	LeFebvre et al.	
	48	7698962	B2	2010-04-20	LeFebvre et al.	
	49	8212685	B2	2012-07-03	LeFebvre et al.	
	50	8244411	B2	2012-08-14	Baker	
	51	8370006	B2	2013-02-05	Kumar et al.	
	52	8672273	B2	2014-03-18	Brown et al.	

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	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	53	8751290	B2	2014-06-10	Schullian et al.	
	54					

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U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020111726	A1	2002-08-15	Dougherty et al.	
	2	20030058091	A1	2003-03-27	Petersen et al.	
	3	20030097885	A1	2003-05-29	Kell	
	4	20070062765	A1	2007-03-22	Michel et al.	
	5	20070084676	A1	2007-04-19	Vithani et al.	
	6	20070151812	A1	2007-07-05	Michel et al.	
	7	20080179269	A1	2008-07-31	Bachman	

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	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	8	20080252515	A1	2008-10-16	Oestermeyer et al.	
	9	20090001226	A1	2009-01-01	Haygood	
	10	20100200307	A1	2010-08-12	Toms	
	11	20120037435	A1	2012-02-16	Duehring	
	12	20120046811	A1	2012-02-23	Murphy et al.	
	13	20020017439	A1	2002-02-14	Hill et al.	
	14	20050259619	A1	2005-11-24	Boettle et al.	
	15	20060264221	A1	2006-11-23	Koike et al.	
	16	20070241610	A1	2007-10-18	Smith	
	17	20080195265	A1	2008-08-14	Searle et al.	
	18	20090173840	A1	2009-07-09	Brown et al.	

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	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	19	20110270475	A1	2011-11-03	Brand et al.	
	20	20110282540	A1	2011-11-17	Armitage et al.	
	21	20120051643	A1	2012-03-01	Ha et al.	
	22	20150083869	A1	2015-03-26	LeFebvre et al.	

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FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	1548419	EP	A1	2005-06-00			
	2	2650191	EP	A1	2013-10-00			
	3	2295207	GB	A	1996-05-00			
	4	05213195	JP	A	1993-08-00			
	5	05343294	JP		1993-12-00			

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	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	6	0815099	JP		1996-01-00			
	7	10217968	JP		1998-08-00			
	8	11192948	JP		1999-07-00			
	9	2005105536	WO	A1	2005-11-00			

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	Topolev, V.P.; Automation of Strain-gauge Crane Scales; Feb. 1966; Translated from Izmeritel'naya Tekhnika, No. 2, pp. 81-82	
	2	Balkov, P.O. et al; Electrical Strain-guage Scales; Oct. 1961; Tanslated from Izmeritel'naya Tekhnika, No. 10, pp. 17-20	
	3	MSI-9300 Series User Guide, Rev 1 Jul. 27, 2002 for SW Ver 1-1	
	4	Dillon EDxtreme Dynamometer and Crane Scale User's Manual, Dec. 2008 EDX_U.P65 PN 29808-0011 Issue AC	
	5	See attached Information Disclosure Statement for Salco Technologies, LLC Handbrake Sensor - Brochure dated Mar. 30, 2007	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /Y.A.S/

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	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	6	http://web.archive.org/web/20130206222004/http://lat-lon.com/gps-products/locomotive-monitoring unit, http://web.archive.org/web/20130206221020/http://lat-lon.com/gps-products/solar-tracking-unit http://web.archive.org/web/20130205074831/http://lat-lon.com/gps-products-sensors Available on the Internet at least as early as Feb. 6, 2013	
	7	Printout of web pages found at http:/lat-lon.com/Available on the Internet at least as early as Sep. 23, 2013	
	8	Printout of web pages found at http://www.skybitz.com/Available on the Internet at least as early as Sep. 23, 2013	
	9	Printout of web pages found at http://www.transcore.com/Available on the Internet at least as early as Sep. 23, 2013	
	10	Printout of web pages found at http://www.id-systems.com/Available on the Internet at least as early as early Sep. 23, 2013	
	11	Printout of web pages found at http://www.microstrain.com/wireless sensors Available on the Internet at least as early as Sep. 23, 2013	
	12	International Search Report in related WO Application No. PCT/IB2013/03267, dated Apr. 23, 2015	
	13	International Search Report in WO Application No. PCT/US2014/072380, dated Apr. 27, 2015	

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature	/YAZAN A SOOFI/	Date Considered	01/04/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15158018
Filing Date	2016-05-18
First Named Inventor	MARTIN ET AL.
Art Unit	3744
Examiner Name	
Attorney Docket Number	037659.00062(P36736B US)

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2017-07-06
Name/Print	Gary A. Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/158,018	Martin et al.
	Examiner	**Art Unit**
	YAZAN A SOOFI	3668

CPC						
Symbol					**Type**	**Version**
B61K	/	9	/	04	F	2013-01-01
B61L	/	15	/	0027	I	2013-01-01
G01K	/	7	/	023	I	2013-01-01
B61H	/	13	/	02	I	2013-01-01
B60T	/	17	/	221	I	2013-01-01
B60T	/	17	/	228	I	2013-01-01
B61L	/	15	/	0081	I	2013-01-01
B61L	/	25	/	025	I	2013-01-01
B61L	/	27	/	0094	I	2013-01-01
B60T	/	13	/	665	I	2013-01-01
B61L	/	15	/	0018	I	2013-01-01
B61L	/	27	/	0077	I	2013-01-01
B61L	/	2205	/	04	A	2013-01-01

CPC Combination Sets								
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	22	
/YAZAN A SOOFI/ Primary Examiner, Art Unit 3668	04 January 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	37	6

U.S. Patent and Trademark Office — Part of Paper No.: 20180103

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/158,018	Martin et al.
	Examiner	**Art Unit**
	YAZAN A SOOFI	3668

INTERNATIONAL CLASSIFICATION					
CLAIMED					
B61K	/	9	/	04	
B60T	/	13	/	66	
B60T	/	17	/	22	

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**
701	1

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 22	
/YAZAN A SOOFI/ Primary Examiner, Art Unit 3668 (Primary Examiner)	04 January 2018 (Date)	O.G. Print Claim(s) 37	O.G. Print Figure 6

U.S. Patent and Trademark Office — Part of Paper No.: 20180103

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/158,018	Martin et al.
	Examiner	Art Unit
	YAZAN A SOOFI	3668

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
-	1	-	10	-	19	-	28	1	37	-	46	18	55		
-	2	-	11	-	20	-	29	2	38	10	47	19	56		
-	3	-	12	-	21	-	30	3	39	11	48	20	57		
-	4	-	13	-	22	-	31	4	40	12	49	21	58		
-	5	-	14	-	23	-	32	5	41	13	50	22	59		
-	6	-	15	-	24	-	33	6	42	14	51				
-	7	-	16	-	25	-	34	7	43	15	52				
-	8	-	17	-	26	-	35	8	44	16	53				
-	9	-	18	-	27	-	36	9	45	17	54				

NONE (Assistant Examiner)	(Date)	Total Claims Allowed: 22	
/YAZAN A SOOFI/ Primary Examiner, Art Unit 3668 (Primary Examiner)	04 January 2018 (Date)	O.G. Print Claim(s) 37	O.G. Print Figure 6

U.S. Patent and Trademark Office — Part of Paper No.: 20180103

CORRECTED INFORMATION DISCLOSURE STATEMENT

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15158018
Filing Date	2016-05-18
First Named Inventor	MARTIN ET AL.
Art Unit	3744
Examiner Name	
Attorney Docket Number	037659.00062(P36736B US)

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3854417		1974-12-17	MacDonnell et al.	
	2	4134464		1979-01-16	Johnson et al.	
	3	4296707		1981-10-27	Kennedy	
	4	4368927		1983-01-18	Billingsley et al	
	5	4801288		1989-01-31	Schmitt et al.	
	6	4905795		1990-03-06	Rains	
	7	5038605		1991-08-13	Tews et al.	
	8	5394137		1995-02-28	Orschek	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /Y.A.S/

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	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	9	5410911		1995-05-02	Severinsson	
	10	5603556		1997-02-18	Klink	
	11	5701974		1997-12-30	Kanjo et al.	
	12	6006868		1999-12-28	Klink	
	13	6014600		2000-01-11	Ferri et al.	
	14	6170619	B1	2001-01-09	Sheriff et al.	
	15	6175784	B1	2001-01-16	Jicha et al.	
	16	6237722	B1	2001-05-29	Hammond et al.	
	17	6397978	B1	2002-06-04	Jackson et al.	
	18	6474450	B1	2002-11-05	Ring et al.	
	19	6739675	B1	2004-05-25	Scharpf et al.	

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	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
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	Attorney Docket Number	037659.00062(P36736B US)

	20	6823242	B1	2004-11-23	Ralph	
	21	7114596	B2	2006-10-03	Borugian	
	22	7180019	B1	2007-02-20	Chiou et al.	
	23	RE40099	E	2008-02-26	Stephens et al.	
	24	8033236	B2	2011-10-11	Michel et al.	
	25	8060264	B2	2011-11-15	Oestermeyer et al.	
	26	6474451	B1	2002-11-05	O'Brien, Jr.	
	27	3718040		1973-02-27	Freeman et al.	
	28	4812826		1989-03-14	Kaufman et al.	
	29	5381090		1995-01-10	Adler et al.	
	30	5440184		1995-08-08	Samy et al.	

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	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	31	5446451		1995-08-29	Grosskopf, Jr.	
	32	5503030		1996-04-02	Bankestrom	
	33	5682139		1997-10-28	Pradeep et al.	
	34	5691980		1997-11-25	Welles, II et al.	
	35	5810485		1998-09-22	Dublin, Jr. et al.	
	36	6161962		2000-12-19	French et al.	
	37	6179471	B1	2001-01-30	Moretti et al.	
	38	6184798	B1	2001-02-06	Egri	
	39	6301531	B1	2001-10-09	Pierro et al.	
	40	6324899	B1	2001-12-04	Discenzo	
	41	6339397	B1	2002-01-15	Baker	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /Y.A.S/

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	Attorney Docket Number	037659.00062(P36736B US)

	42	6441324	B1	2002-08-27	Stimpson	
	43	6487478	B1	2002-11-26	Azzaro et al.	
	44	6535135	B1	2003-03-18	French et al.	
	45	6668216	B2	2003-12-23	Mays	
	46	7336156	B2	2008-02-26	Arita et al.	
	47	7688218	B2	2010-03-30	LeFebvre et al.	
	48	7698962	B2	2010-04-20	LeFebvre et al.	
	49	8212685	B2	2012-07-03	LeFebvre et al.	
	50	8244411	B2	2012-08-14	Baker	
	51	8370006	B2	2013-02-05	Kumar et al.	
	52	8672273	B2	2014-03-18	Brown et al.	

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	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	53	8751290	B2	2014-06-10	Schullian et al.	
	54					

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U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020111726	A1	2002-08-15	Dougherty et al.	
	2	20030058091	A1	2003-03-27	Petersen et al.	
	3	20030097885	A1	2003-05-29	Kell	
	4	20070062765	A1	2007-03-22	Michel et al.	
	5	20070084676	A1	2007-04-19	Vithani et al.	
	6	20070151812	A1	2007-07-05	Michel et al.	
	7	20080179269	A1	2008-07-31	Bachman	

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	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	8	20080252515	A1	2008-10-16	Oestermeyer et al.	
	9	20090001226	A1	2009-01-01	Haygood	
	10	20100200307	A1	2010-08-12	Toms	
	11	20120037435	A1	2012-02-16	Duehring	
	12	20120046811	A1	2012-02-23	Murphy et al.	
	13	20020017439	A1	2002-02-14	Hill et al.	
	14	20050259619	A1	2005-11-24	Boettle et al.	
	15	20060264221	A1	2006-11-23	Koike et al.	
	16	20070241610	A1	2007-10-18	Smith	
	17	20080195265	A1	2008-08-14	Searle et al.	
	18	20090173840	A1	2009-07-09	Brown et al.	

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	Art Unit	3744
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	Attorney Docket Number	037659.00062(P36736B US)

	19	20110270475	A1	2011-11-03	Brand et al.	
	20	20110282540	A1	2011-11-17	Armitage et al.	
	21	20120051643	A1	2012-03-01	Ha et al.	
	22	20150083869	A1	2015-03-26	LeFebvre et al.	

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FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	1548419	EP	A1	2005-06-00	NSK Ltd.		☐
	2	2650191	EP	A1	2013-10-00	Progress Rail Services Corporation		☐
	3	2295207	GB	A	1996-05-00	The Torrington Company		☐
	4	05213195	JP	A	1993-08-00	Sumitomo Metal Ind Ltd		☐
	5	05343294	JP		1993-12-00	NEC Corp		☐

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	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	6	0815099	JP		1996-01-00	Sumitomo Metal Ind Ltd		☐
	7	10217968	JP		1998-08-00	Toshiba Corp		☐
	8	11192948	JP		1999-07-00	Toshiba Corp		☐
	9	2005105536	WO	A1	2005-11-00	Sti Rail Pty Ltd		☐

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NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T5
	1	Topolev, V.P.; Automation of Strain-gauge Crane Scales; Feb. 1966; Translated from Izmeritel'naya Tekhnika, No. 2, pp. 81-82	☐
	2	Balkov, P.O. et al; Electrical Strain-guage Scales; Oct. 1961; Tanslated from Izmeritel'naya Tekhnika, No. 10, pp. 17-20	☐
	3	MSI-9300 Series User Guide, Rev 1 Jul. 27, 2002 for SW Ver 1-1	☐
	4	Dillon EDxtreme Dynamometer and Crane Scale User's Manual, Dec. 2008 EDX_U.P65 PN 29808-0011 Issue AC	☐
	5	See attached Information Disclosure Statement for Salco Technologies, LLC Handbrake Sensor - Brochure dated Mar. 30, 2007	☐

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	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

	6	http://web.archive.org/web/20130206222004/http://lat-lon.com/gps-products/locomotive-monitoring unit, http://web.archive.org/web/20130206221020/http://lat-lon.com/gps-products/solar-tracking-unit http://web.archive.org/web/20130205074831/http://lat-lon.com/gps-products-sensors Available on the Internet at least as early as Feb. 6, 2013	☐
	7	Printout of web pages found at http:/lat-lon.com/Available on the Internet at least as early as Sep. 23, 2013	☐
	8	Printout of web pages found at http://www.skybitz.com/Available on the Internet at least as early as Sep. 23, 2013	☐
	9	Printout of web pages found at http://www.transcore.com/Available on the Internet at least as early as Sep. 23, 2013	☐
	10	Printout of web pages found at http://www.id-systems.com/Available on the Internet at least as early as early Sep. 23, 2013	☐
	11	Printout of web pages found at http://www.microstrain.com/wireless sensors Available on the Internet at least as early as Sep. 23, 2013	☐
	12	International Search Report in related WO Application No. PCT/IB2013/03267, dated Apr. 23, 2015	☐
	13	International Search Report in WO Application No. PCT/US2014/072380, dated Apr. 27, 2015	☐

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EXAMINER SIGNATURE

Examiner Signature	/YAZAN A SOOFI/	Date Considered	01/04/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

EFS Web 2.1.17

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Filing Date	2016-05-18
	First Named Inventor	MARTIN ET AL.
	Art Unit	3744
	Examiner Name	
	Attorney Docket Number	037659.00062(P36736B US)

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2017-06-26
Name/Print	Gary A. Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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The information provided by you in this form will be subject to the following routine uses:

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6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

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9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/158,018	Martin et al.
	Examiner	Art Unit
	YAZAN A SOOFI	3668

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	06/24/2017	01/04/2018							
1	37	✓	=							
2	38	✓	=							
3	39	✓	=							
4	40	✓	=							
5	41	✓	=							
6	42	✓	=							
7	43	✓	=							
8	44	✓	=							
9	45	✓	=							
-	46	-	-							
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13	50	✓	=							
14	51	✓	=							
15	52	✓	=							
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19	56	✓	=							
20	57	✓	=							
21	58	✓	=							
22	59	✓	=							

Bibliographic Data

Application No: 15158018

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No ☐ Met After Allowance

Verified and Acknowledged: /YAZAN A SOOFI/ (Examiner's Signature) | (Initials)

Title: SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
05/18/2016	701	3668	037659.00062 (P36736B US)
RULE			

APPLICANTS

Amsted Rail Company, Inc., Chicago, IL,

INVENTORS

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William D. LeFebvre, West Chester, PA, UNITED STATES

Brent M. Wilson, Edwardsville, IL, UNITED STATES

CONTINUING DATA

13842427 is a CIP of 12861713 08/23/2010PAT 9026281

13842427 is a PRO of 61661661 06/19/2012

15158018 is a CON of 13842427 03/15/2013PAT 9365223

FOREIGN APPLICATIONS

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L25	6	"8060264"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/01/03 14:28
L26	39	"7688218"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/01/03 14:29
L27	10	"8672273"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/01/03 14:31
L28	6	"8751290"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/01/03 14:32
L29	5	"20150083869"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/01/03 14:35
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L31	2	30 and (severity near3 level) with (alarm)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/01/03 14:41
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			USPAT			09:58
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S3	670	andrew near1 martin	US-PGPUB; USPAT	OR	ON	2014/09/18 09:59
S4	7	S3 and railcar	US-PGPUB; USPAT	OR	ON	2014/09/18 09:59
S5	546	lat?lon	US-PGPUB; USPAT	OR	ON	2014/10/28 16:10
S6	63	S5 and (railcar or train)	US-PGPUB; USPAT	OR	ON	2014/10/28 16:10
S7	3	S5 and (railcar or train) and (temperature near1 sensor)	US-PGPUB; USPAT	OR	ON	2014/10/28 16:10
S8	19667	(railcar or train) and (temperature near1 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:12
S9	3308	(railcar or train) and (temperature near1 sensor) and magnet	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:13
S10	1695	S9 and wireless	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:13
S11	985	S10 and alarm	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:13
S12	887	S11 and memory	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:13
S13	524	S12 and mesh	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:14
S14	489	S13 and (satellite or cellular)	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2014/10/28 16:15

			EPO; JPO; DERWENT; IBM_TDB			
S15	66010	(temperature near3 threshold)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:15
S16	144	S14 and (temperature near3 threshold)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:15
S17	0	S16 and (mount near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:18
S18	1	S16 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:18
S19	1	S13 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:18
S20	7	S10 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:18
S21	2160	(railcar or train) and (temperature near1 sensor) and (temperature near3 threshold)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S22	2000833	18and wireless	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S23	793	S21 and wireless	US-PGPUB; USPAT;	OR	ON	2014/10/28 16:19

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S24	691	S23 and memory	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S25	9	S24 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:19
S26	3	S5 and (railcar or train) and (temperature near3 sensor)	US-PGPUB; USPAT	OR	ON	2014/10/28 16:22
S27	3	S5 and (railcar or train) and (temperature near3 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:22
S28	57	microstrain and (railcar or train) and (temperature near3 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:24
S29	1	S28 and (temperature near3 threshold)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:24
S30	4	"12154641"	US-PGPUB; USPAT	OR	ON	2014/10/28 16:27
S31	286	(strain near2 sensor) and (temperature near2 sensor) and (pressure near2 sensor)and (load near2 sensor)and (magnetic near2 sensor)and (vibration near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:53
S32	1	S31 and piezio	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:53
S33	68	piezoresistive near2 microphone	US-PGPUB; USPAT;	OR	ON	2014/10/28 16:54

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S34	1	S31 and S33	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:54
S35	5	S33 and train	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/28 16:54
S36	5	LAT-LON near2 LLC	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:37
S37	113	LAT-LON	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:38
S38	348764	2and (railcar or train)	US-PGPUB; USPAT	OR	ON	2014/10/29 08:38
S39	3	S37 and (railcar or train)	US-PGPUB; USPAT	OR	ON	2014/10/29 08:38
S40	10	S37 and (railcar or train)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:39
S41	1	S40 and alarm	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:45
S42	0	S41 and sensor	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:46
S43	10	S37 and (railcar or train or locomotive)	US-PGPUB; USPAT;	OR	ON	2014/10/29 08:52

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S44	4233	(railcar or train or locomotive) near3 monitoring	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:52
S45	296	S44 and(temperature near1 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:52
S46	15	S45 and (mount$3 near3 (train or railcar))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:53
S47	2	railrider	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 08:58
S48	1	"13842427"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 09:19
S49	4	"8244411"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 09:40
S50	2	"12861713"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 09:44
S51	1	"13842427"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 09:45

S52	0	(vibration near2 sensor) and (hand? brake near4 sensor) and (load near2 cell near3 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:50
S53	0	(vibration near2 sensor) and (hand? brake near4 sensor) and (load near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:50
S54	49244	(vibration near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:50
S55	11	(hand?brake near4 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S56	478	S54 and (brake near3 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S57	174	S56 and(load near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S58	104	S57 and(hall near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S59	96	S58 and(pressure near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:51
S60	98	S58 and(strain near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2014/10/29 12:52

			DERWENT; IBM_TDB			
S61	96	S59 and(strain near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S62	96	S59 and(temperaturenear2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S63	96	S61 and(temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S64	96	S63 and(acceleration)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:52
S65	95	S63 and(gyroscope)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:53
S66	0	S63 and(peizio)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:53
S67	95	S63 and(resistive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:53
S68	96	S63 and(microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:53
S69	1	S63 and(resistive near2 microphones)	US-PGPUB; USPAT; USOCR;	OR	ON	2014/10/29 12:54

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S70	1	S68 and railcar	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:54
S71	95	S68 and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:54
S72	1	S68 and (railcar or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:57
S73	0	((peizioresistive or peizo) near2 microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:57
S74	0	(piezioresistive near2 microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:58
S75	4	((piezioresistive or piezio) near2 microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:58
S76	4	((piezioresistive or piezio) near3 microphones)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 12:59
S77	7344	high near2 alarm	US-PGPUB; USPAT	OR	ON	2014/10/29 14:14
S78	338	(high near2 alarm) and(temperature near3 threshold)	US-PGPUB; USPAT	OR	ON	2014/10/29 14:17
S79	42	S78 and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR;	OR	ON	2014/10/29 14:17

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S80	1	S78 and (railcar or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 14:19
S81	32	S77 and (railcar or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 14:20
S82	1717	(701/19).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:08
S83	0	S78 and S82	US-PGPUB; USPAT	OR	ON	2014/10/29 15:08
S84	0	("andrewnear1martin").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:09
S85	676	andrew near1 martin	US-PGPUB; USPAT	OR	ON	2014/10/29 15:09
S86	1	S78 and S85	US-PGPUB; USPAT	OR	ON	2014/10/29 15:09
S87	8158	(701/1).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:17
S88	1448	(340/870.16).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:17
S89	526	(374/152).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/29 15:17
S90	11742	S82 or S87 or S88 or S89	US-PGPUB;	OR	ON	2014/10/29

			USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			15:18
S91	4	S78 and S90	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/29 15:18
S92	16	"7688218"	USPAT	OR	OFF	2015/08/12 13:46
S93	25	"2005105536"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 13:48
S94	2	"20080195264"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:14
S95	2	"20080195265"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:14
S96	4341	(probe or sensor) near3 ((external or outside) near3 housing)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:31
S97	1120	S96 and (temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:32
S98	103	S97 and (railcar or train)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:32
S99	335	S96 with (temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS;	OR	OFF	2015/08/12 14:44

			EPO; JPO; DERWENT; IBM_TDB			
S100	1	S99 with (magnet$5)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:45
S101	9	S99 and (railcar or train)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 14:46
S102	557	(probe) near3 ((external or outside) near3 housing)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:01
S103	523408	11and (temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:02
S104	83	S102 and (temperature near2 sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:02
S105	90	("20150083869" | "5446451" | "6441324" | "6487478" | "20050259619" | "20110282540" | "20120051643" | "20090173840" | "3718040" | "5440184" | "8751290" | "6339397" | "8244411" | "5503030" | "6184798" | "8672273" | "4812826" | "5810485" | "6301531" | "6535135" | "7688218" | "5682139" | "5381090" | "8212685" | "5691980" | "6161962" | "6179471" | "6324899" | "6668216" | "7698962" | "20110270475" | "20070241610" | "8370006" | "7336156").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:03
S106	0	S102 and S105	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:04
S107	0	S105 and ((probe) near3 (external or outside))	US-PGPUB; USPAT;	OR	OFF	2015/08/12 15:04

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S108	1	S105 and (probe)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:05
S109	0	S105 and ((temperature near3 sensor) near3 (external or outside))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:12
S110	14	S105 and ((temperature near3 sensor))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:12
S111	7	(temperature near2 sensor) with (external near3 housing) with magnet$5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:23
S112	6	(temperature near2 sensor) with (magnet$5 near3 (mount or attach or install))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:28
S113	9574	(temperature near2 sensor) with (magnet$5)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:31
S114	3725	(temperature near2 sensor) near4 (magnet$5)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:31
S115	100	S114 and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 15:33

S116	2	"13993085"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 16:27
S117	3	"20100220250"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/12 16:37
S118	25	"2005105536"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 09:52
S119	36	searle near2 donald	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 09:54
S120	15	S119 and rail	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 09:54
S122	25	"2005105536"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 12:31
S123	2	"20080195265"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 12:33
S124	90	"6339397"	USPAT	OR	OFF	2015/08/19 18:14
S125	0	(temperature near3 sensor) with ((touch$3 or contact$3) near5 surface near5 railcar)	USPAT	OR	OFF	2015/08/19 18:26
S126	0	(temperature near3 sensor) with ((touch$3 or contact$3) near5 surface near5 railcar)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 18:26

S127	0	(temperature near3 sensor) with (surface near5 railcar)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 18:26
S128	0	(temperature near3 sensor) with (surface near5 railcar)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 18:26
S129	11	(temperature near3 sensor) with (railcar)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 18:26
S130	1	"13842427"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/08/19 19:03
S131	1920	(b61l15/0027).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2016/02/05 14:40
S149	232	(strain near2 sensor) and (temperature near2 sensor) and (pressure near2 sensor)and (load near2 sensor)and (magnetic near2 sensor)and (vibration near2 sensor) and (railcar or train or locomotive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2016/02/05 16:58
S150	3767	((temperature near2 sensor) with (housing or cover)) and ((monitor$ or sens$3 or detect$3) near3 temperature) and (circuitry)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2016/02/05 17:00
S151	1	((temperature near2 sensor) with (housing or cover)) and ((monitor$ or sens$3 or detect$3) near3 temperature) and (circuitry) and ((probe) near6 (external or outside) near6 (magnet$5))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2016/02/05 17:02
S171	99	"6339397"	USPAT	OR	OFF	2017/06/24 14:20
S172	20	((sensor or sensing) with railcar with temperature) and (remote) and network and alarm	US-PGPUB; USPAT; USOCR;	OR	OFF	2017/06/24 14:25

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S173	2	"20080195265"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2017/06/24 15:03

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L32	2	(strain near2 sensor) and (temperature near2 sensor) and (pressure near2 sensor)and (load near2 sensor)and (magnetic near2 sensor)and (vibration near2 sensor) and (railcar or train or locomotive) and (severity near3 level) with (alarm)	US-PGPUB; USPAT	OR	ON	2018/01/03 14:56
L33	26	(temperature near2 sensor) and (railcar or train or locomotive) and (severity near3 level) with (alarm)	US-PGPUB; USPAT	OR	ON	2018/01/03 14:57
L34	6224	(701/1).CCLS.	US-PGPUB; USPAT	OR	OFF	2018/01/03 14:58
L35	992	(340/870.16).CCLS.	US-PGPUB; USPAT	OR	OFF	2018/01/03 14:58
L36	394	(374/152).CCLS.	US-PGPUB; USPAT	OR	OFF	2018/01/03 14:59
L37	215	(b61k9/04).cpc.	US-PGPUB; USPAT	OR	OFF	2018/01/03 15:00
L38	1246	(b60t13/665).cpc.	US-PGPUB; USPAT	OR	OFF	2018/01/03 15:01
L39	1236	(b60t17/221).cpc.	US-PGPUB; USPAT	OR	OFF	2018/01/03 15:01
L40	902	(b60t17/228).cpc.	US-PGPUB; USPAT	OR	OFF	2018/01/03 15:01
L41	10680	34 or 35 or 36 or 37 or 38 or 39 or 40	US-PGPUB; USPAT	OR	OFF	2018/01/03 15:03
L42	1	((temperature near2 sensor) and (railcar or train or locomotive) and (severity near3 level) with (alarm)).clm.	US-PGPUB; USPAT	OR	ON	2018/01/03 15:03
L43	3	33 and 41	US-PGPUB; USPAT	OR	ON	2018/01/03 15:03
S132	1476	(701/19).CCLS.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:35

S133	6161	(701/1).CCLS.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:35
S134	984	(340/870.16).CCLS.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:35
S135	385	(374/152).CCLS.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:35
S137	460	(b61l15/0027).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:40
S140	992	(b60t17/221).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:41
S141	1133	(b60t13/665).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:41
S142	761	(b60t17/228).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:41
S143	1064	(b61h13/02).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:41
S144	194	(b61k9/04).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:42
S145	300	(b61l15/0081).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:43
S146	563	(b61l25/025).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:43
S147	158	(b61l27/0094).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:43
S148	134	(g01k7/023).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 14:43
S152	232	(strain near2 sensor) and (temperature near2 sensor) and (pressure near2 sensor)and (load near2 sensor)and (magnetic near2 sensor)and (vibration near2 sensor) and (railcar or train or locomotive)	US-PGPUB; USPAT	OR	ON	2016/02/05 16:58
S153	1	((temperature near2 sensor) with (housing or cover)) and ((monitor$ or sens$3 or detect$3) near3 temperature) and (circuitry) and ((probe) near6 (external or outside) near6 (magnet$5))	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:02
S154	4	((temperature near2 sensor) with (housing or cover)) and ((monitor$ or sens$3 or detect$3) near3 temperature) and ((probe) near6 (external or outside) near6 (magnet$5))	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:03
S155	1476	(701/19).CCLS.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S156	6161	(701/1).CCLS.	US-	OR	OFF	2016/02/05

			PGPUB; USPAT			17:32
S157	984	(340/870.16).CCLS.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S158	385	(374/152).CCLS.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S159	460	(b61l15/0027).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S160	992	(b60t17/221).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S161	1133	(b60t13/665).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S162	761	(b60t17/228).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S163	1064	(b61h13/02).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S164	300	(b61l15/0081).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S165	563	(b61l25/025).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S166	158	(b61l27/0094).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S167	134	(g01k7/023).cpc.	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S168	13242	S155 or S156 or S157 or S158 or S159 or S160 or S161 or S162 or S163 or S164 or S165 or S166 or S167	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:32
S169	299	((temperature near2 sensor) with (housing or cover)) and ((monitor$ or sens$3 or detect$3) near3 temperature) and ((probe) near6 (external or outside))	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:33
S170	3	S168 and S169	US-PGPUB; USPAT	OR	OFF	2016/02/05 17:33

1/3/2018 3:04:11 PM
C:\Users\ysoofi.USPTO\Documents\EAST\Workspaces\15158018.wsp

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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NOTICE OF ALLOWANCE AND FEE(S) DUE

29880 7590 01/29/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NEW JERSEY 08648

EXAMINER	
SOOFI, YAZAN A	
ART UNIT	PAPER NUMBER
3668	

DATE MAILED: 01/29/2018

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/158,018	05/18/2016	Andrew H. Martin	037659.00062 (P36736B US)	1036

TITLE OF INVENTION: SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
REGULAR	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	04/30/2018

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

29880 7590 01/29/2018
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NEW JERSEY 08648

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/158,018	05/18/2016	Andrew H. Martin	037659.00062 (P36736B US)	1036

TITLE OF INVENTION: SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
REGULAR	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	04/30/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
SOOFI, YAZAN A	3668	701-001000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☐ Issue Fee

☐ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

☐ A check is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/158,018	05/18/2016	Andrew H. Martin	037659.00062 (P36736B US)	1036

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EXAMINER	
SOOFI, YAZAN A	
ART UNIT	**PAPER NUMBER**
3668	

DATE MAILED: 01/29/2018

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 15/158,018	Applicant(s) Martin et al.	
	Examiner YAZAN A SOOFI	Art Unit 3668	AIA Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to 10/13/2017 .
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____ .

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 37-45 and 47-59 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information , please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file areply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 07/06/2017 and 09/11/2017
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____ .
5. ☐ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____ .

/YAZAN A SOOFI/
Primary Examiner, Art Unit 3668

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

DETAILED ACTION

The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Prosecution History

Claims 37-45 and 47-59 of U.S. Application No. 15/158018 filed on 15/18/2016 have been examined.

Office Action is in response to the Applicant's amendments and remarks filed 03/30/2017. Claim 50 was amended. Claims 37-45 and 47-59 are presently pending and are presented for examination.

Response to Remarks/Arguments

1. **In regards to rejection under 35 U.S.C. § 103**: Applicant's amendments with respect to **claims 37-45 and 47-59** have been fully considered and are persuasive. The previous rejections under 35 U.S.C. § 103 to claims 37-45 and 47-59 have been withdrawn.

Allowable Subject Matter

2. **Claims 37-45 and 47-59** are allowed over the prior art of record.

As per claim 37-45 and 47-59 the closest prior art of record taken either individually or in combination with other prior art of record fails to teach or suggest:

The prior art fails to explicitly teach a control method applying a heuristic to said

received data to determine deviations from nominal operating conditions; assigning a severity level to said deviations from nominal operating conditions; and determining an alarm condition based on said assigned severity level.

3. Claims 38-45 depend from claim 37, Claims 48-19 depend on claim 47, claims 52-57 depend on claim 51 and claim 59 depends from claim 58, therefore allowable. Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to YAZAN A SOOFI whose telephone number is (469)295-9189. The examiner can normally be reached on Flex schedule.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Fadey Jabr can be reached on 572-272-1516. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR

system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/YAZAN A SOOFI/
Primary Examiner, Art Unit 3668

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/158,018	Martin et al.
	Examiner	Art Unit
	YAZAN A SOOFI	3668

CPC - Searched*		
Symbol	Date	Examiner
b61l5/0027	6/24/2017	/Y.A.S/

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner
701	19	6/24/2017	/Y.A.S/
340	870.16	6/24/2017	/Y.A.S/

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
Google patent search	6/24/2017	/Y.A.S/
Inventor search	6/24/2017	/Y.A.S/
EPO search	6/24/2017	/Y.A.S/
East text search	6/24/2017	/Y.A.S/
Updated East text search	01/03/2018	

/YAZAN SOOFI/ Primary Examiner.Art Unit 3668	/YAZAN A SOOFI/ Primary Examiner, Art Unit 3668

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/158,018	Martin et al.
	Examiner	Art Unit
	YAZAN A SOOFI	3668

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
701	1	01/03/2018	/Y.A.S/
340	870.16	01/03/2018	/Y.A.S/
374	152	01/03/2018	/Y.A.S/
b61k	9/04	01/03/2018	/Y.A.S/
b60t	13/665, 17/221, 17/228	01/03/2018	/Y.A.S/

/YAZAN SOOFI/ Primary Examiner.Art Unit 3668	/YAZAN A SOOFI/ Primary Examiner, Art Unit 3668

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

29880 7590 01/29/2018
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NEW JERSEY 08648

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/158,018	05/18/2016	Andrew H. Martin	037659.00062 (P36736B US)	1036

TITLE OF INVENTION: SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
REGULAR	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	04/30/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
SOOFI, YAZAN A	3668	701-001000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Fox Rothschild LLP
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Amsted Rail Company, Inc.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Chicago, Illinois 60606

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☒ Issue Fee

☐ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies _____

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5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /gah/ Date April 9, 2018

Typed or printed name Gary A. Hecht Registration No. 36,826

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	15158018
Filing Date:	18-May-2016
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Filer:	Gary A. Hecht
Attorney Docket Number:	037659.00062 (P36736B US)

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	1501	1	1000	1000

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**1000**

Electronic Acknowledgement Receipt

EFS ID:	32463086
Application Number:	15158018
International Application Number:	
Confirmation Number:	1036
Title of Invention:	SYSTEM AND METHOD FOR MONITORING RAILCAR PERFORMANCE
First Named Inventor/Applicant Name:	Andrew H. Martin
Customer Number:	29880
Filer:	Gary A. Hecht
Filer Authorized By:	
Attorney Docket Number:	037659.00062 (P36736B US)
Receipt Date:	30-APR-2018
Filing Date:	18-MAY-2016
Time Stamp:	11:32:54
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1000
RAM confirmation Number	043018INTEFSW11333801
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The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	Issue_Fee_Transmittal.pdf	121589 d8a64c9639322d54e7396ad4c84f6df4a89abeea	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30262 dead97029a45e43b3eb681f104920b35c3806a90	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	151851		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/158,018	05/29/2018	9981673	037659.00062 (P36736B US)	1036

29880 7590 05/09/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Andrew H. Martin, West Chester, PA;
Amsted Rail Company, Inc., Chicago, IL;
William D. LeFebvre, West Chester, PA;
Brent M. Wilson, Edwardsville, IL;

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