

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HUM INDUSTRIAL TECHNOLOGY, INC.,
Petitioner,

v.

AMSTED RAIL COMPANY, INC.,
Patent Owner.

IPR2023-00538

PATENT NO. 9,365,223

ISSUED: JUNE 14, 2016

TITLE: SYSTEM AND METHOD FOR MONITORING
RAILCAR PERFORMANCE

EXHIBIT 2171

DECLARATION OF MICHAEL I. SHAMOS, PH.D.
IN SUPPORT OF PATENT OWNER'S REVISED MOTION TO AMEND

AMSTED 2171
IPR2023-00538

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1. I, Michael I. Shamos, declare as follows in connection with the proceedings identified above.

I. INTRODUCTION AND QUALIFICATIONS

2. I have been retained as an expert on behalf of Patent Owner to provide technical analysis and opinions relating to the Petition for Inter Partes Review (“Petition,” Paper 2) filed by Hum Industrial Technology, Inc. (“Hum” or “Petitioner”) challenging the validity of Claims 1–10, 13–18, and 20–32 (the “Challenged Claims”) of U.S. Patent No. 9,365,223 (“the ’223 Patent” or “the Patent”). I have also been asked to opine on the validity of the Substitute Claims presented in Patent Owner’s Motion to Amend (“RMTA”).

3. I am aware of contemporaneous litigation involving the parties in a case styled Amsted Rail Company, Inc. v. Hum Industrial Technology, Inc. and Brett Wilson, 4:22-cv-00445-AGF (E.D. Mo.) (the “Litigation”).

4. I previously submitted three declarations in this matter. The first, “Declaration of Michael I. Shamos, Ph.D. on Behalf of Patent Owner,” was dated May 15, 2023 (“Shamos 1,” Ex. 2001). My background, qualifications and compensation were set forth in ¶¶ 4-14 and 21-22 of Shamos 1. The legal principles I was asked to follow were set forth in ¶¶ 26-33 of Shamos 1. The characterization of a POSITA appears in ¶¶ 42-46 of Shamos 1. The second was a “Declaration of Michael I. Shamos, Ph.D. in Support Of Patent Owner’s Response,” dated

November 3, 2023 (“Shamos 2,” Ex. 2010). The third was a “Declaration of Michael I. Shamos, Ph.D. in Support Of Patent Owner’s Motion to Amend,” dated November 3, 2023 (“Shamos 3,” Ex. 2158). Additional legal principles I was asked to follow were contained in ¶¶ 13-16 of Shamos 3.

5. In this Declaration, all emphasis has been added unless otherwise noted.

6. The statements made and opinions provided in this Declaration are based on my own personal knowledge and, if called as a witness, I could and would testify in a manner consistent with the material in this Declaration.

II. MATERIALS CONSIDERED

7. In preparing this Declaration, I have considered all the material filed through the date of this Declaration in this proceeding and any other materials cited in this Declaration.

8. I have also relied on my education, skill, training, and experience in the relevant fields of technology. I have further considered the viewpoint of a person of ordinary skill in the art (“POSITA”) at the time of the invention of the ’223 Patent.

9. I reserve the right to supplement my opinions as expressed in this Declaration to address any new information obtained in the course of this proceeding, or based on any new positions taken by Petitioner.

III. SUMMARY OF MY OPINIONS

10. The following table summarizes the grounds of challenge (“Grounds”) raised in the Petition:

Grd.	Sec.	References	Challenged Claims
1	§ 103	LeFebvre	2–10, 18, 20, 21, 23, 25–32
2	§ 103	LeFebvre in view of Barone	13–17, 22, and 24
3	§ 103	LeFebvre in view of Denny and Provasnik	1, 24
4	§ 103	Armitage	2, 3, 5, 7, 13–18, 20–22, 26–28, 32
5	§ 103	Armitage in view of LeFebvre	4, 6, 8, 9, 10, 23, 25, 29–31
6	§ 103	LeFebvre, Denny, and Provasnik	1, 24

11. After a review of the Substitute Claims and the alleged prior art asserted by Petitioner, it is my opinion that the Substitute Claims are not invalid under any of the Grounds. My opinions, and the bases therefor, are detailed throughout this Declaration.

IV. WRITTEN DESCRIPTION SUPPORT FOR THE SUBSTITUTE CLAIMS

12. The tables below identify written description support for all limitations of the Substitute Claims.

A. Claim 33 (Substitute for claim 1, if found unpatentable)

Claim Limitation	Support
~~4.~~ <u>33.</u> A sensor device for monitoring temperature on a	Ex. 1001, 3:14-16 (“It is another object to provide specific sensor applications, such as temperature sensors that can monitor the temperature of various components

railcar, comprising:	and items on the railcar.”); Ex. 1013, [00016].
a housing <u>providing a first piece mountable</u> on a railcar;	Ex. 1001, 3:60-62 (“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.”); 5:30-31 (“the individual motes 10 are mounted on the areas of interest on a railcar 38.”); Ex. 1013, [00109], [00115].
a temperature sensor;	Ex. 1001, 6:16-19 (“the mote 10 is constructed ... with the temperature sensor 20 positioned in a probe 48 spaced from the housing 14.”); Ex. 1013. [00109].
electrical circuitry in communication with said temperature sensor <u>via a cable</u> for obtaining information regarding the temperature being sensed, <u>wherein</u> said electrical circuitry <u>is</u> positioned within said housing, <u>and said cable has a proximal end disposed in the housing and a distal end residing external to said housing</u> ;	Ex. 1001, 6:29-33 (“A corresponding electrical connector 58 b connected to corresponding connector 58 a connects temperature sensor 20 via wire 52, preferably a flexible PVC coated cable 62, to the mote housing 14.”); 4:66-5:2, Figs. 1, 5, 5A (“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”); Ex. 1013, [00112], Figs. 8, 8A.
a power source electrically connected to said electrical circuitry ~~to~~ <u>for</u> ~~providing~~ <u>ing</u> power thereto, said power source positioned within said housing;	Ex. 1001, 5:24-25 (“Mote 10 also includes a long-term power source 34, preferably a military grade lithium-thionyl chloride battery.”); Ex. 1013, [00113].
a probe <u>providing a</u>	Ex. 1001, 6:17-33 (“the temperature sensor 20

<u>second piece external to and separated from the first piece provided by said housing, said second piece and which probe comprising a sensor probe head that (i) is spaced apart from the housing, (ii) has a body formed of a heat conductive material, (iii) has a connector electrically interfaced with said temperature sensor and configured to connect to a corresponding electrical connector at the distal end of the cable and includes said temperature sensor, and (iv) a magnet positioned in the body adjacent to a portion of the connector extending inside the body, the magnet configured to magnetically attract the part of the railcar against which the sensor probe head will be placed; and</u>	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. ... Fitting within a head body opening 56 is the temperature sensor 20 electrically attached to an electrical connector 58 a. A ring shaped magnet 60 with an opening in its center fits around the sensor 20 within the head 50. ... A corresponding electrical connector 58 b connected to corresponding connector 58 a connects temperature sensor 20 via wire 52, preferably a flexible PVC coated cable 62, to the mote housing 14.”).
a communication device <u>configured to capable of broadcasting</u> information regarding	Ex. 1001, 3:60-63, Figs. 1-2 (“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.”); Ex. 1013,

the temperature sensed, said communication device positioned within said housing;	[00109], Figs 8, 8A.
wherein the power consumption of said sensor device is managed by placing said sensor device in a standby state and periodically awakening said sensor device to collect readings from said temperature sensor and to transmit the information regarding the temperature sensed via said communication device circuitry.	Ex. 1001, 5:24-29 (“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.”); Ex. 1013, [00044]-[00045].

B. Claim 34 (Substitute for claim 2, if found unpatentable)

Claim Limitation	Support
2. <u>34</u> . A system for monitoring a railcar, comprising:	Ex. 1001, 3:48-49 (“a novel means for monitoring the performance and operation of a railcar is provided.”); Ex. 1013, [0001].
a plurality of sensor devices <u>each</u> located on <u>and mounted to a sidewall of a bearing adapter of the railcar</u> for monitoring parameters or conditions <u>of a bearing</u> of the railcar, each of said sensor devices being separate	Ex. 1001 at 3:50-54 (“The sensors monitor and/or collect data on particular parameters and conditions of the railcar.”); 4:39-48; 4:66-5:7; 5:11-23; 5:30-46 (“The individual motes 10 are mounted on the areas of interest on a

from one another and including a sensor for monitoring one of said parameters or conditions <u>of the bearing</u> of the railcar;	railcar 38. <i>As an example</i>, FIGS. 3 and 3A show a temperature sensing mote ... mounted to a bearing adapter.”); 8:7-10; Table spanning cols. 7-12, specifically col. 9 “<i>adapter mounted accelerometer</i>”); 15:25-30 (“Various embodiments of the invention have been described in the context of various examples, however, <i>the invention is not meant to be limited in any way</i>. As one of skill in the art recognizes there may be many implementations that are within the scope of the invention...”); FIGs 3, 3A; EX1013 at [00109]-[00119], specifically [00109] (“... many different types of sensors could be utilized by the mote, for example,... <i>acceleration</i>, etc. [T]he invention is <i>not meant to be limited by the exemplary implementation</i>.”); [00115] (“The self-contained units are mounted on the areas of interest on a railcar. As an example, Figure 9 shows a temperature sensing unit mounted to a bearing adapter to measure the temperature of a wheel bearing of a railcar.”); FIGs. 3, 9, 10a; Ex. 1002, 510 (originally filed claim 32).
said plurality of sensor devices including at least one temperature sensor device having:	Ex. 1001, 4:5-10, Figs. 1-2 (“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.”); Ex. 1013, [00109], Figs. 8, 8A; Ex. 1014, [0025].

a housing <u>comprising a non-flexible material that is resistant to environmental damage</u> ;	See previous limitation.
a temperature sensor in thermal communication with an item <u>consisting of the bearing adapter</u> of the railcar for which the temperature is being monitored, which item is external to said housing;	Ex. 1001, 4:43-48 (“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 [sic] resistive microphone or an ultrasonic sensor.”); Ex. 1013, [00109], Figs. 8, 8A.
electrical circuitry in communication with said temperature sensor for obtaining information regarding the temperature being ~~sensed~~ <u>monitored</u> , said electrical circuitry positioned within said housing;	Ex. 1001 at 3:60-63, Ex. 1001 at Table spanning cols. 7-12 (in particular “Bearing Temp.: Adapter temperature is correlated to bearing cup temperature using empirical data.”; “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.”; “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.”); 11:39-47 (“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.”); Figs. 1-2 (“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.”); Ex. 1013, [00109]-[00131], Figs. 8, 8A.
a power source electrically connected to said electrical circuitry for providing power thereto, said power source positioned within said housing;	<i>See previous limitation.</i>
a communication device capable of broadcasting information regarding the temperature <u>being monitored sensed</u> via wireless communication, said communication device positioned within said housing, wherein said information regarding the temperature being monitored comprises data representing a condition of the bearing; and	<i>See previous limitation.</i>
a communication management unit, mounted on the railcar, capable of two way wireless communication with each of said plurality of sensor devices for receiving information therefrom, said communication management unit having a wireless communication device for broadcasting information about the parameter or condition being monitored <u>to a land-based remote station, wherein at least one of the communication management unit or the remote station is configured to (i) correlate one or more numeric values derived from the data to the condition of the bearing, (ii) determine a severity of the condition of the bearing, and (iii) determine an alarm</u>	Ex. 1001 at 2:55-58 (“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.”); Ex. 1001 at Table spanning cols. 7-12 (multiple heuristics discussed regarding correlations and indications regarding temperature and vibration); <i>see</i> 34(e)-(g), <i>supra</i> (incorporated here); 11:28-32 (“As shown in FIG. 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.”); Ex. 1001 at 11:63-12:31 (“alert messages are

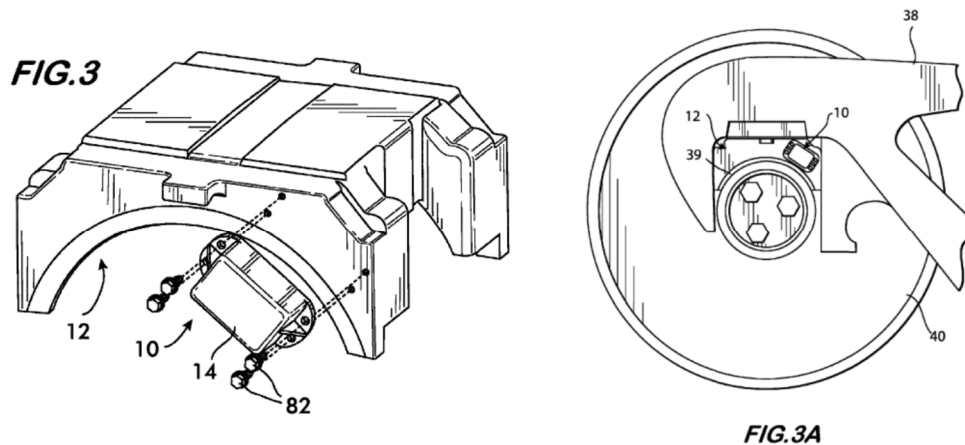
<u>condition based on the severity of the condition of the bearing, wherein said alarm condition comprises one or more recommended actions to be taken with respect to the bearing.</u>	selected such that only actionable messages are sent to the locomotive 46, meaning that only those alarm levels that require the crew to take action are typically transmitted to the locomotive crew. In addition, ... 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....”); Ex. 1013 at [00117]-[00119], [00121]-[00122] (“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. As example of an alert appearing on a locomotive display unit 1310 is shown in Fig. 14. Alerts may also be sent via email or posted to a web site.”).
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1. **“sensor devices each located on and mounted to a sidewall of a bearing adapter of the railcar”**

13. I understand that Petitioner did not challenge written description support for the unamended elements of claim 34. Support for these claim limitations is present in the specification of both the '223 patent and the '661 Provisional, to which it claims priority. See EX1001 at 2:55-58; 3:48-54; 3:60-63; 4:5-10; 4:39-48; 4:66-5:7; 5:11-23; 5:30-46; 8:7-10; Table spanning cols. 7-12; 11:28-32; 11:39-47; 11:63-12:31; 15:25-30; FIGs. 1, 2, 3, 3A; EX1013 at [00064]-[00076], [00109]-

[00131]; FIGs. 3, 9, 8, 8A, 10A; EX1002, 510 (originally filed claim 32); EX1014, [0025].

14. Regarding a sensing unit “mounted on a sidewall of a bearing adapter,” FIGs. 3 and 3A, reproduced below, show mote 10 (sensor) mounted to the sidewall of bearing adapter 12.



15. The specification states that the sensor “*can be any type of sensor.*” Ex. 1001 at 4:51-52; Table, col. 9. This disclosure, together with the disclosures of FIGs. 3 and 3a provide support for a mote with a temperature sensor mounted on a sidewall of a bearing adapter.

2. **“sensor devices each located on and mounted to a sidewall of a bearing adapter of the railcar”**

16. Limitation 34(c) recites “a housing comprising a non-flexible material that is resistant to environmental damage.” The specification states explicitly that, “[p]referably, the housing sections... are composed of a hard plastic resistant to environmental damage.” A POSITA would recognize that “hard plastic” is a non-

flexible material because that is the meaning of the word “hard.” Hard plastic is also resistant to environmental damage, as it is used extensively outdoors and is exposed to the environment. Thus, a POSITA would understand that the specification discloses a housing preferably composed of a non-flexible material that is resistant to environmental damage.

3. “correlate one or more numeric values derived from the data to the condition of the bearing”

17. As discussed in ¶¶13-15, the specification describes a system that monitors the condition of a bearing at a bearing adapter to identify and predict various operational characteristics of the bearing. The specification also discloses that the motes “can include a sensor, a power source, circuitry to read the sensor and convert the readings to a digital form” and describes the circuitry that may be included to accomplish the conversion. EX1001 at 2:45-54; 4:66-5:7. Further, a table of example heuristics that spans columns 7-12 provides a POSITA with the necessary disclosure to understand that the “one or more numeric values” can be “derived from the data or processed information.”

18. Columns 7-12 contain a table of sample heuristics, several of which expressly state that the heuristic correlates calculated values to a condition of the bearing. For example, for the sensed parameter “Adapter Temp,” the heuristic states, “Adapter temperature is correlated to bearing cup temperature using empirical data.” For “Adapter acc.,” a heuristic states, “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.” An FFT generates an array of numeric values. Also for “Adapter acc.,” another heuristic states, “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.” Kurtosis is an indicator of the proportion of a distribution that consists of outliers, i.e., values that are significantly far from the mean and is a numeric value.

C. Claim 35 (Substitute for claim 3, if found unpatentable)

Claim Limitation	Support
~~3.~~ <u>35.</u> The system of ~~claim 2~~ <u>claim 34</u> , wherein said communication management unit can make a determination of an alarm condition based on data collected by two or more of said sensor devices.	Ex. 1001, 2:57-60 (“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.”); 8:6-9 (“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.”); Ex. 1013, [00117]-[00119].

D. Claim 36 (Substitute for claim 4, if found unpatentable)

Claim Limitation	Support
~~4.~~ <u>36.</u> The system of ~~claim 2~~ <u>claim 34</u> , wherein each of said plurality of sensor devices is capable of exchanging data with other of said plurality of sensor	Ex. 1001, 5:16-19 (“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

devices and with said communication management unit.	Management Unit (CMU) 32.”); Ex. 1013, [00117].
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E. Claim 37 (Substitute for claim 26, if found unpatentable)

Claim Limitation	Support
~~26.~~ <u>37.</u> The system of ~~claim 2~~ <u>claim 34</u> , wherein said communication management unit applies heuristics to analyze data collected from said ~~one or more~~ <u>plurality of</u> sensor devices (a) to determine if an actual failure exists and (b) to predict potential or imminent failures based on a statistical analysis of said collected data.	Ex. 1001, 2:60-62 (“During such data analysis, heuristics may be applied to determine potential failures based on statistical models and empirical data”); Ex. 1013, [00117]-[00118], [00129].

F. Claim 38 (Substitute for claim 27, if found unpatentable)

Claim Limitation	Support
~~27.~~ <u>38.</u> The system of ~~claim 2~~ <u>claim 34</u> , further comprising a second temperature sensor located on said railcar for measuring ambient air temperature, wherein said system uses information obtained from said second temperature sensor about the ambient temperature to calibrate the temperature data received from said first sensor regarding the item of the railcar being monitored.	Ex. 1001, 5:40-47 (“In addition, an ambient temperature sensor mote 10 may also be mounted on an area of the railcar 38 receiving free airflow. FIG. 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.”); Ex. 1013, [00116]-[00117].

G. Claim 39 (Substitute for claim 28, if found unpatentable)

Claim Limitation	Support
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~~28.~~ <u>39.</u> The system of ~~claim 2~~ <u>claim 34</u> , wherein said communicating management unit is capable of communicating data and alarms to a remote location located off of the train of which the railcar is a part.	Ex. 1001, 11:28-32 (“As shown in FIG. 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.”); Ex. 1013, [00130]-[00131].
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H. Claim 40 (Substitute for claim 29, if found unpatentable)

Claim Limitation	Support
~~29.~~ <u>40.</u> The system of ~~claim 2~~ <u>claim 34</u> , wherein the power consumption of each of said sensor devices is managed by placing each said sensor device in a standby state and periodically awakening said sensor device to collect readings from said sensor device and to transmit the information regarding the parameter or condition being sensed via said communication circuitry.	Ex. 1001, 5:36-42 (“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.”); Ex. 1013, [00044]-[00045].

I. Claim 41 (Substitute for claim 30, if found unpatentable)

Claim Limitation	Support
~~30.~~ <u>41.</u> The system of ~~claim 2~~ <u>claim 34</u> , wherein said communication management unit and said plurality of sensor devices form a wireless mesh network for said railcar.	Ex. 1001, 5:12-23 (“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. ... The ad-hoc mesh network is preferably formed using the Time Synchronized Mesh Protocol, a

	communications protocol for self organizing networks of wireless devices.”); Ex. 1013, [00116].
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J. Claim 42 (Substitute for claim 5, if found unpatentable)

Claim Limitation	Support
~~5.~~ 42. A system for monitoring the operation of a railcar comprising:	Ex. 1001, 3:48-49; Ex. 1013, [00001]. See Claim 34, above, incorporated here.
a. one or more sensor units mounted <u>to a sidewall of a bearing adapter on</u> said railcar, each of said sensor units monitoring an operating parameter of said railcar wherein each of said sensor units comprises	Ex. 1001, 3:50-54; Fig. 3; 4:43-48; 5:30-34; Ex. 1013, [00109]-[00119], FIGs. 9, 10a; <i>see</i> Claim 34, above (incorporated here).
a sensor,	Ex. 1001, 3:60-63, Figs. 1-2; 5:36-42; Ex. 1013, [00044]-[00045], [00109], [00118]-[00119], Figs. 8, 8A; <i>see</i> Claims 33 & 34, above (both incorporated here).
a power source,	<i>See</i> previous limitation.
a processor,	<i>See</i> previous limitation.
memory,	<i>See</i> previous limitation.
communications circuitry, and	<i>See</i> previous limitation.
software, stored in said memory and executed by said processor, said software performing the functions of collecting data from said sensor at periodic intervals software, stored in said memory and executed by said processor, said software performing the functions of	<i>See</i> previous limitation.

collecting data from said sensor at periodic intervals <u>and calculating one or more numeric values based on the collected data, wherein the one or more numeric values represent a condition of a bearing; and</u>	
b. a communication management unit, mounted on said railcar, said communication management unit in wireless communication with said one or more sensor units;	Ex. 1001, 2:55-58; Ex. 1013, [00117]-[00119]; <i>see</i> Claim 34, above (incorporated here).
wherein said communication management unit applies heuristics to analyze data collected from said one or more sensor units	Ex. 1001, 2:57-60; 8:6-9; Ex. 1013, [00117]-[00119]; <i>see</i> Claim 35, above (incorporated here).
(a) to determine if an actual failure exists and	Ex. 1001, 2:57-60; 8:6-9; 11:63-12:31; 11:28-38; Ex. 1013, [00117]-[00119], [00121]-[00122]; <i>see</i> Claims 34 and 37, above (incorporated here)
(b) to predict potential or imminent failures based on a statistical analysis of said collected data <u>by correlating one or more numeric values derived from the data to the condition of the bearing and determining a severity of the condition of the bearing;</u>	<i>See</i> previous limitation.
<u>c. a land-based remote base unit, in wireless communication with said communication management unit, configured to:</u>	<i>See</i> previous limitation.

<u>(i) receive data from said communication management unit;</u> <u>(ii) determine a severity of the condition of the bearing based on the data received from said communication management unit;</u> <u>(iii) determine an alarm condition based on the severity of the condition of the bearing, wherein said alarm condition comprises a recommended action with respect to the bearing.</u>	
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1. **“one or more sensor units mounted to a sidewall of a bearing adapter”**

19. See ¶¶13-15, above.

2. **“calculating one or more numeric values based on the collected data, wherein the one or more numeric values represent a condition of a bearing”**

20. See ¶¶17-18, above.

K. **Claim 43 (Substitute for claim 6, if found unpatentable)**

Claim Limitation	Support
6. ~~43.~~ The system of ~~claim 5~~ <u>claim 42</u>, wherein said determination of an alarm condition can be made by one of said sensor units.	Ex. 1001, 3:3-8 (“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.”); Ex. 1013, [00117]-[00118].

L. Claim 44 (Substitute for claim 7, if found unpatentable)

Claim Limitation	Support
~~7.~~ <u>44.</u> The system of ~~claim 5~~ <u>claim 42</u> , wherein said determination of an alarm condition can be made by said communication management unit based on data collected by two or more of said sensor units..	Ex. 1001, 8:6-9 (“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.”); Ex. 1013, [00117]-[00119].

M. Claim 45 (Substitute for claim 8, if found unpatentable)

Claim Limitation	Support
~~8.~~ <u>45.</u> The system of ~~claim 5~~ <u>claim 42</u> , wherein each of said sensor units comprises: ~~a. a vibration sensor or accelerometer configured to sample dynamic vibration data; and;~~ ~~b. a power source;~~ ~~c. a processor;~~ ~~d. memory;~~ ~~e. communications circuitry;~~ and ~~f. wherein software, stored in said memory and executed by said processor, said software further performs performing the functions of collecting sampled dynamic vibration data from said sensor at periodic intervals, wherein the one or more numeric values is calculated based on the sampled dynamic vibration data, and wherein the severity of the condition of the~~	Ex. 1001, 3:60-63, Figs. 1-2; 4:43-48; Ex. 1013, [00109], [00118]-[00119], Figs. 8, 8A; <i>see</i> Claims 33, 34, 42, above (all incorporated here).

bearing is determined based on the one or more numeric values.	
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1. **“a vibration sensor or accelerometer configured to sample dynamic vibration data”**

21. Claim 45 substitutes for issued claim 8, which itself depends from issued claim 5. Claim 5 was originally filed as claim 17. See EX1002 at 31-32, 563. Originally filed claim 32 further limits a sensor to a Markush group that includes “vibration sensors” and “acceleration sensors”. *Id.* at 34. Further, the Table of heuristics spanning columns 7-12 of the '223 Patent discloses “[a]n adapter mounted accelerometer can be used to sample dynamic bearing data” and that the “[s]ensor can be mounted on an adapter... to sample dynamic data.” EX1002 at 20-22. The specification describes a condition of a bearing as an operational characteristic that is monitored using accelerometers at a bearing adapter. See Table at col. 9 (reproduced in part below).

Parameter Sensed	Sensor Type	Output	Heuristic
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.
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.

22. A POSITA would understand from this disclosure that the inventors had possession of a sensing unit that includes “a vibration sensor or accelerometer configured to sample dynamic vibration data.”

2. **“wherein the one or more numeric values is derived from the sampled dynamic vibration data”**

23. See ¶¶17-18, above.

N. **Claim 46 (Substitute for claim 9, if found unpatentable)**

Claim Limitation	Support
9. ~~46.~~ The system of ~~claim 8~~ <u>claim 45</u>, wherein said software further performs the function of: assessing the ~~collected~~ <u>sampled dynamic vibration</u> data to determine if an alarm condition exists; ~~and~~ communicating said alarm condition to said communication management unit via said communications circuitry; and managing the power consumption of said sensor unit by placing said sensor unit in a standby state and periodically awakening said sensor unit to collect data from said sensor and to transmit information regarding said operating parameter to said communication management unit via said communications circuitry.	Ex. 1001, 3:3-8; 5:36-42; Ex. 1013, [00044]-[00045], [00117]-[00118]; <i>see</i> Claim 43, above (incorporated here).

O. Claim 47 (Substitute for claim 10, if found unpatentable)

Claim Limitation	Support
~~10.~~ <u>47.</u> The system of ~~claim 5~~ <u>claim 42</u> , wherein said one or more sensor units and said communication management unit are in wireless communication with each other and form a local area wireless network for said railcar.	Ex. 1001, 2:50-3:3 (“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. ... The CMU is capable of wirelessly collecting data from each of the motes and ... communicating both the data and the results of any analysis to a receiver remote from the railcar.”); Ex. 1013, [00117]-[00119].

P. Claim 48 (Substitute for claim 13, if found unpatentable)

Claim Limitation	Support
~~13.~~ <u>48.</u> The system of ~~claim 5~~ <u>claim 42</u> , ~~further comprising a wherein~~ <u>said land-based remote base unit is</u> <u>further configured to, said base unit</u> ~~being in wireless communication with~~ ~~said communication management unit,~~ ~~said based unit performing the functions~~ ~~of.~~	Ex. 1001, 11:39-47: (“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. 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.”); Ex. 1013, [00117]-[00121]; <i>see</i> claims 34 & 42, above.

a. ~~collecting~~ <u>collect</u> data and alarms from said communication management unit;	See previous limitation.
b. ~~displaying~~ <u>display one or more</u> alarm conditions raised by said communication management unit, <u>said alarm conditions are based on the severity of the condition of the bearing and comprises a recommended action with respect to the bearing</u> ; and	See previous limitation.
c. ~~determining~~ <u>determine</u> high level alarms based on data and alarms collected from said communication management unit <u>by comparing the one or more numeric values with a plurality of defined parameter value ranges associated with the bearing</u> .	See previous limitation.

1. **“comparing the one or more numeric values with a plurality of defined parameter value ranges associated with the bearing”**

24. The specification of the '223 Patent broadly refers to temperature thresholds when discussing alerts and alarms. See EX1001 at 4:66-5:7, 6:1-7, 6:35-38, 13:23-24 (“a temperature a predetermined amount above ambient”); 13:41-42 (“a predetermined bearing temperature”). A “temperature” is a :numeric value.” Further, the specification discusses “alarm thresholds” and “tiered alarm levels” that indicate parameter value ranges of acceptable and unacceptable levels. *See id.* at 11:61-12:38. This disclosure demonstrates to a POSITA that the inventors had possession of the invention of Substitute Claim 48.

Q. Claim 49 (Substitute for claim 14, if found unpatentable)

Claim Limitation	Support
~~14.~~ <u>49.</u> The system of ~~claim 13~~ <u>claim 48</u> , wherein said base unit is in wireless communication with multiple communication management units.	Ex. 1001, 2:65-3:3 (“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.”); Ex. 1013, [00118].

R. Claim 50 (Substitute for claim 15, if found unpatentable)

Claim Limitation	Support
~~15.~~ <u>50.</u> The system of ~~claim 14~~ <u>claim 49</u> , 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.	Ex. 1001, 3:3-8; Ex. 1013, [00117]-[00118]; <i>see</i> Claims 43 and 46, above (both incorporated here).

S. Claim 51 (Substitute for claim 16, if found unpatentable)

Claim Limitation	Support
~~16.~~ <u>51.</u> The system of ~~claim 14~~ <u>claim 50</u> , wherein said base unit applies heuristics to data collected from said one or more communication management units to determine if a high level alarm should be raised.	Ex. 1001, 3:3-8; Ex. 1013, [00117]-[00118]; <i>see</i> Claims 43, 46, and 50, above (all incorporated here).

T. Claim 52 (Substitute for claim 17, if found unpatentable)

Claim Limitation	Support
~~17. 52.~~ The system of ~~claim 16~~ <u>claim 51</u> , 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.	Ex. 1001, 11:28-38 (“As shown in FIG. 6, CMU 32 also communicates data and alarms to a ... stationary, land-based base station 44. ... 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.”); Ex. 1013, [00035], [00120].

U. Claim 53 (Substitute for claim 18, if found unpatentable)

Claim Limitation	Support
~~18. 53.~~ The system of ~~claim 5~~ <u>claim 42</u> , 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, piezoelectric microphones and switches.	Ex. 1001, 3:50-54; 5:30-34; Ex. 1013, [00109]-[00119], FIGs. 9, 10a; <i>see</i> Claims 34 and 42, above (both incorporated here).

V. Claim 54 (Substitute for claim 20, if found unpatentable)

Claim Limitation	Support for Substitute Claim 54
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20- <u>54</u> . The system of ~~claim 5~~ <u>claim 42</u> , wherein said alarm <u>condition</u> is determined using distributed event processing based on a comparison between current data and statistical models of behavior.	Ex. 1001, 3:3-8; 13:45-46; Ex. 1013, [00117]-[00118], [00129] <i>see</i> Claims 43, 46 , and 50, above (all incorporated here)..
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W. Claim 55 (Substitute for claim 21, if found unpatentable)

Claim Limitation	Support
21- <u>55</u> . The system of ~~claim 5~~ <u>claim 42</u> , wherein said ~~alarms are~~ <u>alarm condition is</u> determined based on a comparison of currently collected data versus data collected over a pre-determined preceding time period.	Ex. 1001, 13:51-54 (“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.”); Ex. 1013, [00122].

X. Claim 56 (Substitute for claim 22, if found unpatentable)

Claim Limitation	Support
22- <u>56</u> . The system of ~~claim 5~~ <u>claim 42</u> , 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 a 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	Ex. 1001, 13:57-15:16 (“Criteria 1—Peak Analysis: Count the percentage of bearing temperature values>a predetermined value ... Criteria 2—Above Ambient Analysis: Count the percentage of bearing temperature values>a defined value above ambient ... 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 ... Criteria 4—Deviation from Fleet Average Analysis: Calculate the average bearing temperature and standard deviation of each bearing

standard deviation from all railcars in the fleet; or e. the rate of change of current data readings exceeds a pre-determined threshold.	compared to the average of bearing temperatures for the rest of the fleet ... Criteria 5—Heating Rate of Change Analysis: Calculate the percent of operating time that a bearing is heating quickly.”); Ex. 1013, [00130].
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Y. Claim 57 (Substitute for claim 31, if found unpatentable)

Claim Limitation	Support
~~31.~~ <u>57.</u> The system of ~~claim 5~~ <u>claim 42</u> , wherein the power consumption of each of said sensing units is managed by placing each sensing unit in a standby state and periodically awakening said sensing unit to collect readings from said sensor and to transmit information via said communications circuitry.	Ex. 1001, 5:36-42; Ex. 1013, [00044]-[00045]; <i>see</i> Claim 40, above (incorporated here).

Z. Claim 58 (Substitute for claim 32, if found unpatentable)

Claim Limitation	Support
~~32.~~ <u>58.</u> The system of ~~claim 5~~ <u>claim 42</u> , wherein said communication management unit is capable of communicating with a remote location located off of a train of which said railcar is a part.	Ex. 1001, 11:28-32; Ex. 1013, [00117]-[00119]; <i>see</i> Claim 39, above (incorporated here).

AA. Claim 59 (Substitute for claim 23, if found unpatentable)

Claim Limitation	Support for Substitute Claim 59
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23- 59. A monitoring device for monitoring temperature on a railcar, comprising:	Ex. 1001, 3:14-16; Ex. 1013, [00016]; see Claim 33, above (incorporated here).
a housing mountable on a railcar;	Ex. 1001, 3:60-62; Ex. 1013, [00109], [00115]; <i>see</i> Claim 33, above (incorporated here)..
a temperature sensor configured to be in thermal communication with a portion of the railcar to be monitored for temperature, which portion is external to said housing, <u>the temperature sensor positioned within a probe head and interfaced with an electrical connector, the probe head configured to receive a cable having a corresponding electrical connector;</u>	Ex. 1001, 6:16-19; 6:29-33; <i>see</i> Claim 33, above (incorporated here).
electrical circuitry in communication with said temperature sensor <u>via the cable</u> for obtaining information regarding the temperature being sensed, <u>said electrical circuitry positioned within said housing, said cable having a proximal end disposed in the housing and a distal end residing external to said housing;</u>	Ex. 1001, 4:66-5:2, Figs. 1, 5, 5A (“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”).
a power source electrically connected to said electrical circuitry for providing power thereto, said power	Ex. 1001, 5:24-25; Ex. 1013, [00113]; <i>see</i> Claim 33, above (incorporated here).

source positioned within said housing; and	
a communication device capable broadcasting information regarding the temperature sensed, said communication device positioned within said housing;	Ex. 1001, 3:60-63, Figs. 1-2; Ex. 1013, [00109], Figs 8, 8A; <i>see</i> Claims 33, 34, 42, and 45, above (all incorporated here).
wherein the power consumption of said monitoring device is managed by placing said monitoring device in a standby state and periodically awakening said monitoring device to collect readings from said temperature sensor and to transmit the information regarding the temperature sensed via said communication circuitry.	Ex. 1001, 5:24-29; Ex. 1013, [00044]-[00045]; <i>see</i> Claim 33, above (incorporated here).

BB. Claim 60 (Substitute for claim 24, if found unpatentable)

Claim Limitation	Support
~~24.~~ <u>60.</u> The monitoring device of ~~claim 23~~ <u>claim 59</u> , wherein at least a section of said temperature sensor is disposed outside of and spaced from said housing to be capable of contacting the surface of the railcar for which the temperature is to be monitored.	Ex. 1001, 4:33-34 (“the heat transfer element 22 will contact the surface on which the mote is attached.”); 6:46-47 (“allowing the probe head 50 to be attached to the cleaned outside surface 78 of the vessel 70”).

CC. Claim 61 (Substitute for claim 25, if found unpatentable)

Claim Limitation	Support for Substitute Claim 61
~~25. 61.~~ The monitoring device of ~~claim 23~~ <u>claim 59</u> , wherein said circuitry is configured to apply heuristics to analyze data collected from said temperature sensor to determine if a problem exists.	Ex. 1001, Table spanning cols. 7-12; 11:39-47; Ex. 1013, [00064]-[00076]; <i>see</i> Claims 34 and 42, above (both incorporated here).

25. Each of the Substitute Claims adds limitations not found in the corresponding issued claim, hence do not broaden any issued claim.

V. SUBSTITUTE CLAIMS 33 THROUGH 61 ARE PATENTABLE OVER THE PRIOR ART REFERENCES OF RECORD, ALONE OR IN COMBINATION

26. I am not aware of any prior art that would anticipate or render obvious proposed substitute claims 33 through 58. Further, substitute claims 34 through 58 find written description support in Provisional Application 61/661,661 (Ex. 1013, the “’661 Provisional”), filed June 19, 2012, to which the ’223 Patent claims priority. Claims 33 and 59-61 have a priority date of March 15, 2013. I understand that Patent Owner may claim priority through prior invention should it be appropriate to do so.

A. Independent Substitute Claims 33 and 59

27. Independent Substitute Claim 33 corresponds to claim 1 of the Challenged Claims. It recites a sensor probe head that (i) is spaced apart from the

housing, (ii) has a body formed of a heat conductive material, (iii) has a connector electrically interfaced with said temperature sensor and configured to connect to the distal end of the cable and includes said temperature sensor, and (iv) has a magnet positioned in the body adjacent to a portion of the connector extending inside the body. Claim 59 (corresponding to claim 23 of the Challenged Claims) includes similar limitations.

28. Support for these limitations, and the other limitations of substitute claims 33 and 59, is cited in the preceding charts.

29. Petitioner cites Denny, Culbertson, and Provasnik in arguing that independent claims 33 and 59 are obvious. See Paper 28 at 20-25. Petitioner fails to explain how these disparate references should be combined to arrive at the claimed invention, and, in particular, fails to explain why specific disclosures should be plucked from the references and combined as in the Substitute Claims. Denny discloses a temperature probe having a housing with a lower portion that “is inserted into the wheel assembly” using a threaded connection. Ex. 1008 at 5:26-35, FIG. 2. Culbertson discloses a temperature probe designed for some undefined “operational environment” and requires a “mounting assembly in [the] operational environment” to be secured in place. Ex. 1032 at 4:46-48. Provasnik discloses a temperature sensor which can readily be attached to and removed from an automobile engine and is well-suited for automotive garages and repair shops (e.g., in connection with an

automotive engine analyzer). Ex. 1009 at 2:46-49. It is also notable that the embodiment to which claims 33 and 59-61 are directed involves a temperature probe extending to a commodity tank in a specialized railcar, and not to a wheel assembly. It is unclear how Petitioner's combination teaches or suggests any claim as a whole.

30. Further, claims 33 and 59 recite that the temperature sensor is electrically interfaced using a connector. A POSITA would have understood that a connector allows for connecting or disconnecting electrical components without the need for special tools or processes. Provasnik discloses soldering the leads 12, 14 of his heat sensitive device 10 permanently to the leads 16, 18 of his lead-out cable 20 at points 22, 24, respectively. Thus, Provasnik fails to disclose at least this connector limitation of claims 33 and 59.

31. Petitioner cites Denny for the idea that the electronic components of a railcar temperature sensor should be "situated away from the outer surface of the wheel assembly so that the electronic circuit will not be subjected to heat from the wheel assembly so that the electronic circuit will not be subjected to heat from the wheel." Petition, 54. Petitioner does not apply Denny for any other purpose.

32. Denny does not disclose a magnetic sensor attachment or a connector, and thus does not remedy the deficiencies of LeFevbre, Armitage, or Provasnik. Petitioner does not apply Barone to Challenged Claims 1 or 23.

B. Independent Substitute Claims 34 and 42

33. Independent Substitute Claims 34 and 42 correspond, respectively, to Challenged Claims 2 and 5. They recite a land-based remote station that (i) correlates or calculates one or more numeric values derived from sensor data that represent the condition of the bearing, (ii) determine a severity of the condition, and (iii) determine an alarm condition based on the severity that at least includes a recommended action to be taken with respect to the bearing. Support for these elements, as well as the remainder of the limitations of substitute claim 34 and 42 is provided in the above charts. These limitations, as an ordered combination, are not taught or suggested by the references cited by Petitioner.

34. A POSITA would have understood “calculating a numeric value based on the dynamic vibration data sampled by the accelerometer” to include, e.g., performing an FFT on the sampled data (e.g., to isolate known frequencies of interest); or performing a kurtosis or other statistical analysis on the sampled data; and so forth. Ex. 1001, Table spanning cols. 7-12. The claimed system uses these numeric values to determine the condition of the bearing, determine a severity of that condition, and determine an alarm condition which identifies a recommended action to be taken with respect to the bearing. The cited combination does not disclose, teach, or suggest this specific combination of elements.

35. Regarding claim 5, Petitioners assert that LeFebvre’s use of “frequency spectrum analysis” teaches the claimed “applies heuristics to analyze data collected

from said one or more sensor units.” Petition, 31-32. Petitioners cite portions of LeFebvre that disclose using a load sensor in the top of instrumented pad 16 to monitor vibrations emitted from the bearing. LeFebvre, [0059]. Substitute claim 42 (a substitute for claim 5) adds the limitation, “calculating a numeric value based on the dynamic vibration data sampled by the accelerometer, wherein the calculated numeric value represents a condition of a bearing” and “comparing the calculated numeric value with a plurality of defined parameter value ranges associated with the bearing, each of which represents one of a plurality of severity levels and from which a severity of the condition of the bearing is determined, and communicating information about the condition being monitored to a land-based remote station,” among others. LeFebvre does not disclose comparing a calculated value against defined value ranges to determine a severity of the condition of the bearing.

36. With respect to heuristics (as in claim 5), Petitioner asserts that the statistical analysis of Armitage teaches using “heuristics to determine actual, potential, or imminent failures based on a statistical analysis of the collected data.” Petition, 65. In support of this assertion, Petitioner cites portions of Armitage that disclose the use of “moving average and trend analysis” and “time series analysis,” the latter with respect to vibration monitoring. Armitage, [0030], [0045]. Armitage not disclose comparing a calculated value against **defined** value ranges to determine a severity of the condition of the bearing, as recited in Substitute Claim 34 and

similarly in Substitute Claim 42. Therefore, Armitage does not cure the deficiencies of LeFebvre.

37. Regarding Challenged Claims 2 and 5, Petitioner relies on Barone only for disclosing a plurality of railcars. Petition, 45. Otherwise, Petitioner characterizes Barone as similar to LeFebvre. *Id.*, 41-42. Thus, like LeFebvre and Armitage, Barone also fails to teach these limitations.

38. Claims 35-41 all depend, directly or indirectly, from claim 34. Claims 42-58 all depend, directly or indirectly, from claim 42.

VI. CONCLUDING STATEMENT

39. Relying on my education, experience, skill, and training in the relevant field of art, and after reviewing the materials identified above, it is my opinion that the Substitute Claims find written description support in the '223 Specification and the '661 Provisional. Further, the Substitute Claims are patentable over the prior art applied in the Petition.

40. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-

examination remotely within the United States during the time allotted for such cross-examination at a time and place agreed by counsel.

41. I reserve the right to supplement my opinions in the future to respond to any arguments that Petitioner raises and to take into account new information as it becomes available to me.

42. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed March 8, 2024 at Pittsburgh, PA.


Michael I. Shamos