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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor:	RETTERATH, James E., et al.	)	Attorney Docket: 26,227-02
Serial No:	60/	)	Art Group Unit:
Filing Date:	June 7, 2001	)	Examiner:
Title:	Method and Apparatus for Determining Retroreflectivity from a Moving Platform	)	

TRANSMITTAL

Box Provisional Application
Commissioner of Patents
Washington, D.C. 20231

Sir/Madam:

Enclosed for filing please find the following:

1. Provisional Application Cover Sheet, consisting of 2 pages;
2. Provisional Application, consisting of cover sheet and 34 pages of text, 13 sheets of drawings (including Figs. 1-16) and Appendix A (92 pages);
3. Verified Statement (Declaration) Claiming Small Entity Status (37 CFR 1.9(f) and 1.27(b)) – Independent Inventor, signed by James Retterath (2 pages);
4. Verified Statement (Declaration) Claiming Small Entity Status (37 CFR 1.9(f) and 1.27(b)) – Independent Inventor, signed by Robert Laumeyer (2 pages);
5. Declaration Claiming Small Entity Status Under 37 CFR 1.9(f) and 1.27(c) – Small Business Concern (2 pages);
6. Power of Attorney (1 page);
7. Check in the amount of $75.00 for filing fee (small entity);
8. Assignment and attached Recordation Form Cover Sheet (3 pages);
9. Check in the amount of $40.00 for recordation fee; and
10. Return Receipt Post Card.

Please charge any additional fees necessitated by this correspondence, or credit any overpayment, to the deposit account of the undersigned firm of attorneys, Deposit Account 12-0449.

Please direct any questions or comments to Paul H. McDowall at (952) 896-3220.

Respectfully submitted,

Date: June 7, 2001 By: Paul H. McDowall

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Certificate of Express Mailing

Pursuant to C.F.R. 1.10, I hereby certify that this Transmittal and accompanying documents are being deposited with the United States Postal Service by "Express Mail Post Office to Addressee" service, addressed to: Box Provisional Patent Application, Commissioner for Patents, Washington, D.C. 20231, as of the date of deposit and under the mailing label indicated below:

Date of Deposit: June 7, 2001

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Geralyn M. Vita

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PROVISIONAL APPLICATION COVER SHEET

Box Provisional Application
Commissioner for Patents
Washington, D.C. 20231

Sir:

This is a request for filing a Provisional Application under 37 C.F.R. 1.53(b)(2).

Attorney Docket No.: 26,227-02

INVENTOR/APPLICANT

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TITLE OF THE INVENTION

Method and Apparatus for Determining Retroreflectivity from a Moving Platform

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ENCLOSED APPLICATION PARTS

1. Application consisting of cover sheet and 34 pages of Specification; Appendix A (92 pages) — No. of pages 127

2. Drawings — No. of sheets 13

PAYMENT

A check in the amount of $75.00 is enclosed to cover the filing fee for this provisional application.

The Commissioner is authorized to charge any additional fees which may be required by this paper, or refund any overpayment, to Deposit Account No. 12-0449.

The invention was not made by an agency of the United States Government or under a contract with an agency of the United States Government.

Respectfully submitted,

Facet Technology Corporation

Date: June 7, 2001

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U.S. Provisional Patent Application

Entitled

Method and Apparatus for Determining Retroreflectivity from a Moving Platform

Invented by James E. Retterath and Robert A. Laumeyer

METHOD AND APPARATUS FOR DETERMINING ENTRANCE ANGLES AND RETROREFLECTIVITY FROM A MOVING PLATFORM

RELATED APPLICATIONS AND STATEMENT OF INCORPORATION BY REFERENCE

The applicant hereby fully incorporates herein the contents of U.S. utility patent application serial no. 09/177,836 filed 23 October 1998 (now allowed) and entitled, "Method and Apparatus for Identifying Objects Depicted in a Videostream;" and a divisional patent application (of U.S. patent application serial no. 09/177,836) filed 29 January 2001, as U.S. patent application serial no. 09/xxx,xxx and entitled, "Method and Apparatus for Rapidly Determining Whether a Digitized Image Frame Contains an Object of Interest;" and further incorporates by reference the contents of following additional documents (complete copies of which are attached hereto): (i) "Installation and Operation Guide for 'HIGH INTENSITY OBSTRUCTION LIGHTING SYSTEM' for Model No. SG-60," dated 30 July 1999; (ii) product data sheet for the "'Impulse RM' Retro-reflectometer" manufactured by Laser Technology, Inc. of Englewood, 'CO, USA; (iii) "Driver Needs and Maintained Sign Retroreflectance" by Charles H. Goodspeed, 3Company [sic], St. Paul, MN, USA; (iv) unpublished nine (9) page document (including Appendix A, B, C) entitled, "Proposal To Facet Technology Corporation January,", (v) unpublished six (6) page document entitled, "Holometrics 3D Vision Technology," and, (vi) a twenty-eight (28) page document entitled, "Mobile Sign Retroreflectometer Van."

FIELD OF THE INVENTION

The present invention relates to the field of automated mobile electronic measurement and object identification systems. More particularly, the present invention is directed to methods and an apparatus for measuring, identifying, precisely locating, and determining certain characteristics of desired target objects and classifying the target objects as to the level of

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retroreflectivity (i.e., a quality related to the ability of a surface material to reflect incident electromagnetic radiation back to the source of the radiation). The techniques of the present invention may be operated either in a "run time" mode (i.e., when a vehicle employing the system is simultaneously collecting target object data) or in a "post processing mode" (i.e., wherein the system operates independent of such data collection). In addition, this disclosure teaches, enables and illustrates (i) preferred sensor selection and sensor/receiver/processor configurations wherein the sensors operate independently in collecting data from a scene containing retroreflective surfaces of interest; (ii) a preferred moving platform supporting such preferred sensor selection and configurations for measuring, logging (storing) and/or processing via computer the data collected from such surfaces of interest present in a scene; (iii) preferred post-processing methods for deriving a variety of different useful outputs and graphical representations (e.g., 3D simulation by magnitude of retroreflectance) from each such surface or for many such surfaces for the processed outputs herein, and (iv) preferred methods for processing the data collected to schedule, in a preselected priority sequence, a master service plan for dispatching service personnel to work on select of such surfaces in a most efficient manner (given the priority sequence).

BACKGROUND OF THE INVENTION

Safe motor vehicle travel during low light conditions requires that directional, informational and cautionary information (also referred to as regulatory, warning and information) displayed upon roadside signage are all visible to a vehicle operator traveling at a reasonable velocity down a roadway. Such low light conditions may occur at any time of day due to a variety of natural phenomena, such as inclement weather, haze, inclination of the sun, clouds, fog, thunder or snow storms, and the like. In addition, such natural phenomena promote

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aging of materials used to fabricate such signage thus oftentimes degrading the ability of a vehicle operator to accurately perceive relevant information displayed thereon. Such materials include the post(s) that support signs, the typically metallic sign base or substrate, paint or decal with specific colors and indicia, a retroreflective layer typically containing adhesives, binders, emulsions and the like and, finally, a sheeting layer or overlayer.

Primarily due to concerns for motorist safety, nearly every transportation department and agency must typically manually review, manage and perform work maintaining all traffic control devices (TCD) in their respective jurisdictions. On a continuing basis an estimated 58 million individual TCD are monitored and maintained in the United States and new TCD installations increase this number daily. Such work typically involves manual inspection procedures over, in aggregate, millions of miles of roadside terrain to confirm that the directional, informational and cautionary indicia displayed on a variety of signs are visible and useful to motorists at all times. These procedures must be capable of assessing the physical condition of all variety of signs whether disposed laterally adjacent, suspended over, or printed on a section of roadway. The assessment typically includes a manual survey of the condition of the surface of the face of the sign (including the indicia, level of retroreflectivity and sheeting type, the sign location), and the structure location. For damaged and dilapidated signs, typically a road work crew will be assigned to revisit the sign location as recorded by the assessment personnel to correct or replace such signs. With the end result that motorists may continue to safely traverse the roadway during all variety of lighting conditions at any time of the day or night. Needless to say, these procedures are cumbersome, costly, ineffective, and they ultimately rely upon human observation and perception and accurate recording of many variables, including actual location of each sign. Furthermore, if the original entry data regarding a sign is not accurate, accurately

locating and identifying the original sign may take additional time and effort and increases the likelihood that a different sign will be manually serviced. Moreover, in the case of signs that are completely missing or otherwise are not visible from the roadway, these prior art manual procedures rely upon the accuracy of prior data collection and human memory as to the types of sign(s) and the proper location of signs that are missing. These prior art techniques and practices clearly create considerable inefficiencies and redundancies in the management, administration, monitoring, repair and replacement of roadside signage.

Prior art so-called automated data collection systems for roadside signage often required that normal traffic be stopped during data collection because either the acquisition vehicle moved very slowly or because the acquisition vehicle had to come to a full stop before recording data about the roadside scene. Furthermore, as described with respect to some specific prior art, a human operator is required to point one or more measurement devices at a sign of interest, perform data collection for that particular sign and then set up the device for another particular sign of interest. In some roadside scenes, where a multitude of individual signs are present, these prior art procedures are not only cumbersome, they interrupt normal traffic flows.

Adequate nighttime and low light visibility of roadway signs by vehicle operators is best associated and most impacted with the retroreflectance properties of the individual signs. Retroreflectivity (defined as the ability of a material to reflect incident light back towards its source), specified in candelas per lux per square meter (cd/lux/m^2), is an important measure utilized by transportation agencies to assess the nighttime visibility of their signs. Retroreflectivity, designated as "$\mathbf{R_A}$" generally (and from time to time in this disclosure), varies according to two key parameters, observation angle and entrance angle.

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Observation angle is the angular displacement between the light source and the light sensor, as measured from the face of the object being measured. In the case of a car moving along a highway, observation angle is defined by the vehicle's distance from a sign, the placement of the headlights on the vehicle, and the position of the eyes of the driver of the vehicle. Figure 1 illustrates the observation angle.

Entrance angle is defined as the angular displacement of the incident light relative to the normal vector from the sign surface. Entrance angles are impacted by the angular position of a sign relative to the roadway, the sign's lateral distance from the roadway, and the vehicle's distance from the sign. Figure 2 illustrates the entrance angle concept for the uninitiated. The inventors hereof are believed to be the first persons to successfully decrease the complexity and increase the efficiency of measurement of R_A in the field.

In general several prior art techniques exist for measuring and determining $\mathbf{R_A}$, including U.S. Patent No. 6,212,480 entitled, "Apparatus And Method For Determining Precision Reflectivity Of Highway Signs And Other Reflective Objects Utilizing An Optical Range Finder Instrument" issued 3 April 2001 to Dunne. The Dunne patent relates to a device commercialized by the assignee thereof and marketed as the "Impulse RM" retro-reflectometer. In use, handheld devices fabricated according to the Dunne patent must be manually directed toward, or precisely at, a target object and then manually "fired." Inherent limitations of this prior art device and technique include: (i) a human operator must point such a device at a single target object being measured; (ii) such a device only measures a single color at a time; (iii) such a device can only measure one object at a time; (iv) the measurement of R_A is valid only for the actual location, or discrete measurement point, along the roadway at which the measurement was made by the human operator; (v) such devices are not susceptible of easy operation on a moving platform or

vehicle; (vi) in order to validate a measurement made by such devices, the device must be taken back to the precise location in the field where an original measurement occurred and the measurement must be reproduced.

The present invention addresses these and other shortcomings of the prior art as will be appreciated by those of skill in the art to which the present invention is directed with reference to the written disclosure, drawings and claims appended hereto.

SUMMARY OF THE INVENTION

The present invention is directed to, teaches, and enables one of skill in the art to practice a method and apparatus for accurately determining the retroreflectivity of a target object such as one or more reflective signs adjacent a roadway (also referred to herein as "reflective assets") at various discrete locations along a roadway. The methods and apparatus of the present invention described herein are best suited to measurements from a moving platform, or vehicle, but the methods and apparatus apply to and may be used in conjunction with a stationary platforms as well.

In addition, this disclosure teaches, enables and illustrates (i) preferred sensor selection and sensor/receiver/processor configurations wherein the sensor operates independently in collecting data from a scene containing retroreflective surfaces of interest; (ii) a preferred moving platform supporting such preferred sensor selection and configurations for measuring, logging (storing) and/or processing via computer the data collected from such surfaces of interest present in a scene; (iii) preferred post-processing methods for deriving a variety of different useful outputs and graphical representations (e.g., 3D simulation by magnitude of retroreflectance) from each such surface or for many such surfaces for the processed outputs

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herein for several distinct purposes, and (iv) preferred methods for processing the data collected to schedule, in a preselected priority sequence, a master service plan for dispatching service personnel to work on select of such surfaces in a most efficient manner (given the priority sequence).

These and other objects, features and advantages will become apparent in light of the following detailed description of the preferred embodiments in connection with the drawings. Those skilled in the relevant art will readily appreciate that these drawings and embodiments are merely illustrative and not intended to limit the true spirit and scope of the invention disclosed, taught and enabled herein.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will be described in detail hereinafter with reference to the accompanying drawings.

FIG. 1 depicts the concept of observation angle (i.e., angle between incident light from a light source and an human observer, or light sensor, of the light as reflected from the face of a reflective asset) in the context of a conventional passenger vehicle traversing a vehicle pathway and where light from the vehicle reflects from a stop sign to the vehicle operator (shown in ghost).

FIG. 2 depicts the concept of entrance angle (i.e., angle between incident light from a light source mounted to a vehicle and a normal vector relative to the substantially flat face of a reflective surface disposed adjacent a vehicle pathway).

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FIG. 3 depicts a block diagram of the systems, sub-systems and processes for capturing and processing roadside information from a moving platform in order to compute retroreflectivity according to the teaching of the present invention wherein the arrows connecting the blocks of the diagram illustrate the connections between the systems and sub-systems for measuring $\mathbf{R_A}$ for each reflective asset recorded by the system of the present invention.

FIG. 4 depicts in diagram form, a preferred configuration of a sensor suite for use with a four wheeled vehicle and the interconnections and couplings between the physical subcomponents of a system designed according to the present invention.

FIG. 5 is a plan view of a divided multi-lane vehicle pathway and depicts how periodic light intensity measurements may be made as a vehicle traverses the vehicle pathway over time and the discrete locations where such periodic light intensity measurements are performed by a data acquisition vehicle operating in accordance with the present invention.

FIG. 6 depicts four digital frames of data as captured by the intensity sensor at various discrete locations along the vehicle pathway depicted in FIG. 5.

FIG. 7 depicts a flowchart showing the steps required to convert intensity measurements into foreground and background retroreflectivity for a single reflective asset.

FIG. 8 depicts a typical light source intensity profile over the visible electromagnetic spectrum which illustrates how different wavelengths of electromagnetic radiation possess different light intensities.

FIG. 9 depicts a preferred methodology for creating a 3D retroreflectivity profile for all lanes and locations adjacent a vehicle pathway for a single reflective asset or sign which 3D

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retroreflectivity profile is based upon a single pass of a data acquisition vehicle over the vehicle pathway.

FIG. 10 illustrates the facts that the normal vector of a reflective asset and the sheeting type of such a reflective asset create symmetry that may be used to determine retroreflectivity values along all rays (or vectors) that have the same relative angle to the normal vector of the reflective asset.

FIG. 11 is a perspective view of roadway edges and lane dividers created from the imaging system on-board the moving platform.

FIG. 12 is a perspective view depicting a 3D retroreflectivity profile for a stop sign created from the moving platform

FIG. 13 is a perspective view depicting a modified 3D retroreflectivity profile resulting from a change to the sign sheeting type that produces increased retroreflectivity values over the entire road surface.

FIG. 14 is a perspective view depicting a modified 3D retroreflectivity profile resulting from a clockwise change to the sign angle that produces increased retroreflectivity values for the leftmost lanes of the road surface.

FIG. 15 is a perspective view depicting the modified 3D retroreflectivity profile resulting from an increase in the observation angle.

FIG. 16 depicts the geometry of entrance angle and observation angle for retroreflective pavement markings disposed upon a vehicle pathway.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Pursuant to the teaching of the present invention a method and apparatus for measuring retroreflectivity of relatively flat surface portions of objects disposed adjacent a vehicle pathway are taught, enabled and depicted. The present invention requires a retroreflective surface of interest disposed in a scene of non-retroreflective surfaces. That is, at least one relatively flat surface portion which exhibits retroreflectivity over a relatively narrow conical volume of magnitude of several degrees from a normal, or orthogonal, vector originating from said relatively flat surface portion. In accordance with the present invention, the following information and steps are set forth toward creating accurate measurements of retroreflectivity of objects adjacent a vehicle pathway: (i) precise position and attitude of a data acquisition vehicle; (ii) precise position of the object of interest relative to the vehicle; (iii) intensity values from an active light source/intensity sensor system from discrete vantage points along said vehicle pathway. Thus, a single-pass data acquisition vehicle system operating the sensor suite taught herein eliminates many shortcomings of the prior art and allows a single vehicle operator to conduct virtually continuous data measurement and acquisition of reflective assets disposed adjacent a vehicle pathway, from vantage points on said vehicle pathway, without disrupting or interrupting other vehicles traversing said vehicle pathway.

Figure 3 shows a block diagram of the on-board systems and the desktop systems required to create retroreflectivity (R_A) measurements and three dimensional (3D) R_A profiles for various signs along a vehicle pathway, or more typically, a roadway. The Vehicle Positioning System contains all of the equipment to precisely locate the vehicle (XYZ coordinate) as well as its attitude (XYZ vector denoting the heading of the vehicle). All location information is synchronized with a master clock, which allows other data types to be merged with the vehicle

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location information at later stages in the post-processing. All of the on-board systems utilize the same master clock information, thus allowing any events (like image capture, intensity capture, and light source triggering) to be correlated to the precise vehicle location and attitude during real-time, near real-time, or post-processing of the data acquired by the data acquisition vehicle.

The Image Capture System consists of at least one set of stereoscopic cameras that gather digital imagery along the vehicle pathway. Each capture event is combined with time stamp information from the Positioning System. These images and associated time stamps are later combined with photogrammetry to create Objects of Interest and their Associated Attributes.

The Light Intensity Measurement System consists of the high output light source(s) and the associated intensity sensor(s). The precise control for these items is contained within the Light Intensity System, and master clock information received from the Positioning System tags the events so precise vehicle information can be utilized during post-processing.

The Data Recording System is constantly monitoring control information from the other three on-board systems and records the necessary information. No post-processing is performed in the Data Recording System. As computer power increases in the future, one skilled in the art could produce a system whereby most, if not all, of the post-processing functions were performed in the vehicle, perhaps even in real time. The inventors can imagine several uses for the production of real-time information from the vehicle capture system, but the cost of obtaining such information with today's computing power makes this option prohibitively expensive.

The lower half of Figure 3 shows the functional blocks for data post-processing. There are two main functions – the creation of Object of Interest and their Associated Attributes, and the determination of Retroreflectivity for each Object of Interest. There are many methods for

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creating Objects of Interest from digital imagery, a few of which are discussed in this disclosure. The specific steps required to compute R_A are outlined in the following discussion below.

Figure 4 shows a typical configuration within a capture vehicle that is capable of producing data and imagery to create Objects of Interest and Retroreflectivity for these Objects of Interest. The Distance Measuring Instrument (DMI), GPS Receiver and Inertial Navigation System (INS) constitute the vehicle positioning system. Not all of these components are necessary to obtain the desired results, but better precision, and therefore more meaningful data, are produced if all three components are included.

The High Output Light Source(s) and Intensity Sensor(s) constitute the Intensity Measurement System. These components make if possible to gather on-the-fly information for a desired roadway to allow the computation of R_A for various Objects of Interest, as well as a full 3D R_A profile for those same objects.

The Stereoscopic Cameras constitute the digital imagery system that allows for the creation of Objects of Interest and their Associated Attributes during post-processing. More than one set of Stereoscopic Cameras can be employed, thus increasing the accuracy of positional measurements for Objects of Interest. Other, non-stereoscopic imaging systems could also be employed with no change to the positioning system or to the Intensity Measurement System.

Figure 5 shows the top view of a four-lane divided highway with a stop sign. The capture vehicle is traveling in the rightmost lane and makes intensity measurements at periodic intervals while traveling the depicted route. The techniques described herein will allow a retroreflectivity value for this stop sign to be computed for any point along the roadway, independent of whether the intensity measurement was made at that point and also independent of whether the capture vehicle actually drove over that point.

It should be noted that intensity measurements are made continuously while the vehicle is in motion, thus requiring no prior knowledge of either the positions or the existence of signs.

Figure 6 shows some typical intensity frames as captured by the intensity sensor at various discrete locations along the roadway. These intensity frames are the result of the high intensity light source being energized (or flashed) while each frame is captured by one or more intensity sensors. Since most of the objects in the scene are not reflective, and due to the high setting of the threshold range in the intensity sensor(s), the intensity frames will actually show very few objects. For effective luminance results throughout a wide range of retroreflective materials, more than one intensity sensor may be required in order to get enough levels of gray within the active part of the visible spectrum; that is, for each such intensity sensor the threshold sensitivity range of each such intensity sensor may be tuned to different portions of the visible spectrum. When multiple intensity sensors are required or used, they may each have different threshold ranges and each thus detect luminance values in different parts of the desired luminance ranges.

In order to compute retroreflectivity (R_A), one needs to know the luminance of the reflected energy. Luminance (expressed in candelas per square meter, or cd/m^2) will vary according to the intensity profile of the sensor(s) and the color of the material from which light is reflected.

Figure 7 shows a block diagram of the steps required to transform intensity into luminance. First, a black and white camera is preferably used as a sensor to maximize the sensitivity of intensity measurements (intensity will be determined from the gray value of the corresponding pixels). Intensity values will vary according to the color of the reflected light, since not all colors of incoming light excite the camera pixels in the same way. By knowing the

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background or foreground color of the object along with the sensor's ability to sense, or the sensor's profile, for a particular color, the intensity value can be converted into a luminance value. Sensor characterization is essential since N photons of a given particular color (or wavelength) of light will represent a different gray value (intensity level) in the sensor than N photons of another color (or wavelength) of light.

The reader should note and appreciate that luminance is strictly a measure of the reflected light, while retroreflectivity (or R_A, expressed in candelas/lux/m^2) is a measure of the reflected light with respect to the incident light for that object. Figure 7 shows the information needed to convert luminance to R_A: sensor location, object location, light source characterization, and color of reflective material.

The preferred light source is a uniform full-spectrum (visible spectrum) light. In practice, this light source will not emit the same intensity for all wavelengths of visible light. One aspect of light source characterization required is the output profile of the light throughout the visible spectrum. Figure 8 shows a typical full-spectrum light source output profile. Note that the intensity in the blue area (400-500 nm) of the spectrum is stronger than in the red area (600-700 nm). This profile specifies the amount of light energy (number of photons) emitted for a given frequency. Since R_A depends on the intensity of the incident light, the light source characterization and background/foreground sheeting color must be combined to determine how the luminance value is converted to R_A (i.e., what percent of the incident photons of the foreground/background color were reflected back to the sensor).

The inventors pragmatically recognize that light emitted from the light source(s) will not be perfectly columnated but will in fact provide some level of light beam divergence. In fact, to get broad coverage within the scene, a fair amount of beam divergence is required. Because of

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the diverging light source, objects farther from the source will receive less incident light than those objects closer to the source.

Part of the process of characterizing the light source requires mapping of the beam divergence profile for each such light source. For each luminance number, the location of the light source and the measured object must be known. Four pieces of data – object location, light source location, light source divergence profile, and sheeting color – allow us to determine the amount of incident light (for a given color) that corresponds to the luminance value.

The divergence pattern for the light source may have different profiles for various portions of the visible spectrum. In practice, a separate light source divergence profile may be required for each possible foreground and background color of any given reflective asset.

The measurement system described herein attempts to remove observation angle as a R_A variable. This is done by keeping the offset between the light source(s) and sensor as low as possible. Once a full R_A profile for a particular roadway is created, observation angles can be varied within the 3D display software to show their effects on the R_A for a given roadway and any as-placed sign.

As mentioned previously, an R_A map of an entire roadway can be computed, even though the intensity was not measured at every point and even though the capture vehicle did not drive over every point. First, it's critical that the geometry of R_A is understood. Reflective materials like sign sheeting are designed to project near-columnated light back toward the light source. If we assume perfectly columnated light being reflected from the object being measured, the R_A values for all discrete locations along a ray projected from the object will be identical.

Figure 9 shows how to compute R_A for any discrete location along the vehicle pathway. The R_A value for the desired point will be based on the R_A value that lies along the pathway

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traveled by the data acquisition vehicle. To compute the R_A value for this point, we draw a ray from the desired location to the face of the reflective asset. The discrete location where the ray intersects the vehicle path will be used as the reference R_A value. Since the discrete location on the vehicle path will always lie between two measured locations where intensity measurements were made, the reference R_A value is computed by interpolating the two closest (in distance) R_A values along the vehicle path. As used herein, interpolate has the usual and typical meaning and shall also include such other special mathematical expressions used or created to account for non-linear border effects and effects at the lateral periphery and at the furthest distance where R_A may be reliably detected and measured by application of the teaching of this disclosure.

If we assume perfectly columnated light, the value of R_A at our desired point will be the same as the reference R_A value. In practice, all sign sheeting materials will have some beam divergence for reflected light. This beam divergence information can be used to adjust the computed R_A value up (or down) from the reference R_A value for discrete locations closer to (or farther from) the sign face.

While knowing the normal vector to a sign face is not required, there are some advantages for planning and maintenance purposes that make the information useful. Several ways to compute the normal vector for a sign exist. First of all, the "assumption" method requires that the normal vector from the surface of the sign is assumed to be parallel to the vehicle pathway at the nearest location of the vehicle pathway to the sign. Second, a scanning laser operating in conjunction with an optical sensor and having a common field of view may be used to more precisely resolve the normal vector from the face of the sign. Third, stereo imaging cameras may be employed in a useful, albeit very imprecise manner of determining the normal vector. Fourth, the assumption method and stereo imaging method may be combined whereby

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the normal vector is assumed to lie parallel to the vehicle pathway unless the stereo imaging output renders the assumption false.

Of the methods listed above, the highest precision normal vector measuring system consists of a scanned laser and associated optical sensor. This combination yields relative distance measurements between the vehicle and sign face that are more precise than optical measurements with cameras. A laser scanner attached to the moving platform and directed toward a roadside scene populated with retroreflective signs generates a series of reflection points to the optical sensor that appear as a horizontal segment of points. The optical sensor must be fast enough (i.e., have adequate data acquisition rates) to capture at least several individual discrete measurements across the face of a sign of interest or other reflective asset. In general, two types of laser scanners are suitable to be utilized according to the present invention; namely, single-axis scanners and dual-axis scanners. A preferred sensor is of the type set forth in the attached (previously unpublished) proposal entitled, "Holometrics 3D Vision Technology," a copy of which is attached hereto and is hereby incorporated herein in its entirety.

Since most all types of roadside signs to be measured are disposed at various elevations relative to the roadway and the moving platform, a single-axis laser scanner cannot be mounted such that the scanning laser beam covers only a single elevation or constant height relative to the roadway and the moving platform. Rather, the inventors hereof suggest that use of a single-axis type laser scanner must either be mounted high on the moving platform with a downward facing trajectory, or be mounted low on the moving platform with an upward facing scanning trajectory. These two mounting schemes for a single-axis laser scanner helps ensure the lateral scan will intersect with virtually every face of all signs or other reflective assets present in a roadside

scene regardless of the elevation or height or such signs relative to the roadway or to the moving platform.

Dual-axis laser scanners circumvent the varying sign height problem inherently encountered if single-axis laser scanners are employed as the source of integrated energy when practicing the teaching of the present invention. A dual-axis laser scanner operates by continuously moving the scanning beam scan up and down at a relatively slow rate while sweeping the laser beam laterally from side to side across the field of view at a relatively more rapid rate.

In order to obtain the normal vector for a sign as taught hereunder, only a select horizontal series of discrete locations across the face of the sign needs to be sensed by the high-speed optical sensor. For each point in the horizontal series of discrete locations recorded for a given sign due to the incident radiation provided by the scanning laser, as sensed by the high speed optical sensor, the precise direction of the incident laser is recorded, thus allowing both distance and direction of the measured point to be determined.

Either of the scanning methods produces a massive number of sensed discrete locations representing discrete reflections of the incident laser radiation and each must be processed in order to correlate each of the sensed discrete locations with the face of a particular sign. Once the lateral series of discrete locations for a sign is determined, simple triangulation methods are used to combine: (i) the vehicle location, (ii) vehicle heading vector, and (iii) scanned sign point to ultimately determine the normal vector for the face of a sign.

As stated earlier, knowing the sign's normal vector can expand the utilization of the present invention. The retroreflective properties of sign sheeting materials are typically

symmetrical about the vertical axis of the sign face. Because of this symmetry, R_A values (either computed or extrapolated/interpolated values) will be identical for rays that are symmetrical about the vertical axis.

Figure 10 shows how the sign's normal vector can be used to extrapolate more R_A points. The R_A value for Point B is the same as the R_A value for Point A since their angle relative to the normal vector is the same and since their distance from the sign is the same. If Point B has the same relative angle (from the sign's normal vector) as Point A, but lies closer to (or farther from) the sign face, the sign material's beam divergence profile can be used to adjust the R_A value for Point B up (or down) from the value obtained for Point A.

While the imaging system described herein can be used for locating objects of interest, it can also be used for mapping purposes. By creating representations of roadway edges and lane dividers, a very precise map can be created from the same digital imagery used for Object of Interest creation. This mapping feature of the imaging system will be a key component in our 3D R_A profile mapping for signs, to be discussed later.

The imaging system and intensity measurement system are preferably free running, with measurements being made periodically during vehicle operation. There is no requirement that these two systems be synchronized. In fact, these systems could operate in completely different data acquisition vehicles, if necessary. When both systems are contained within the same data acquisition vehicle, the only constraint for simultaneous operation is placed on the imaging system. Because of the intensity of the light source in the high intensity lighting system, it is preferred that the imaging system not capture frames at the same instant that the light source is triggered. If images are actually captured while the light source is triggered, their positional

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results would still be valid, but the colors displayed would be inaccurate because of the high intensity light being directed toward the (typically lower-thresholded) color cameras.

One skilled in the art could completely eliminate any need for the imaging system to know the firing events of the intensity system by choosing sampling rates for the two systems that didn't share any harmonic frequencies. On the rare occasions when the imaging system captured images while the light source was energized (or flashed), the skilled implementer could use time stamps to determine when this system simultaneity occurred and discard the imaging frames.

Producing an "as-built" map of the roadway is an essential part of creating a R_A profile for a given vehicle pathway. All maps of a roadway will contain some degree of error. Even survey-grade maps, which are expensive to create and cumbersome to build, may have errors of a few centimeters to a few inches or more. Maps created via other methods, such as those made from data gathered from moving platforms, could have errors ranging from a few centimeters to several meters.

In practice, the roadway map created from the inventive imaging system as disposed in or on a moving platform and as otherwise described herein will be of higher value for the R_A profile than a survey-grade map. Even though the absolute errors may be greater in a 2D or 3D map created using the imaging system of the present invention, they will be very small relative to the actual location of individual reflective assets and also very small with respect to the discrete locations where the R_A measurements – both computed and extrapolated or interpolated values – were made. The same systematic location errors may permeate all data points, but the relative accuracy will be high. Since R_A is very dependent on the geometry of the objects and the magnitude and direction of the light incident thereon, a high degree of relative accuracy is more

important than high absolute accuracy in creating a base map of such all inventoried reflective assets.

Figure 11 shows another typical roadway that was driven by a data acquisition vehicle fabricated according to the teaching of the present invention. Data from this vehicle's imaging system was used to create the map of the roadway edges and lane dividers. The same imaging system data was used to locate the sign, measure it's size, and determine other attributes. This same vehicle also gathered intensity measurements for the roadway shown in Figure 11. The intensity measurements, along with the sign location and sign colors, were used to create R_A values for the discrete locations within the lane of travel. A "point cloud" of data points was then calculated to create a full 3D R_A profile for this particular sign along the entire roadway.

Figure 12 shows a 3D representation of the point cloud of R_A values for the sign along our roadway. Planning and maintenance departments within transportation agencies will see the obvious benefits in graphically representing a sign's R_A performance over the surface of a roadway. Along with understanding a sign's current performance, these agencies can use the R_A profile software to understand how changes to a sign can affect its performance along a given roadway.

Figure 13 shows the impact of one possible variable on the sign's R_A profile. If, for example, the measured sign utilized a medium performance sheeting type, the display software can show the impact of changing the sheeting type for this sign. The display software has performance curves for the desired sheeting type and computes the new R_A profile for this sign using its current location, size, and facing direction.

Figure 14 shows how changing the sign angle (which changes the entrance angle) would impact the sign's R_A profile. Even though a system fabricated according to the present invention

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may not have direct measurement or other data regarding the exact angle entrance angle, one may use the computed R_A columnated data points to create an R_A profile and rotate the R_A profile as specified by the user any arbitrary degree or fraction thereof. This feature assists traffic sign maintenance department personnel in "tuning R_A" for all or any portion of such reflective assets and/or each roadside sign (i.e., various entrance angles from different segments of a vehicle pathway yield different results).

If a sign on the right hand side of the road is rotated on an axis perpendicular to a vehicle pathway one may not have enough computed R_A points from the data acquisition vehicle given the track or path of such vehicle with which to compute the complete R_A profile for the entire road surface. However, if we know the normal vector for the sign (via any of the various methods described herein), one may can use the typical horizontal symmetry of sign sheeting materials to create the rest of the R_A profile.

As mentioned earlier, observation angle is a key determinant for sign R_A behavior. The intensity system contained herein attempts to eliminate this variable by placing the light source(s) and sensor very close to one another. Planning departments can change observation angles within the R_A profile software to understand its impact on sign performance. Since the R_A profile software knows the as-measured sign sheeting type and have available an R_A performance profile preferably embedded in a look up table of all popular or required sheeting types and/or as stored in memory, or dynamically generated for use in practicing the present invention. A new R_A profile can then be generated for the newly-desired observation angle. Figure 15 shows the R_A profile for our sign along our sample roadway when the observation angle is changed from its present value to a higher value.

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Reflective pavement markings display similar properties to reflective assets (and other reflective objects), but the measurement of pavement marking retroreflectivity requires some extra constraints. Pavement marking retroreflectivity is measured in millicandelas per square meter per lux (mcd/m^2/lux) and is designated R_L. Along with observation angle and entrance angle, the lateral distance between the light source and the measured point must also be known. Figure 16 shows the R_L geometry for a typical passenger vehicle.

Studies have shown that there is no correlation between pavement marking retroreflectivity (R_L) values with different geometries. Because of this lack of correlation, agreed-upon geometries must be utilized when measuring and reporting R_L.

When measuring and computing R_A we attempted to dramatically reduce (essentially eliminate) observation angle with the light source and intensity sensor placement. When measuring intensity for computing R_L, we need to position the light source and intensity sensor such that our agreed-upon geometry is met for the desired measurement distance. At the time of this disclosure, both the European Committee for Normalization and the American Society for Testing and Materials (ASTM) have standardized on the same R_L geometry of 1.05 degree observation angle, 88.76 degree entrance angle, and 30 meter measurement distance.

The intensity of light reflected from pavement markings will be less than that of signs. As a result, we'll need another intensity sensor for the determination of R_L. Therefore, we have two reasons for requiring a different intensity sensor for measuring R_A and R_L – the range of intensities and the placement of the sensor. However, the same high intensity light source(s) can be used for determining R_A and R_L.

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There are at least six fundamental aspects of the present invention that by way of example but without limitation, the inventors hereof believe renders the present invention new, useful and non-obvious and therefore patentable:

1. The retroreflectivity calculation for a sign at a given point along the roadway does not require that the acquisition vehicle actually occupy a particular portion of a roadway. It merely requires that each discrete location at which the retroreflectivity calculation is made was visible from an imaging system that was capable of surveying a particular ground point (or unobstructed sign-viewing location).

2. The retroreflectivity calculation for various discrete locations along the roadway does not require that the intensity measuring system actually obtained a reading at that point in the roadway. By taking intensity readings of a reflective asset at various discrete locations, luminance values for the sign can be computed, thus allowing retroreflectivity calculations to be made for a plurality, or literally "N" discrete locations on, along and adjacent to a roadway.

3. The intensity measurements do not require any prior understanding or actual knowledge of the location of and/or number of signs along a roadway. By periodically capturing intensity measurements, the luminance conversions and the associated retroreflectivity calculations can be performed as post-processing activities.

4. No human interaction is required during the data gathering process. By constantly running the two image acquisition systems : (1) digital video for

position surveying and (2) preferably black and white camera(s) synchronized to pulsed light source(s) for intensity measurements, all necessary computations can be performed well after the initial raw data is collected. Or, if computational capability is not constrained, all necessary computations could run in real-time (or very nearly real-time).

5. No synchronization of the two image capture systems is required. However, both systems must be linked to receive and record precise vehicle position at least when each of the various "measurement events" are captured. Significantly, there is no need for simultaneous measurement events or any other or additional synchronization of such measurement events. The only requirements are that the pulsed light source for the intensity measuring system should not be energized (or fired or flashed) while digital images are being captured for the positioning system. This requirement follows because of the intensity of the pulsed light source, if the digital camera attempts to capture an image when the pulsed light source is energized, any resulting digital images will be grossly over-exposed and of little use.

6. Intensity measurements can be made at or near posted roadway speeds, thus dramatically increasing the safety for the personnel gathering the information as well as the motorists traveling the selected roadways.

Using the enabling teaching, written description, documents incorporated, and the illustrations and examples herein, one may:

- Create three dimensional (3D) color-coded representations of data collected from reflective surfaces on objects of interest showing retroreflectivity for any or all such objects in an area and using real or experimental lighting sources and conditions.

- Improve upon existing (and create new) product life and aging models by comparing actual data collected from the field and comparing predictive models for same.

- Improve scheduling procedures for personnel who repair, replace and install reflective assets by identifying damaged or poorly performing retroreflective assets or surfaces of signs and optionally subject to a preselected priority sequence.

- Create a sensor suite assembly, sensor platform and methods to systematically collect retroreflectivity data for all reflective assets in an area for comparison to applicable regulations, guidelines and laws.

- Accident recreation(s) and/or traffic simulation(s).

- To monitor vehicle manufacturer compliance with applicable vehicle lighting regulations, guidelines and laws.

- To measure, monitor and compare retroreflectivity, sheeting type, luminance and/or brightness between and among certain reflective objects depicted in a scene to ensure that the regulatory, warning and information

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signage present in the scene are reasonably visible to motorists traversing the scene.

The teaching hereof is applicable to capture data from reflective surfaces of all varieties present in a scene, including without limitation, whether the surface is present in: (i) a scene from and including sea or water vehicle routes; (ii) a scene from and including air and space vehicle routes; or, (iii) a scene from and including terrestrial pedestrian and vehicle routes and the like. The invention hereof is also applicable to measuring R_L of reflective markings placed on the surface of vehicle pathways.

Additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader aspects is, therefore, not limited to the specific details, representative apparatus and illustrative examples shown and described. Accordingly, departures from such details may be made without departing from the spirit or scope of the applicant's general inventive concept.

DISCLAIMER: THE FOLLOWING NUMBERED SENTENCES ARE APPENDED HERETO MERELY AS PLACEHOLDERS INTENDED FOR THE INVENTORS HEREOF TO UNDERSTAND THE GENERAL SUBJECT MATTER THAT MAY BE DEEMED PATENTABLE AND UNLESS LATER ADOPTED BY THE INVENTORS HEREOF SHALL IN NO MANNER INDICATE NOR ACT AS AN ADMISSION AS TO THE SCOPE OR BREADTH OF ANY LATER FINAL OR AMENDED CLAIM SUBMITTED FOR EXAMINATION TO ANY PATENT JURISDICTION.

Subject to foregoing disclaimer, we hereby stake claim to at least the following:

1. A method for use in measuring retroreflectance of reflective surfaces disposed and visible from a data stream collected by a vehicle traversing a vehicle pathway, comprising the steps of:

energizing a light source at several discrete locations along a vehicle pathway;

collecting light intensity information reflected from the light source with a intensity sensor directed to cover a field of view which includes a portion of the area illuminated by the intensity sensor and at least one reflective surface at the same time the light source is energized;

making at least one intensity value determination for the surface of the at least one reflective surface; and,

determining a reference retroreflectivity value of the at least one reflective surface at the location where the at least one intensity value determination was made.

2. The method of claim 1, further comprising the steps of:

determining the color of the object being measured; and,

utilizing a characterization profile for the intensity sensor to compute retroreflectivity for each color displayed on the at least one reflective surface at the location where the luminance measurement was made.

3. The method of claim 1, further comprising the steps of providing for each step set forth in claim 1, the following:

recording the XYZ coordinate location of the vehicle while the light source is energized;

determining the XYZ coordinate location of the object being measured; and,

utilizing a characterization profile for the light source to compute retroreflectivity for each color displayed on the at least one reflective surface at the location where the luminance measurement was made.

4. The method of claim 1, further comprising the steps of providing for each step set forth in claim 1, the following:

recording scene information at discrete locations along the vehicle pathway with an imaging system;

recording the XYZ coordinate location of the vehicle while the imaging system is triggered;

using photogrammetry to determine a XYZ coordinate location of the object;

recording the XYZ coordinate location of the vehicle while the light source is energized; and,

utilizing a characterization profile for the light source to compute retroreflectivity for each color displayed on the a least one reflective object at the location where the luminance measurement was made.

5. The method of claim 1, further comprising the steps of providing for each step set forth in claim 1, the following:

selecting a discrete location, other than the location where the reference retroreflectivity measurement was made, for making a second retroreflectivity measurement of the at least one reflective object;

drawing a ray from the least one reflective object through the discrete location and through a path traversed by a retroreflectivity data acquisition vehicle, wherein said retroreflectivity data acquitision vehicle makes a series of at least two periodic measurements of the reference retroreflectivity value of the at least one reflective object; and,

assigning a unique retroreflectivity value to all points disposed on said ray based on interpolating between a set of two closest of said series of at least two periodic measurements of the reference retroreflectivity value.

6. The method of claim 5, further comprising the steps of providing for each step set forth in claim 5, the following:

determining a beam divergence profile of reflected light from the surface of the at least one reflective object; and,

assigning a set of retroreflectivity divergence values to at least one additional ray disposed adjacent to the ray based upon the beam divergence profile of the surface of the at least one reflective object.

7. The method of claim 6, further comprising the steps of providing for each step set forth in claim 6, the following:

determining an angular divergence of the ray from a normal vector for the face of the at least one reflective object; and,

assigning the unique retroreflectivity value to all points disposed on a symmetrical ray having the same angular divergence of the ray.

8. The method of claim 1, further comprising providing for each step set forth in claim 1, the following steps of:

repeating the steps set forth in claim 1 at least twice;

interpolating between two successive determinations of the reference retroreflectivity at the location and a second location to generate an interpolated retroreflectivity measurement value for a third location;

drawing a ray from the at least one reflective object of interest through said third location; and,

assigning the interpolated retroreflectivity measurement value to all points of the ray.

9. The method of claim 8, further comprising the steps of providing for each step set forth in claim 8, the following steps:

displaying a computed retroreflectivity point cloud as a three dimensional overlay on the surface of a depiction of the roadway; and,

providing for the changing of object geometry and other characteristics to graphically display the new 3D retroreflectivity information.

10. A data acquisition vehicle for assessing reflective surfaces of reflective assets disposed adjacent a vehicle pathway, comprising:

a frame/chassis member adapted for forward travel;

a motive force coupled to the frame/chassis member;

a GPS transceiver coupled to the frame/chassis member and providing an output signal on an output cable;

a CPU (or network connection circuitry and/or telemetry equipment) having associated memory (RAM/ROM/DRAM/FLASH) and input/output (I/O) ports coupled therebetween with one said port coupled to the output cable of the GPS;

a digital camera linked to the CPU via an I/O port;

a source of illumination having a trigger switch coupled to the digital camera;

a digital compass linked to the CPU via an I/O port.

11. The vehicle of claim 10, further comprising a weather proof enclosure for said vehicle wherein said enclosure has a set of weatherproof windows formed therein.

12. An apparatus for collecting data for use in measuring, locating and depicting reflective surfaces of interest disposed and visible in a scene adjacent a vehicle pathway, from a moving vehicle, said apparatus comprising:

a CPU, memory, power, cabling and I/O ports disposed in a vehicle;

a GPS/INS/DMI equipment suite coupled to the CPU;

a digital camera coupled to the CPU;

a source of illumination coupled to the digital camera;

a dual-axis scanning laser which periodically scans an eyesafe laser beam both laterally and vertically across the scene and wherein a lateral scan rate is appreciably faster than the vertical scan rate and which scanning laser is coupled to the CPU; and,

a high speed optical sensor oriented to receive laser radiation reflected from the surfaces of interest present in the scene optically coupled to the scanning laser and electronically coupled to the CPU.

13. The apparatus of claim 12, further comprising an imaging system added for the determination of attributes for reflective assets.

METHOD AND APPARATUS FOR DETERMINING ENTRANCE ANGLES AND RETROREFLECTIVITY FROM A MOVING PLATFORM

Abstract of the Disclosure

The present invention relates to the field of automated mobile electronic measurement and object identification systems. More particularly, the present invention is directed to methods and an apparatus for measuring, identifying and determining certain characteristics of desired target objects and classifying the target objects as to the level of retroreflectivity (i.e., a quality related to the ability of a surface material to reflect incident electromagnetic radiation back to the source of the radiation). The techniques of the present invention may be operated either in a "run time" mode (i.e., when a vehicle employing the system is simultaneously collecting target object data) or in a "post processing mode (i.e., wherein the system operates independent of such data collection). In addition, this disclosure teaches, enables and illustrates (i) preferred sensor selection and configurations of sensors, receivers, and computer processors wherein the sensors operate independently in collecting data from a scene containing retroreflective surfaces of interest (sometimes referred to as reflective assets herein); (ii) a preferred moving platform supporting such preferred sensor selection and configurations for measuring, logging (storing) and/or processing via computer the data collected from such reflective assets present in a scene; (iii) preferred post-processing methods for deriving a variety of different useful outputs and graphical representations (e.g., 3D simulation by magnitude of retroreflectance) from each such surface or for many such surfaces for the processed outputs herein, and (iv) preferred methods for processing the data collected to schedule, in a preselected priority sequence, a master service plan for dispatching service personnel to work on select of such surfaces in a most efficient manner (given the priority sequence).

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Figure 1 - Observation Angle Description

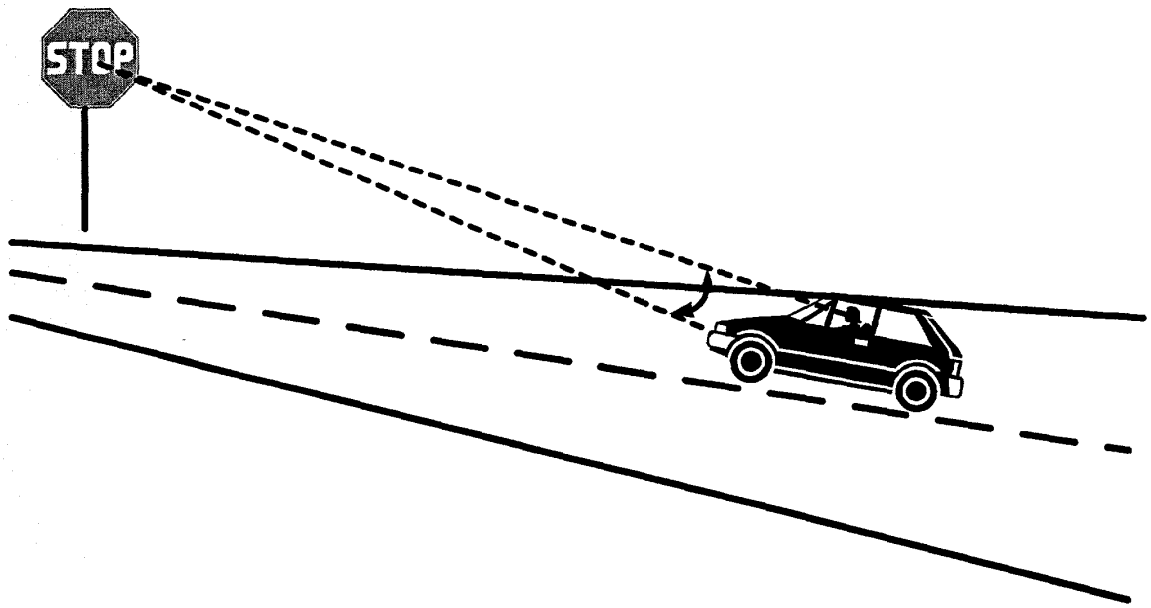

Figure 2 - Entrance Angle Description

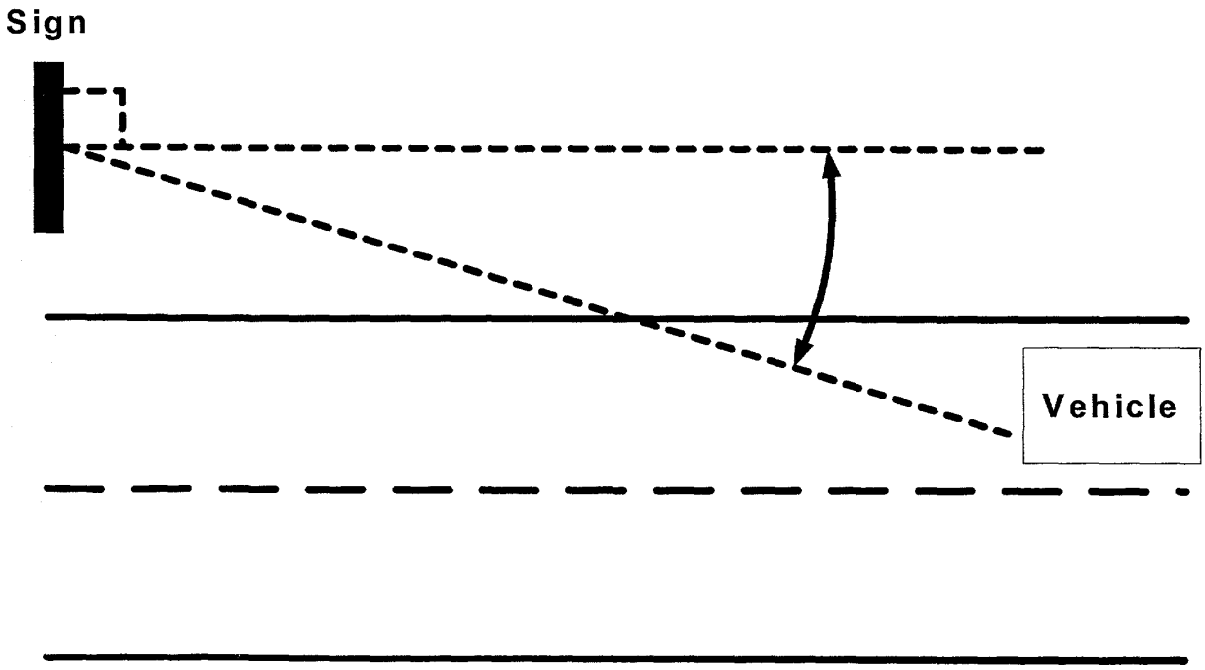

Figure 3 - Capture Vehicle and Data Processing Functional Block Diagram

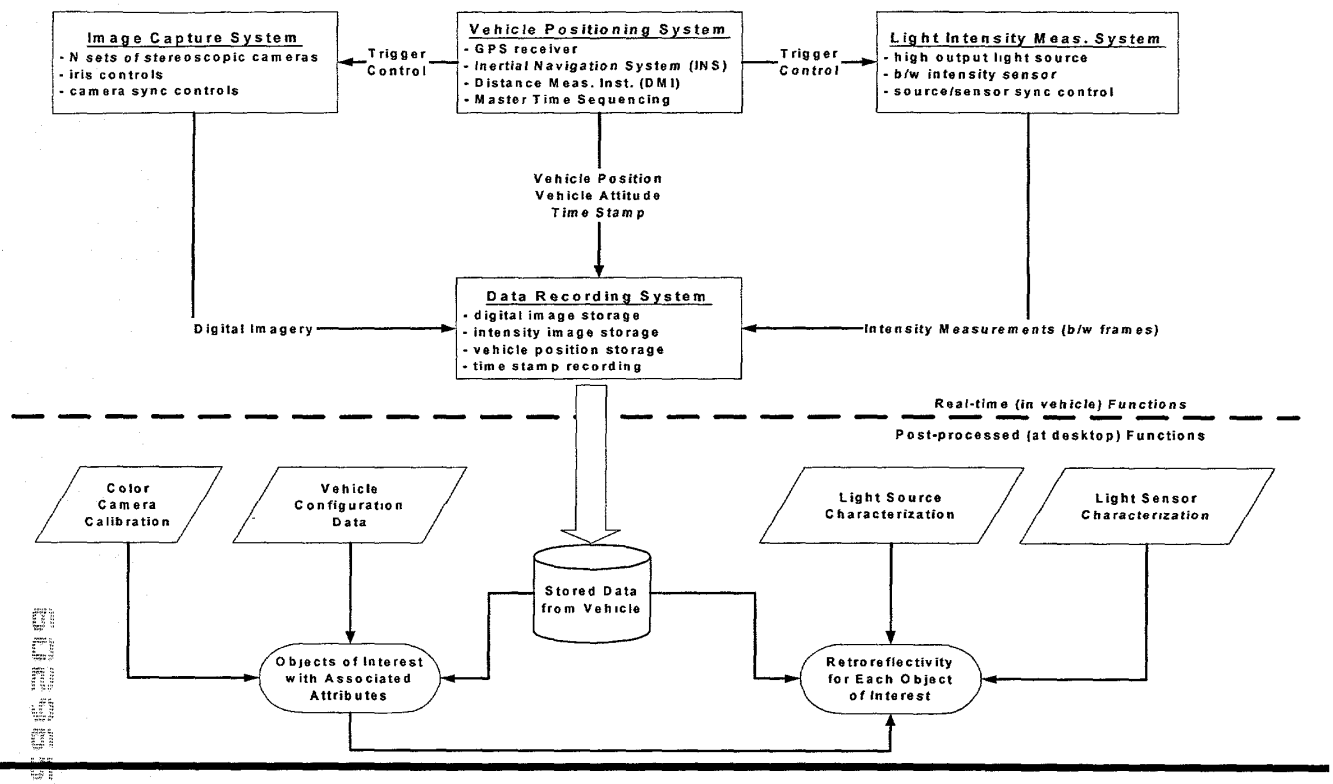

Figure 4 - Capture Vehicle System Diagram

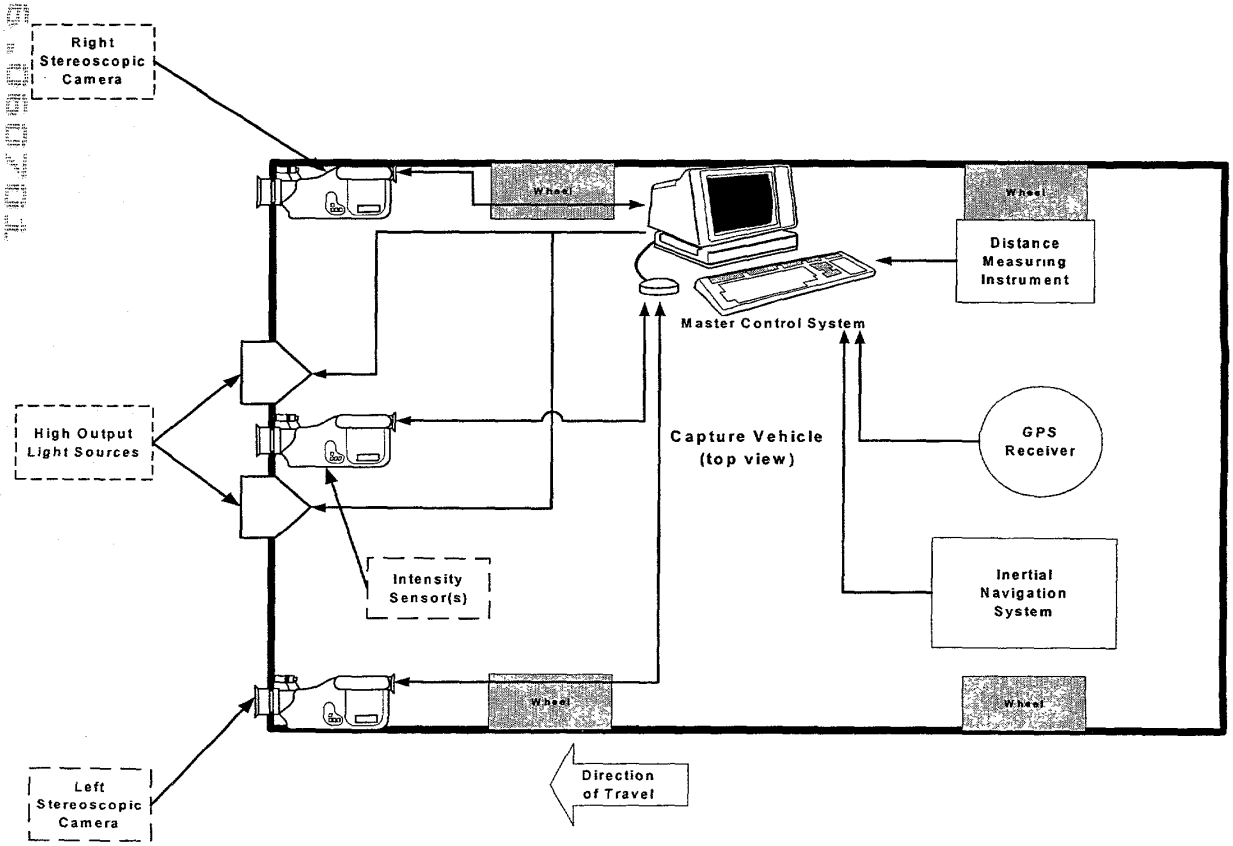

Figure 5 - Reflected Light Intensity Measurements Along a 4-lane Divided Highway

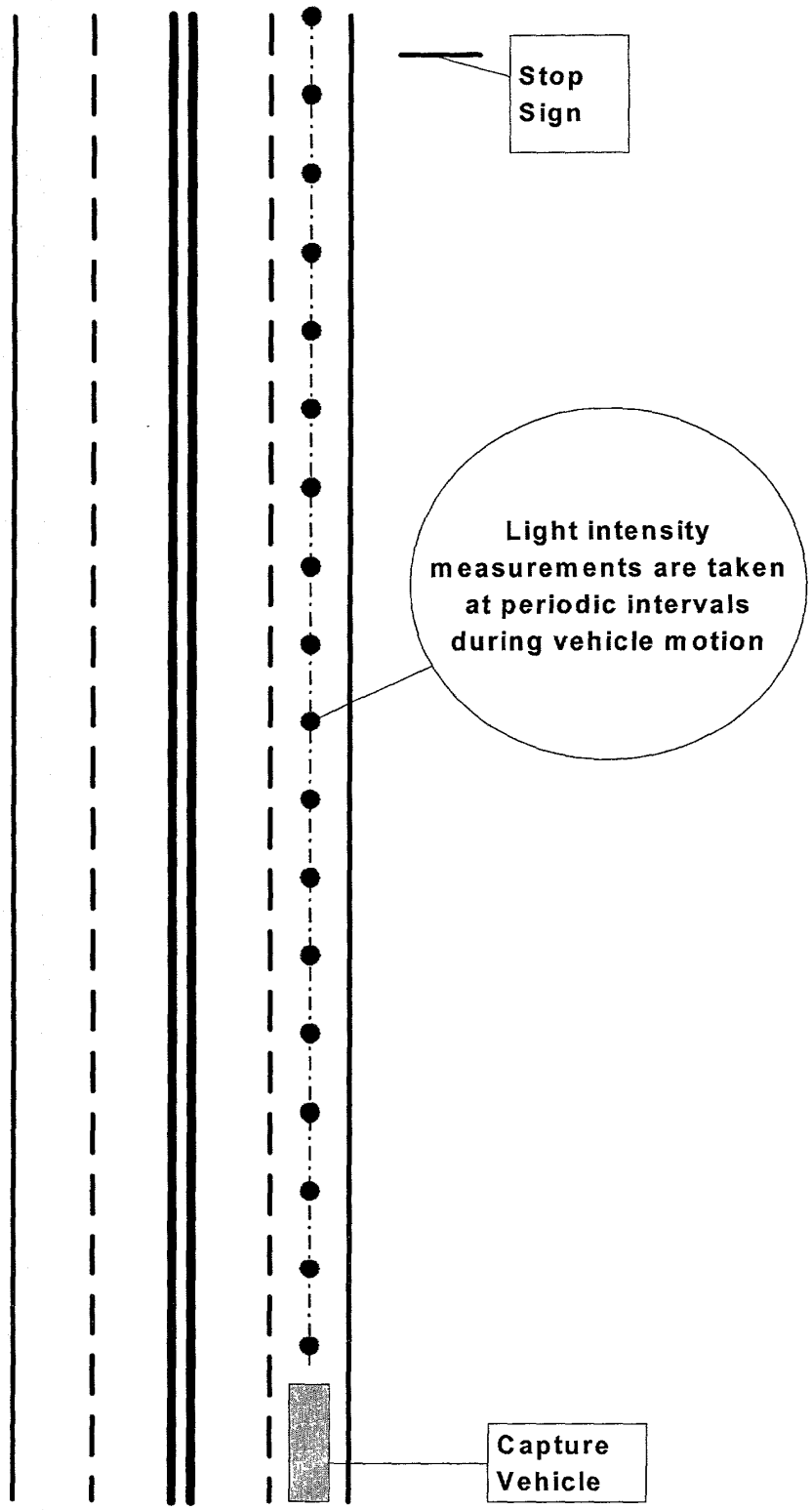

Figure 6 - Reflected Light Intensity Frames Along a 4-lane Divided Highway

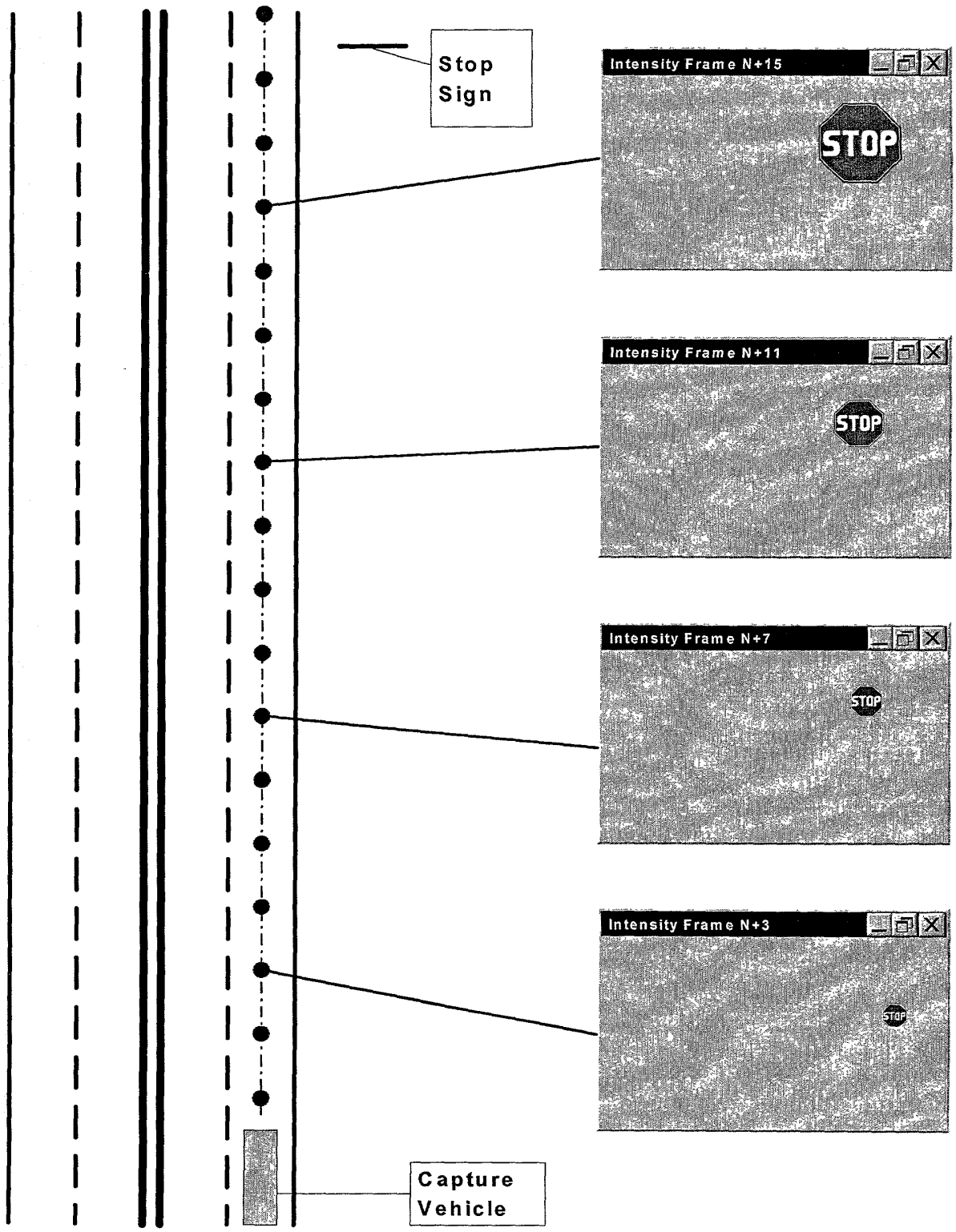

Figure 7 - Determining Retroreflectivity from Light Intensity Measurements

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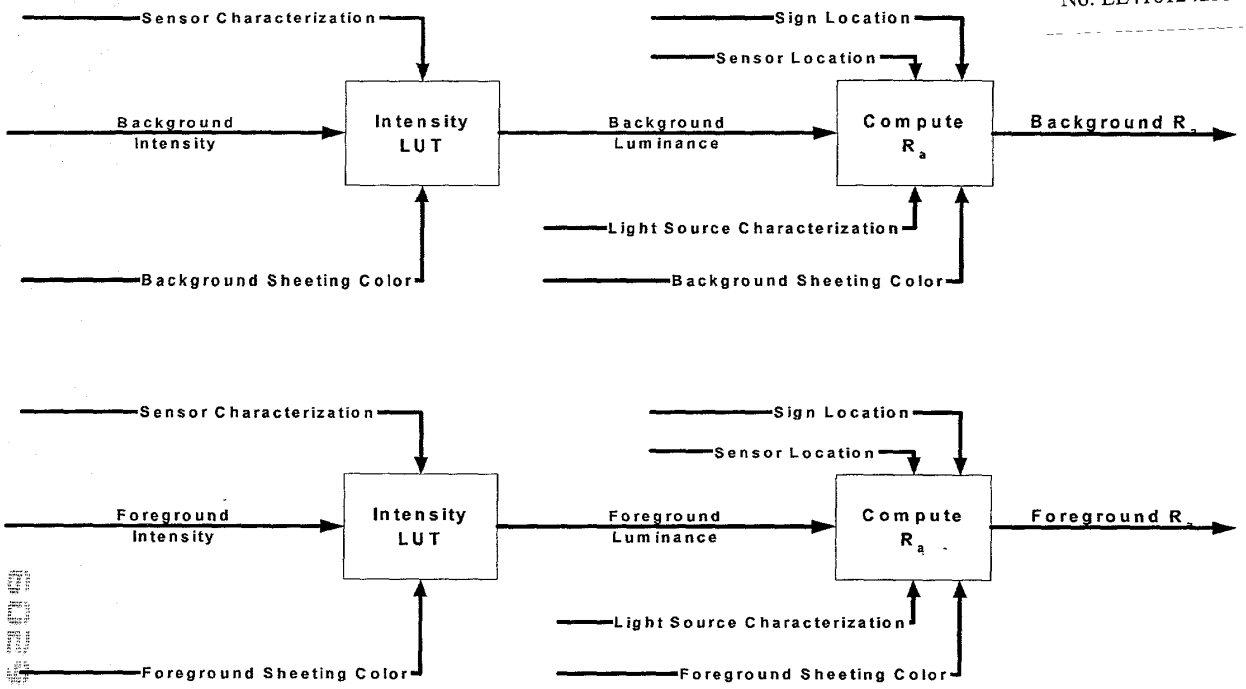

Figure 8 - Light Source Wavelength Intensity Profile

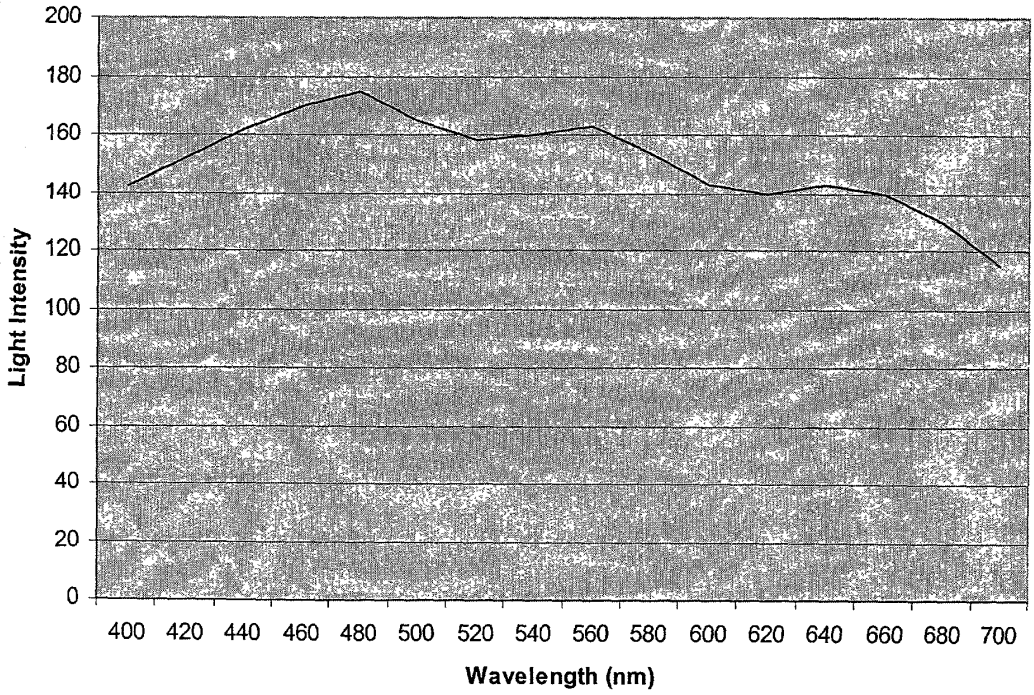

Figure 9 - Creating a Retroreflectivity Profile Along a 4-lane Divided Highway

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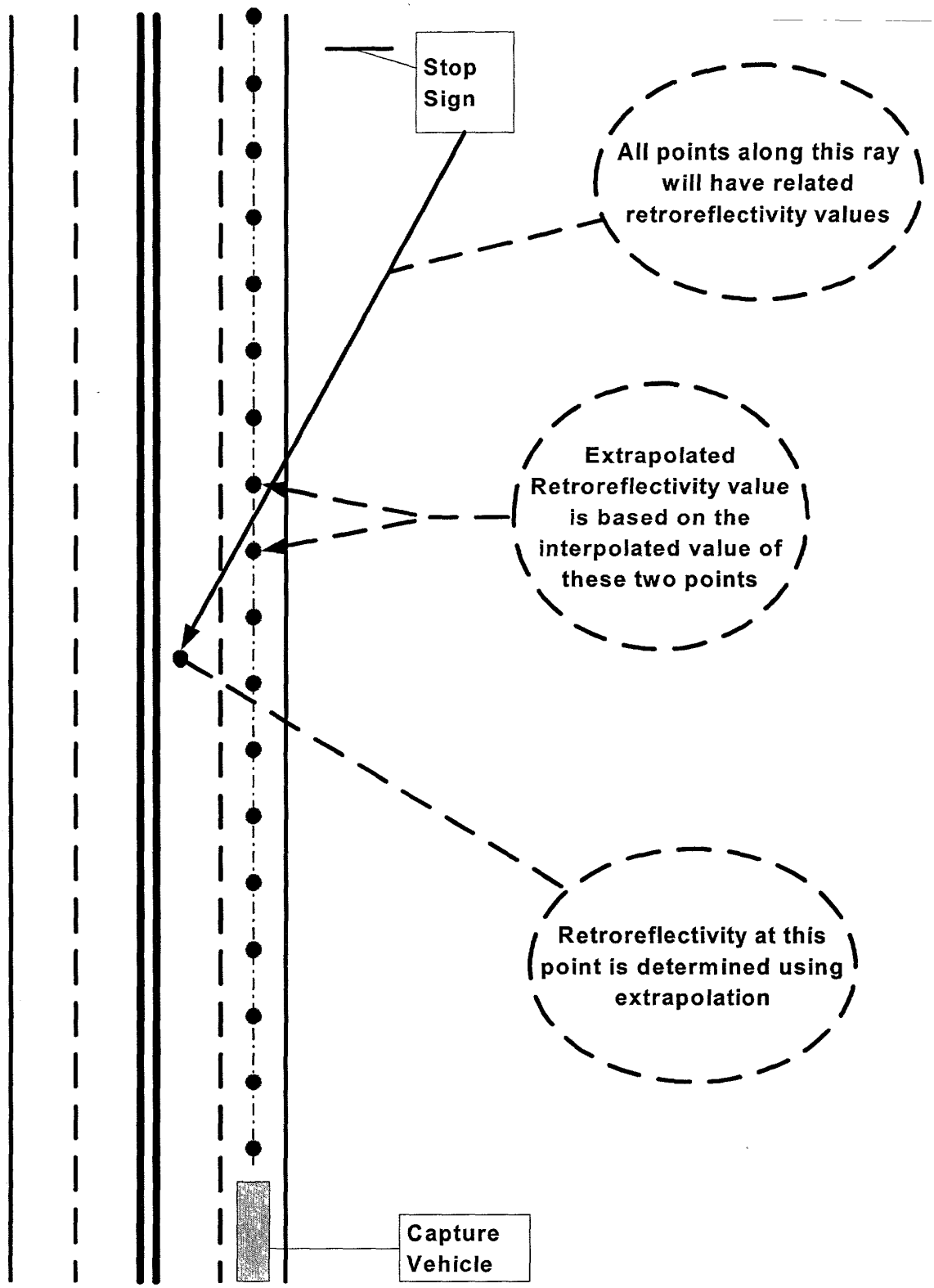

Figure 10 - Using a Sign's Normal Vector to Compute Retroreflectivity

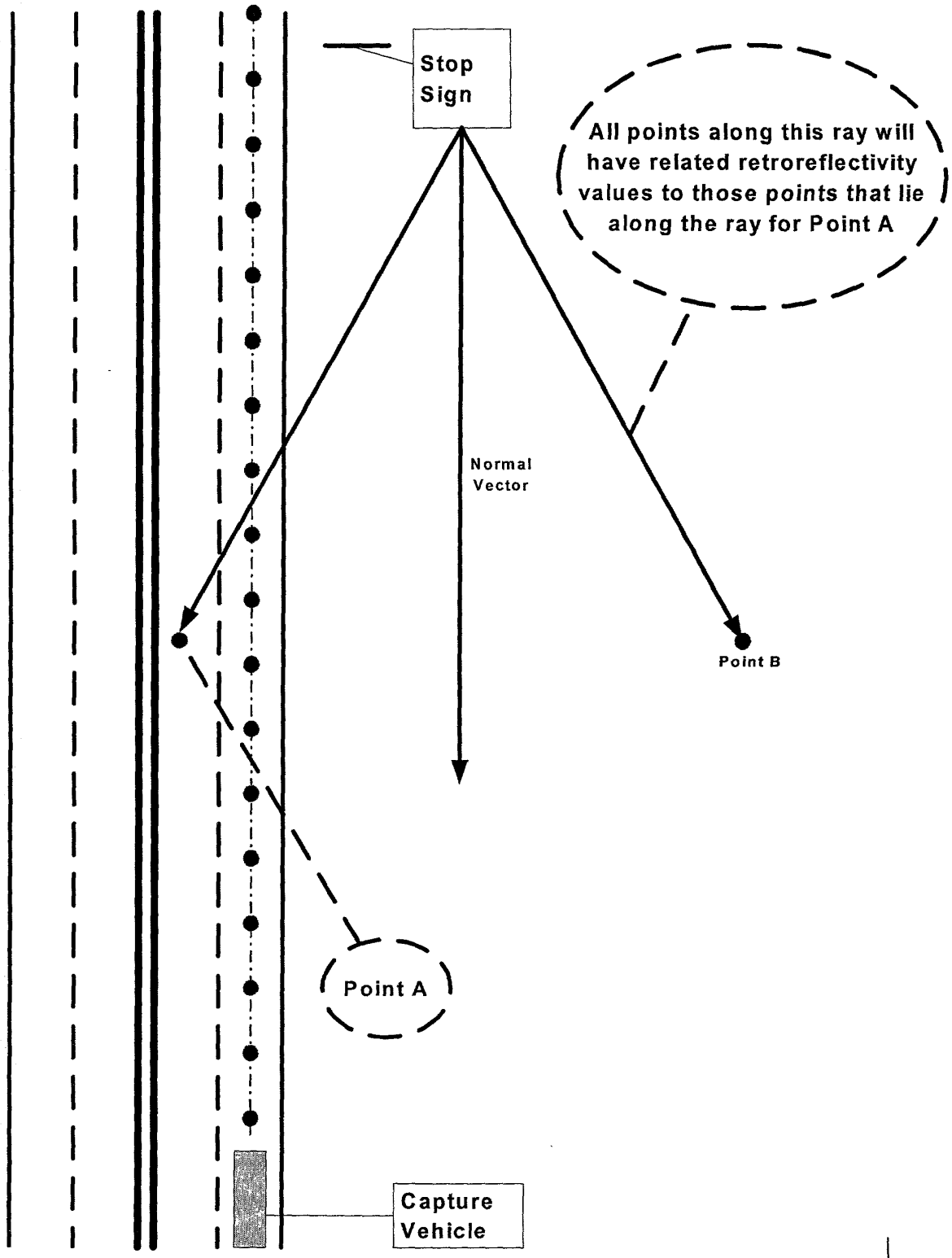

Figure 11 - Roadway and Sign Created with Mobile Acquisition Vehicle Data

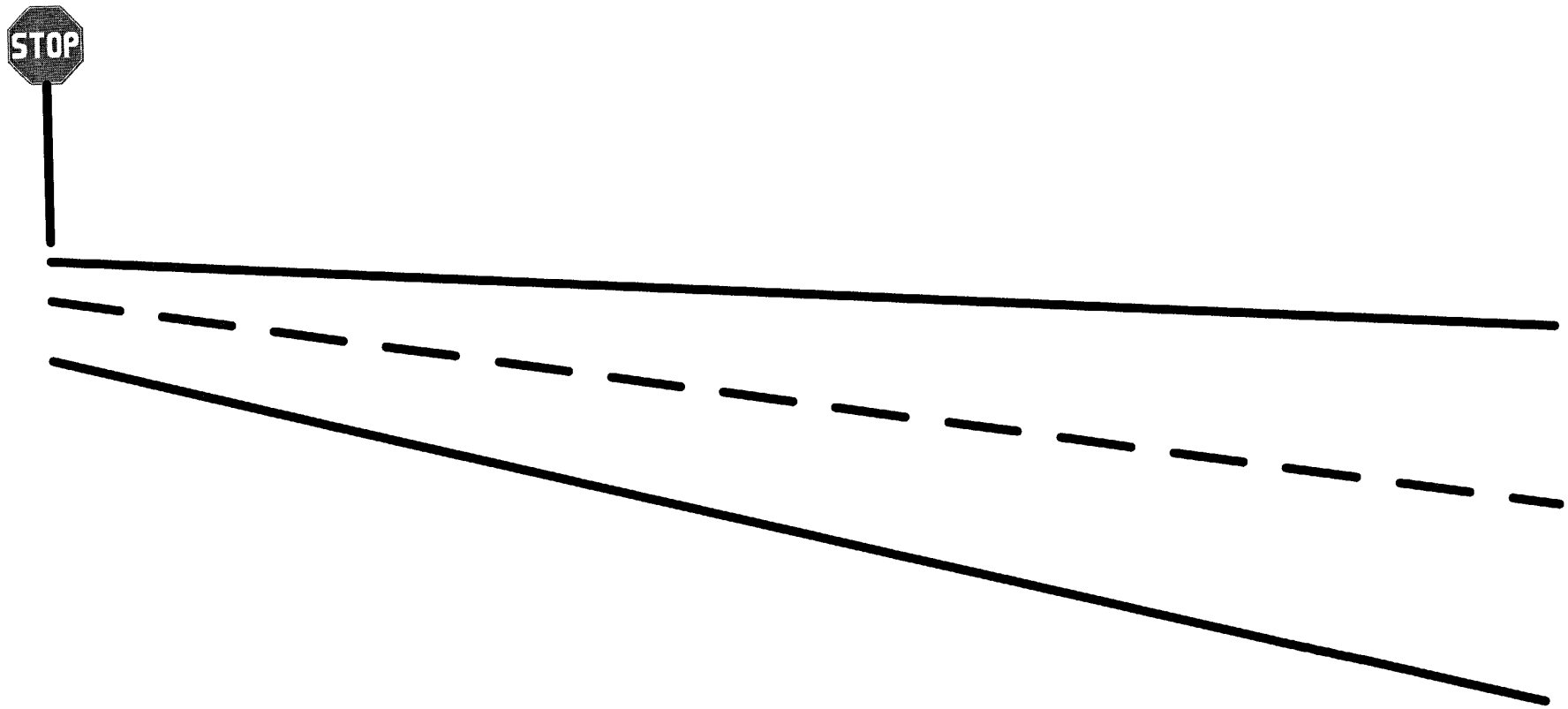

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Figure 12 - 3D Representation of a Sign's R_A Profile

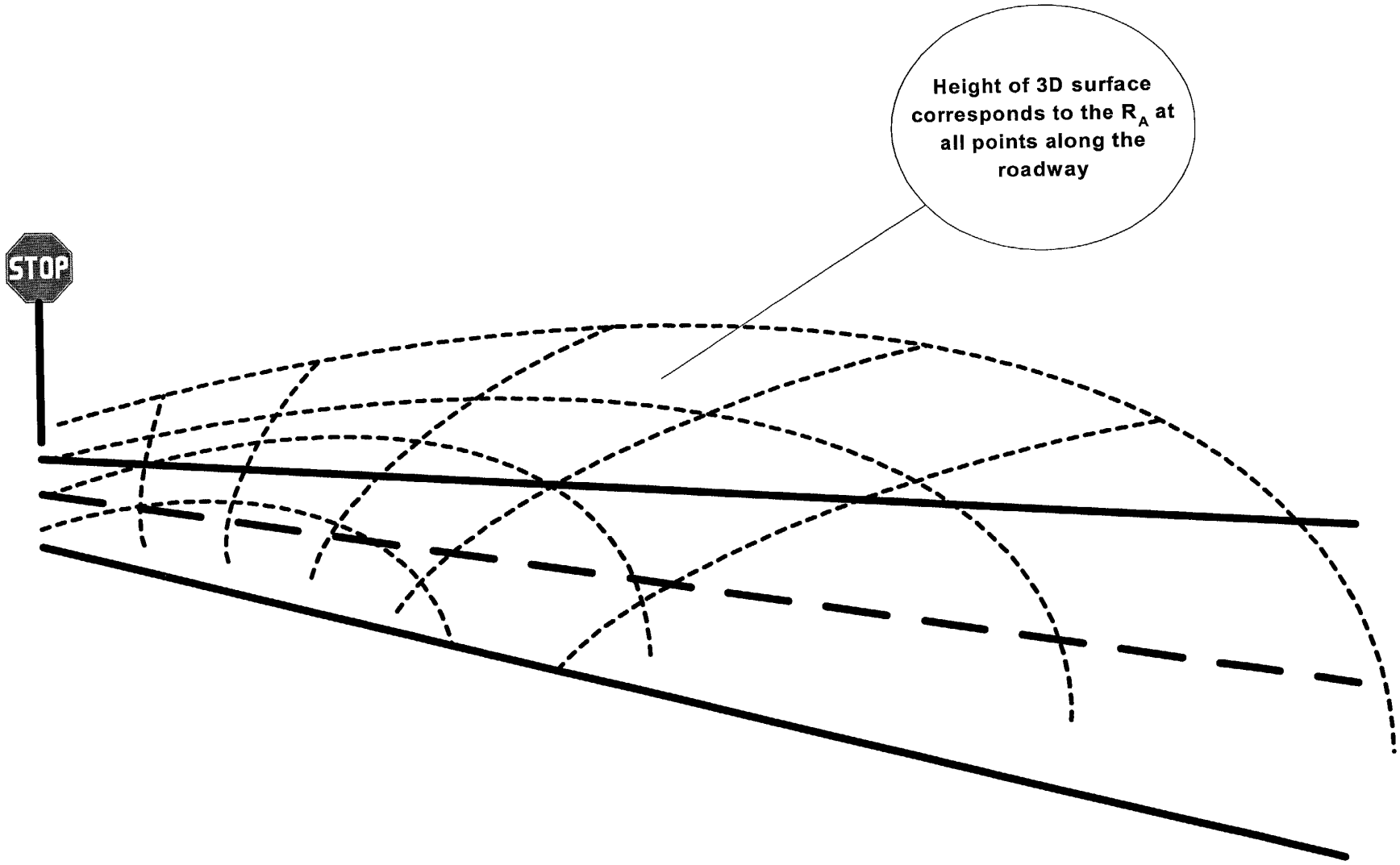

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Figure 13 - Effects of Sheeting Type Improvement on a Sign's R_A Profile

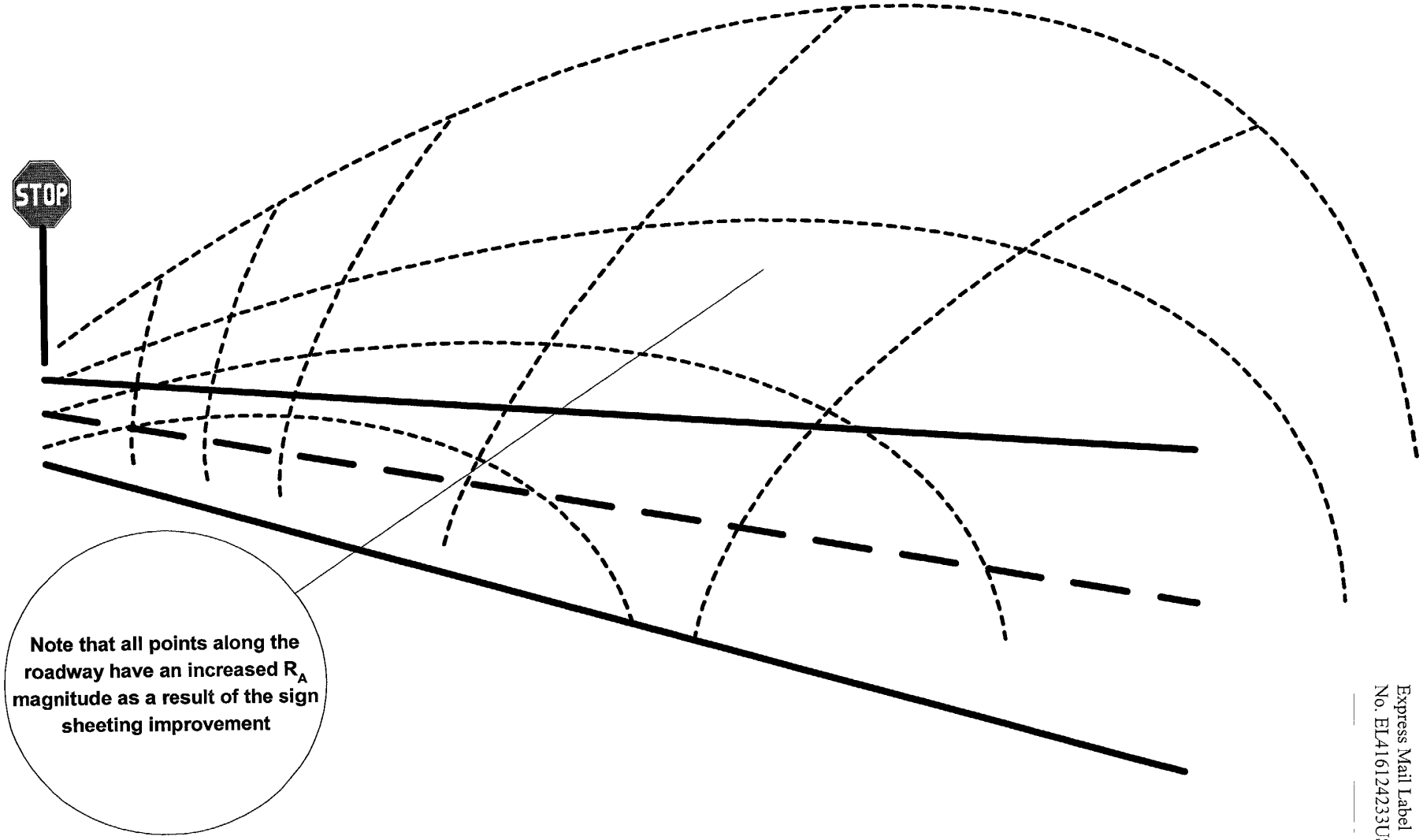

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Figure 14 - Effect of a Clockwise Rotation on a Sign's R_A Profile

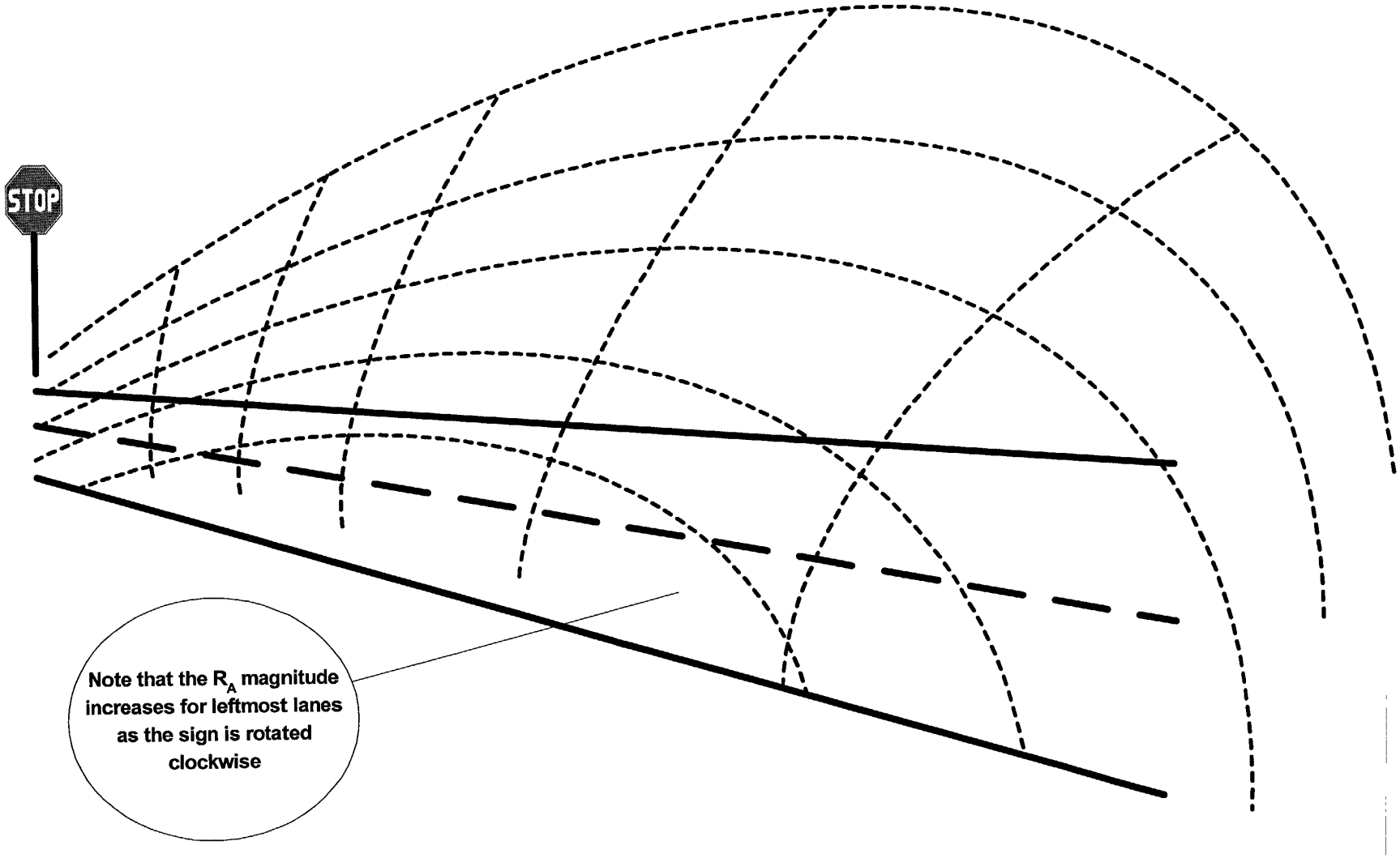

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Figure 15 - Effect of Observation Angle on a Sign's R_A Profile

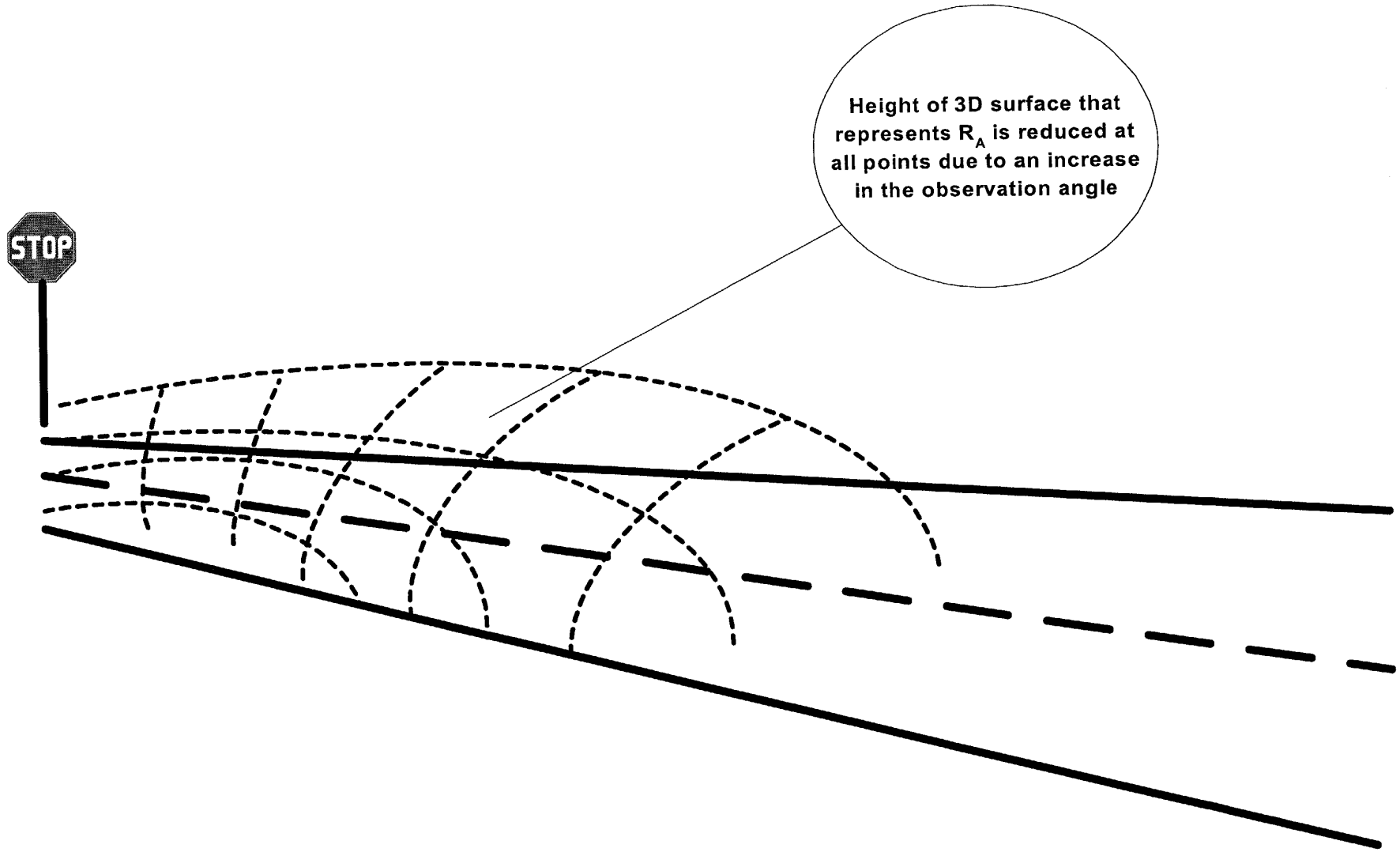

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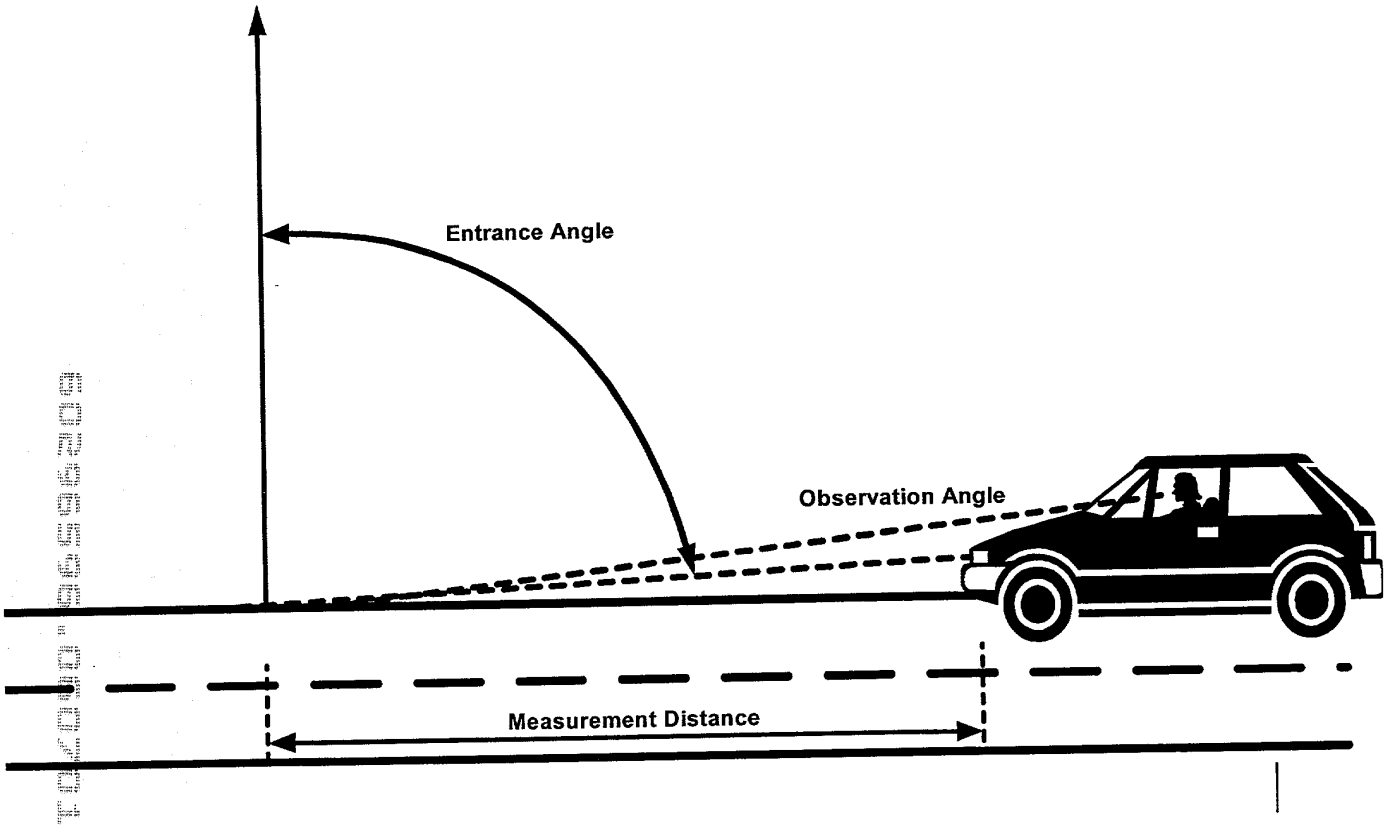
FIG. 16 Pavement Marking Geometry



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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor:	RETTERATH, James E., et al.	)	Art Group Unit:
Serial No:	60/	)	Examiner:
Filing Date:		)	Attorney Docket: 26,227-02
Title:	Method and Apparatus for Determining Retroreflectivity from a Moving Platform	)	**VERIFIED STATEMENT**

Box Provisional Application
Commissioner of Patents
Washington, D.C. 20231

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) AND 1.27 (b)) - INDEPENDENT INVENTOR

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR §1.9(c) for purposes of paying reduced fees under Sections 41(a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled Method and Apparatus for Determining Retroreflectivity from a Moving Platform described in the specification filed herewith.

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey, or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR §1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR §1.9(d) or a non-profit organization under 37 CFR §1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention listed below:

NAME Facet Technology Corporation

ADDRESS 4555 Merrywood Lane, Excelsior, Minnesota 55331

☐ Individual ☒ Small Business Concern ☐ Nonprofit Organization

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR §1.28(b)).

I hereby 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, United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of inventor: Robert A. Laumeyer

Inventor's Signature: Robert A. Laumeyer

Date: 6/7/2001

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Mobileye v Facet, IPR2024-01110

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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. of:	RETTERATH, James E., et al.	Attorney Docket:	26,227-02
Serial No:	60/	Art Group Unit:	
Filed:		Examiner:	
For:	Method and Apparatus for Determining Retroreflectivity from a Moving Platform		

Box Provisional Application
Commissioner for Patents
Washington, D.C. 20231

DECLARATION CLAIMING SMALL ENTITY STATUS UNDER
37 CFR 1.9(f) AND 1.27(c) - SMALL BUSINESS CONCERN

Name and Address of Small Business Concern:

Facet Technology Corporation
4555 Merrywood Lane
Excelsior, Minnesota 55331
United States of America

I hereby state that I am:

☐ the owner of the small business concern identified above.

☒ an official of the above identified small business concern, empowered to act on its behalf.

I hereby state that the above identified small business concern qualifies as a small business concern as defined in 13 C.F.R. Part 121 for purposes of paying reduced fees to the United States Patent and Trademark Office with regard to the invention entitled Method and Apparatus for determining Retroreflectivity from a Moving Platform, in that the number of employees of the concern, including those of its affiliates, does not exceed 500. For purposes of this statement: (1) the number of employees of the concern is the average, over the previous fiscal year of the concern, of the persons employed on a full-time, part-time, or temporary basis during each of the pay periods of the fiscal year; and (2) concerns are affiliates of each other when, either directly or indirectly, one concern controls or has the power to control the other, or a third party controls or has the power to control both concerns.

I hereby state that rights under contract or law have been conveyed to and remain with the above identified small business concern, with regard to the invention described in:

☒ the specification filed herewith

☐ the above identified application

☐ the above identified patent.

I hereby state that no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 C.F.R. 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 C.F.R. 1.9(d) or a non-profit organization under 37 C.F.R. 1.9(e).

If the rights held by the above identified small business concern are not exclusive, I hereby identify each person, concern or organization having rights in the invention, each of which must file a separate statement as to small entity status:

☒ There is no such person, concern or organization.

☐ Each such person, concern, or organization is listed below.

Name:

Address:

☐ Individual ☐ Small business concern ☐ Non-Profit Organization

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the loss of entitlement to small entity status (37 C.F.R. § 1.28(b)).

I hereby 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, United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of individual signing:	James E. Retterath
Title, if other than owner:	President
Address of individual signing:	4555 Merrywood Lane Excelsior, Minnesota 55331

Signature: James E Retterath

Dated: 6-7-01

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POWER OF ATTORNEY

Provisional Application

Title: Method and Apparatus for Determining Retroreflectivity from a Moving Platform

Inventors: 1) James E. Retterath
4555 Merrywood Lane
Excelsior, MN 55331

Citizenship: United States

2) Robert A. Laumeyer
1200 Nicollet Avenue South, #223
Minneapolis, MN 55403

Citizenship: United States

As inventors of the subject matter described in the above-identified and accompanying Provisional Application, we hereby appoint Paul H. McDowall, Registration No. 34,873, Frederick W. Niebuhr, Registration No. 27,717; John F. Klos, Registration No. 37,162; Aleya R. Champlin, Registration No. 36,251; of Larkin, Hoffman, Daly & Lindgren, Ltd., 1500 Wells Fargo Plaza, 7900 Xerxes Avenue South, Bloomington, Minnesota 55431; as attorneys/agents with full power of substitution and revocation to transact all business in the Patent and Trademark Office connected herewith.

Please direct all communications regarding this Provisional Application to:

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Date: 6-7-01

James E. Retterath

Date: 6/7/2001

Robert A. Laumeyer

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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor:	RETTERATH, James E., et al.	)	Art Group Unit:
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Each person, concern or organization to which I have assigned, granted, conveyed or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention listed below:

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I hereby 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, United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of inventor: James E. Retterath

Inventor's Signature: James E Retterath

Date: 6-7-01

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No. EL416124233US

APPENDIX A

to

U.S. Provisional Patent Application

Entitled

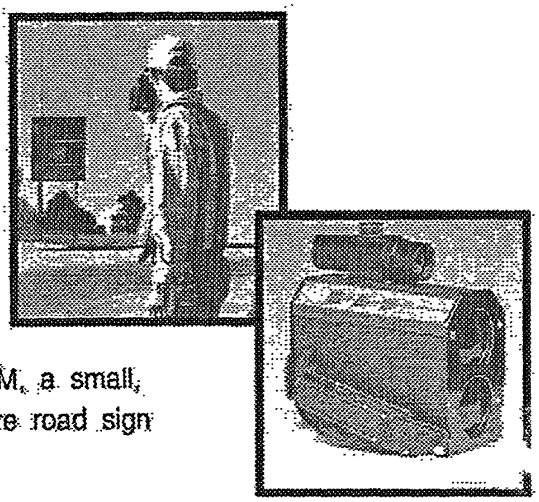
Method and Apparatus for Determining Retroreflectivity from a Moving Platform

Invented by James E. Retterath and Robert A. Laumeyer

IMPULSE RM

RETRO-REFLECTOMETER

Small, Lightweight, Lower Priced



Now there's a rugged, compact, point-and-shoot retro-reflectometer that will revolutionize road sign management!

Laser Technology, Inc. introduces the IMPULSE RM, a small, lightweight, cost effective laser designed to measure road sign retro-reflectivity.

The IMPULSE RM puts the power and speed of a reflectorless laser rangefinder and a retro-reflectometer, *right in the palm of your hand.*

From a remote point, the IMPULSE RM can obtain distance, height, and retro-reflectivity from a glass beaded sign, in a fraction of a second - *all from just the push of a button!*

Laser Technology makes it economically possible for you to measure sign retro-reflectance, quickly and conveniently. The size, weight, and serial output capabilities of the IMPULSE RM make it the perfect tool for sign inventory and basic measurement tasks.

Features

- Rugged, waterproof, one-piece aluminum housing built for every working environment.
- Measures retro-reflectance from distances of 25 to 35 meters (80 - 120 ft.) away from the sign.
- Intelligent on-board computer, calculates horizontal and vertical distances that can be displayed in feet or meters.
- Audio and visual indicators assure positive target acquisition.
- RS232 serial port allows you to store data externally; data is transferred automatically or by manual key press.

Applications

- Sign Inventory and Management
- GPS Offset Mapping
- GIS Data Collection
- Traffic Engineering
- Safety Asset Management

Optional Interfacing

- Laser Technology's MapStar Compass Module
- Public Works Software Inc. Management Software
- GIS software systems
- Works with most GPS-GIS grade receivers

Specifications*

Weight:	1 kg (2.2 lb.)
Size:	15.2 x 6.4 x 12.7 cm (6 x 2.5 x 5 in.)
Range:	75 m (246 ft.) minimum 575 m (1,886 ft.) maximum
Reflectometer:	33 m (150 ft.)
Range Accuracy:	3 cm (0.1 ft.) to a white target at 50 m (164 ft.)
Eye Safety:	FDA Class 1 (CFR 21)
Power Supply:	2 AA batteries
Environment:	Waterproof to IP 67 and NEMA 6
Patent Numbers:	D390,483 • 5,780,999 • 5,790,244

*Specifications subject to change without notice.

For further information or ordering, contact:
Public Works Software
P.O. Box 923
Durham, NH 03824
Voice (603) 498-6PWS or
(603) 862-1362
Email rstrobel@nh.ultranet.com

LASER TECHNOLOGY

Laser Technology, Inc. 7070 S. Tucson Way, Englewood, CO 80112 Voice: (303) 649-1000 Fax: (303) 649-9710 www.lasertech.com

Driver Needs and Maintained Sign Retroreflectance

Charles H. Goodspeed
3Company
3Center, Bldg. 225-5S-08
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St. Paul, MN 55144-1000

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Introduction

Highway statistics show that nighttime vehicle crash rates are nearly three times higher than daytime. Although the mileage driven after dark is approximately one-third that of daylit hours, 56% of all motor vehicle fatalities occur after dark (Traffic Safety, 1989)[1]. While alcohol and fatigue are partly responsible for this disparity, reduced visibility is considered a major factor. Retroreflective devices and markings are designed to help provide important visual cues to ensure a safe nighttime driving environment.

Natural weathering of signage plays a negative role in the upkeep of high sign visibility, causing signs and markings to have a finite useful service life. Currently, the Manual on Uniform Traffic Control Devices (MUTCD) requires that signs be either illuminated or reflectorized, but offers no minimum in-service retroreflective performance standards or guidelines to assist transportation agencies in determining when signs and markings need to be replaced. Maintenance of traffic sign visibility is a very important safety issue. This maintenance includes routine inspection of sight lines, clearing of obstructions, hardware maintenance, and regular replacement of retroreflective sign faces. Outdoor conditions cause all sign sheeting material to degrade in retroreflectance and color intensity. In addition, some sheeting may exhibit other failure modes such as cracking or delamination.

The Federal Highway Administration (FHWA) conservatively estimates over 58 million traffic control devices (TCD's) are in use on our nation's roadways. Further estimates on their condition state that up to 1/2 of all TCD's are beyond their useful service life. Similarly, the ITE Traffic Safety Toolbox (1993)[2] reported that field studies showed a significant portion (60%) of our nation's signing systems are in need of maintenance.

Retroreflectance

For nighttime visibility, luminance of a sign is the best correlate to a driver's perception of brightness. Luminance depends on the retroreflectance of a material, the illumination provided by a vehicle's headlamps, and the geometry between the vehicle and the sign. Safe maintained levels of nighttime sign visibility have been associated with 7 cd/m^2 (FHWA, 1993)[3]. Since luminance is a dynamic, vehicle-dependent metric, it is difficult to directly use luminance as a maintenance criterion. Instead, a material characteristic such as retroreflectance can be used as a surrogate for luminance. This paper will explain the process of calculating proper safety levels of retroreflectance for maintaining traffic signs to meet motorist needs.

Sign retroreflectance has traditionally been specified at standard "photometric instrument measurement" angles of 0.2/-4 degrees (observation and entrance angles, respectively), which are not very representative of roadway geometries. The 0.2/-4 degree

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standard specified testing geometry corresponds to a typical vehicle approximately 600 ft from a sign, correctly positioned on a straight roadway. In use, sign sheeting materials interact as a system that includes illumination sources, the roadway environment, and the motorist. By measuring the luminance of a traffic control device in actual use, it can be determined if the TCD is meeting motorists needs. The geometry between the light source, the retroreflector, and the observer is critical when calculating sign luminance. This three-part system (light source, retroreflector, observer) determines the perception of brightness. If a change occurs in any one of the three parts of this system or in the geometry of the three parts, perceived brightness is affected. Other variables that can play a detrimental role in sign visibility include inclement weather, oncoming traffic (glare sources), and visual clutter.

Lighting Source - The Vehicle Headlamp

Headlamps, being the only source of illumination for retroreflective traffic control devices, must be appropriately quantified for calculating sign illuminance. There is great variance in the quality of the illumination provided to sign locations by different headlamp and vehicle designs. Bible and Chrysler (1995)[4] measured the headlamp output of 32 U.S. vehicles and calculated, using computer models of roadway geometry, the luminance for a sign mounted in each of three locations. Table 1 shows the wide range of luminance provided by different headlamps from the data set. For overhead and left shoulder sign positions, the 15th percentile lamp does not provide adequate illumination. Sivak et al (1998)[5] evaluated headlamp output from 23 best selling 1997 model year cars. Their findings showed from the 25% to the 75% vehicles, differences up to 300% in headlamp output towards standard sign locations at 100 meters (300 ft.).

Table 1. Candela values of headlamp output (cd) and luminance values (cd/m^2) of white enclosed lens sheeting at 100 meters for different headlamp types from a set of 32 vehicles.

	Right Shoulder		**Overhead**		**Left Shoulder**	
Headlamp	Output (cd)	Lum. (cd/m^2)	Output (cd)	Lum. (cd/m^2)	Output (cd)	Lum. (cd/m^2)
Minimum	563	6.84	0	1.98	0	0.70
Maximum	9386	116.63	4975	63.70	5539	77.14
Median	4455	60.84	2792	36.75	3274	48.34
15th %	932	12.32	99	2.76	79	3.43

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In addition to headlamp intensity, lamps must be clean and aimed properly to provide optimum illumination. The headlamp's position on the vehicle, relative to the driver's eye, also affects luminance. As the separation between these two elements increases, so does observation angle, see Figure 1. Truck drivers, on average, receive 40% of the luminance that passenger vehicle drivers receive, due to increased observation angles. Figure 2 shows the dynamic nature of this luminance difference across a range of distances.

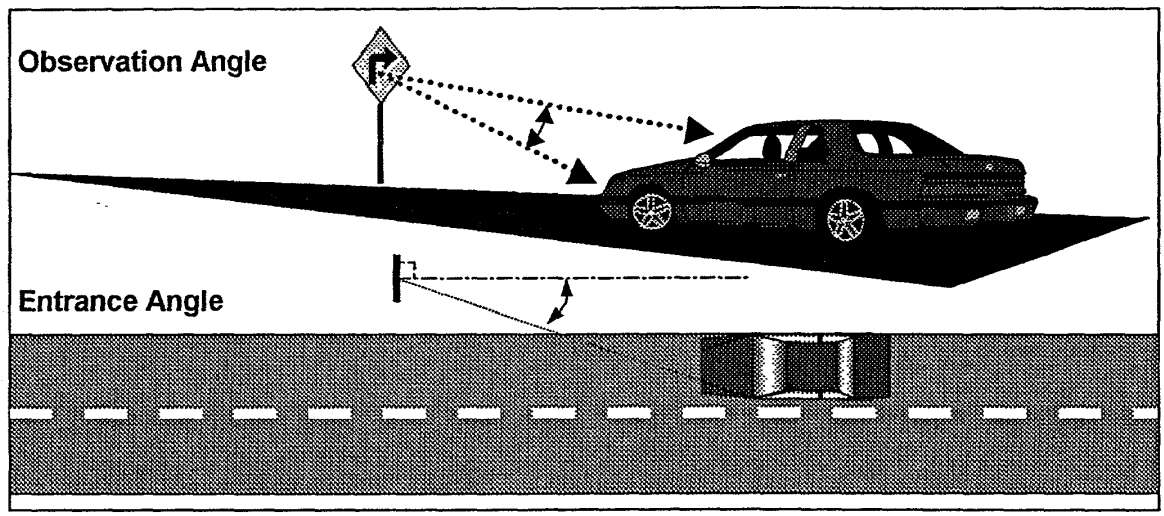

Figure 1. Observation and Entrance Angle Definitions

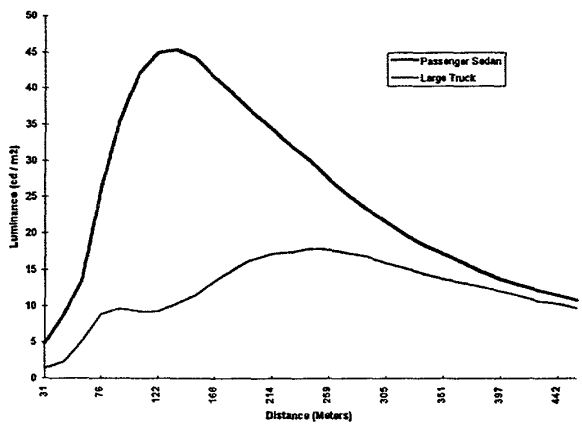

Figure 2. Luminance of encapsulated lens sheeting on a right shoulder mounted white sign for different vehicle types. Separation between driver's eyes and headlamps affects observation angle, which affects luminance.

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Sheeting Characteristics

Retroreflection refers to the physical principle of returning light to its source. The returned light is delivered in a conical distribution, with virtually all of the reflected light within 3° of the source. The amount of light returned depends on the geometry of the situation, (the angle to which the TCD is observed – "observation angle", and the angle at which the light source enters the sheeting – "entrance angle, as illustrated in Figure 1), and the retroreflective properties of the material. The entrance angle is formed between the light source, the face of the retroreflective target, and the line normal to the sign face. As Figure 1 shows, the entrance angle of a sign can be affected by the offset of the sign from the roadway edge, the distance of the vehicle to the sign, the travel lane of the vehicle, curvature of the road, and twist of a sign mounting. The observation angle is formed between the light source, the target, and the observer (either a human eye or a light measuring instrument). Observation angle is affected by distance from the sign and driver eye height (passenger car vs. truck). Given the complexities of the relationships between the three parts of a signing system (driver, headlamps, sign) and the dynamic nature of real world driving, wide angle retroreflective materials will provide a larger range of available lighting conditions, which translates to more viewing opportunities for the motorist.

The coefficient of retroreflection (R_A or R') characterizes materials at a certain geometry. This number is often used in specifications for traffic control devices (for example 0.2^0 observation angle, -4^0 entrance angle). R_A is measured in candelas (reflected) per lux (incident light) per square meter (of reflective material). Table 2 provides typical R_A values at 0.2/-4 degree testing geometry for various sheeting types.

Table 2. Typical Sheeting Retroreflectance Values (white sheeting)

Sheeting Type	Retroreflectance (cd/lux/m^2) 0.2/-4 geometry
Type I	97
Type II	160
Type III	303
Type VIIa	488
Type VIIb	1206

Retroreflective characteristics of the various sheeting materials previously listed, fluctuate differently across the range of typically experienced observation angles. For the majority of sign categories experienced on the road (e.g. regulatory, warning, guide), an expected minimum recommended visibility distance (MRVD) of 200 feet was determined by the FHWA (Paniati, 1993)[3], as an appropriate distance on which to base retroreflectance guidelines.

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The viewing geometry at 200 feet (a typical MRVD) is approximately 0.5 degrees observation angle. The retroreflectance difference between 0.2 and 0.5 degree observation angles is not equivalent across the sheeting materials listed. The following table illustrates the differences.

Table 3. Observation Angles and Retroreflectance

Sheeting Type	Retroreflectance (cd/lux/m^2)* Observation Angle 0.2 degree (600 ft)	0.5 degree (200 ft)	Percent Retained
Type I	97	37	38 %
Type II	160	70	44 %
Type III	303	117	39 %
Type VIIa	488	315	65 %
Type VIIb	1206	456	38 %

*All values based on white sheeting

Observing the relationship between observation angle differences among the sheeting types listed, it is clear that different retroreflectance values are needed for each sheeting type. Higher entrance angles cause further discrepancies between sheeting types, which further necessitates the need for wide angle performance information.

Sign Position

The location of signs in the driving environment must be considered when setting minimum guidelines. Typical headlamp distributions focus most of the light down and to the right, away from left shoulder and overhead sign locations, (see Table 1). It is therefore paramount that traffic sign sheeting accommodates geometries induced by left, overhead, and right shoulder positioned signs.

Background

The visibility of traffic signs and their role in highway safety has been addressed by a large number of researchers, over the past few decades. Researchers at University of Michigan's Transportation Research Institute, UMTRI (Sivak and Olson, 1983)[6], summarized the findings of sign visibility studies (Smythe 1947[7], Allen & Straub 1955[8], Allen et. al. 1967[9], Hills & Freeman 1970[10], Richardson 1976[11], and Olson et. al. 1983[12]). They concluded that the average minimum sign luminance needed for legibility was 2.4 cd/m^2. Further efforts of Sivak and Olson (1983)[6] recommended replacement levels of retroreflectance for various driver percentile levels, that provide a given level of luminance, as displayed in Table 4.

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Table 4. Sign Replacement Criteria by Sivak and Olson (1983)

		Sign Location			
Level	Luminance	Left[1]	Overhead[1]	Right[1]	Right Guide[1]
50th %	2.4 cd/m^2	90	114	24	27
75th %	7.2 cd/m^2	270	342	72	81
85th %	16.8 cd/m^2	630	798	168	189

[1] units are cd/lux/m^2

Additional work conducted by Olson (1988)[13] showed high-complexity areas (e.g. visual clutter from commercial signs) required at least 10 times more sign luminance than low complexity areas for equal visual performance. Furthermore, elderly drivers were found to require three times the sign luminance needs of younger drivers to achieve equal performance. The 1988 Transportation Research Board Special Report 218, "Transportation in an Aging Society" estimated that by 2020 there would be over 50 million Americans 65 years and older, with a great percentage being vehicle dependent. Maintained sign retroreflectance levels will have to provide for the vast majority of drivers on our roads.

Calculating Maintained Sign Retroreflectance Levels

Following the logic of the 1993 FHWA[3] report on retroreflectance levels (which aimed to accommodate 75 to 85% of drivers), the proceeding approach was used to calculate levels of maintained retroreflectance which provides 7 cd/m^2 of luminance to the driver.

To accommodate as many signing locations as feasible, a total of four sign locations were identified. Table 5. provides the exact dimensions associated with each sign location. All dimensions are relative to the centerline of a two lane opposed traffic highway with 12 ft. lanes. Table 6 lists the MRVD's used for each sign type.

Table 5. Sign Location Dimensions

Sign Location	Offset (feet)	Height - to bottom of sign (feet)
Right Rural	24	5
Right Urban	14	7
Left Shoulder	-24	5
Overhead	6	20

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Table 6. MRVD's Used in Sign Luminance Calculations

Sign Type		MRVD (feet)
Warning Signs (black on yellow/orange)		202
Regulatory/Guide (black/red on white)	45 mph or greater	242
	40 mph or less	200
Regulatory (white on red)	45 mph or greater	608
	40 mph or less	293
Guide Signs (white on green)	45 mph or greater	480
	40 mph or less	307

The headlamp distribution matrix used for calculating sign luminance was derived by averaging 42 headlamps from 1993 model year vehicles. The data file used, (UMTRI 50% file), is a 50th percent average, meaning half of the vehicles tested had higher intensity levels, and 50 percent had lower intensity levels. It could be argued that these values are not conservative enough, and that lower headlamp output intensities should be used. To provide some consistency from the FHWA 1993[3] report on minimum retroreflective guidelines, the UMTRI 50% headlamp file was used. If lower values are desired, the recommended retroreflectance numbers included in the appendix can be directly scaled to accommodate.

Procedure used for calculating sign luminance:

1. Observation and entrance angles were calculated from both the left and right headlamps, using the FHWA defined vehicle, the corresponding sign location (left, right rural, right urban, and overhead). Viewing distances corresponded to the MRVD's listed in Table 6.
2. Using the geometries created from the roadway dimensions, corresponding retroreflectance values were gathered for each type of sheeting material, using new, "typical" sheeting information.
3. Horizontal and vertical angles were calculated from the vehicles left and right headlamps to each of the sign locations.
4. Intensity values were gathered from the headlamp distribution file for each of the calculated horizontal and vertical angles.
5. Sign luminance values were then calculated by multiplying the available illuminance from the left and right headlamps by retroreflectance values for each sheeting type, corresponding to the left and right headlamp geometries. The calculated luminance represents what new sheeting provides. Retroreflectance values corresponding to 7 cd/m^2 of luminance were calculated by multiplying new sheeting retroreflectance by the ratio of 7 cd/m2 to the luminance provided by new sheeting. The following example illustrates this final step:

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R_A for new EG (white) sheeting @ 200' ≅ 98, which provides 24 cd/m^2 of luminance. Therefore, The minimum R_A needed to provide 7 cd/m^2 is calculated by:

$$R_{A(\text{for } 7 \text{ cd/m2})} = 98 \times 7/24$$
$$= 29 \text{ cd/lux/m}^2$$

Conclusions

The collective agreement for minimum sign luminances that provide safe driving conditions has been defined at 7 cd/m^2. The maintained retroreflectance levels included in appendix A provide, at a minimum, this luminance level.

Complex Backgrounds

Studies conducted at UMTRI (Sivak and Olson, 1983)[6] have found that sign reflectance values need to be 10 times higher when going from low to high complexity backgrounds. Scene complexity should be evaluated on a per sign basis, and is therefore not included in the maintained retroreflectance levels. However, it is suggested that increases in minimum retroreflectance levels be between 3 and 10 times brighter. It is further recommended that higher reflective sheeting be used in those situations, such that higher maintained sign luminances exist across the life of the sign.

Elderly Drivers

A similar concern to high complexity backgrounds exist for increased populations of elderly drivers. Research on elderly driver needs has shown that 3 times as much light, or 1/3 bigger signs are needed to accommodate the aging eye (Sivak and Olson, 1983)[6]. This should also be considered on a situational basis, and is therefore not included in the calculations.

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APPENDIX A. Revised Minimum In-Service Retroreflectance Guidelines

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Maintained retroreflectance guidelines were calculated for each of the identified sign locations. These levels provide a minimum sign luminance of 7 cd/m^2 (on the sign background), with a minimum contrast between background and legend of 1:4.

Table 3. Warning Signs

Legend Color: **Black,** Background Color: **Yellow or Orange**
(all values - cd/lux/m^2)

Material Type:	Right Rural	Right Urban	Left Shoulder
Type I	n/a ↓	n/a ↓	n/a ↓
Type II	50	70	n/a ↓
Type III	70	90	n/a ↓
Type IV	40	65	n/a ↓
Type VIIa	40	50	140
Type VIIb	85	105	215

Table 4. Regulatory Signs
Legend Color: **White,** Background Color: **Red**
(all values - cd/lux/m^2)

Color	Right Rural	Right Urban	Left Shoulder
White	90	180	330
Red	30	60	110

Table 5. Regulatory and Guide Signs

Legend Color: **Black,** Background Color: **White**
(all values - cd/lux/m^2)

Speed:	45 MPH or Greater			40 MPH or Less		
Sheeting	Right Rural	Right Urban	Left Shoulder	Right Rural	Right Urban	Left Shoulder
Type I	35	60	n/a ↓	50	70	n/a ↓
Type II	35	60	n/a ↓	50	70	n/a ↓
Type III	45	70	150	70	90	185
Type IV	40	65	195	40	65	155
Type VIIa	35	45	125	35	50	130
Type VIIb	50	75	170	85	105	220

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Table 6. Guide Signs
Legend Color: **White,** Background Color: **Green**
(all values - cd/lux/m^2)

	Right Rural	Right Urban	Overhead
White	75	165	735
Green	25	55	245

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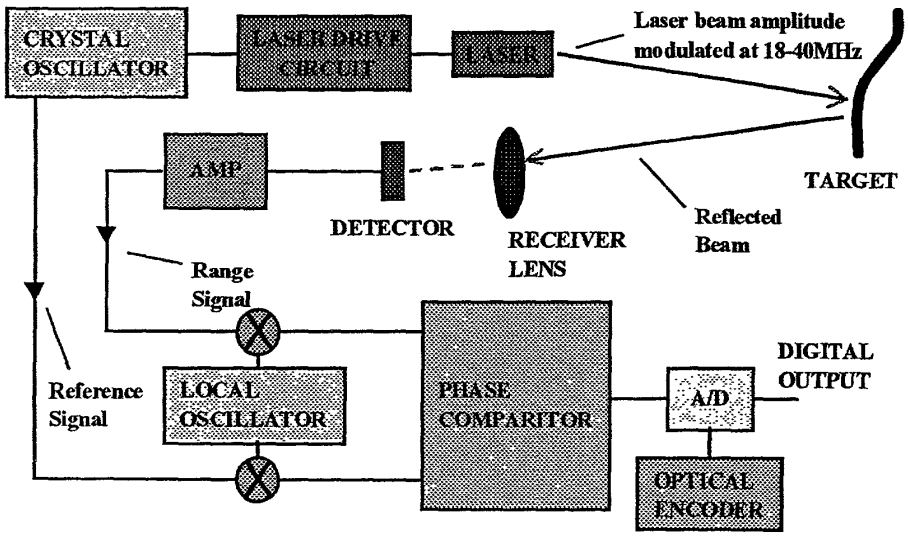
Holometrics 3D Vision Technology

Non-contact, scanning, range measurement features are the foundation of a 3D Vision system. The Holometrics 3D Vision System employs direct range measurements with phase-comparison of an amplitude-modulated laser, which provides the best balance in operating range and scanning speed for many important applications. In addition, Holometrics patented scanning laser radar technology allows operation over a wide range of conditions that other phase-comparison based 3D Vision systems cannot achieve.

Phase-Comparison Range Measurement
The diagram below shows a functional diagram of the Holometrics 3D Vision sensor.



Holometrics 3D Vision Sensor Block Diagram

A crystal oscillator generates a signal that modulates the laser output intensity, and a reference signal. A scanning unit (not shown) scans the modulated laser beam across the target area. A fraction of the beam is reflected back to a silicon APD detector. The phase difference between the output (range) signal from the detector and the reference signal is proportional to the range. Since the reflected signal does not have to be at a different angle from the laser source, it is a relatively simple task to scan only the laser beam, and not the entire detector unit.

Range versus Intensity Solution
The phase-comparison range measurement technique is relatively simple for laboratory environments, when the reflectivity of the target is held reasonably uniform. A commercially useful 3D sensor, however, needs to have operational

capability across a very wide range of target reflectivity, angle of incidence, range, variations in target composition and viewing conditions.

The Holometrics patented technology uses a combination of optical and electrical signal processing techniques to allow accurate phase measurements across several orders of magnitude in the intensity of the return laser beam.

Holometrics Technology Advantages

Important characteristics of a 3D Vision system are as follows:

- High level of confidence in object identification.
- Operating range on the order of 1-30 meters (±3mm accuracy).
- High range measurement rate of >500,000 samples/second.
- Wide variety of target material and viewing conditions that can be accurately ranged.

High confidence of object identification is achieved with a direct range measurement. There is very low probability of misinterpreting the detection of an object when range is measured directly. Without a direct range measurement, some level of interpretation is required to extract range information.

For example, stereovision requires object recognition and matching. Natural stereovision systems (people and many animals) have excellent ability to recognize and match objects to achieve depth perception. Non-biological implementations of stereovision, on the other hand, have not yet achieved a similar level of reliability.

The phase-comparison measurement method with a single frequency oscillator allows operation in the 1-10 meter range interval at a very high sampling rate. This operating range is necessary for many important applications such as autonomous vehicle navigation, material handling by robotic arms, and cargo dimensional measurement. The fast measurement rate allows high-resolution images on the order of a million pixels to be acquired in seconds. Dual-frequency phase-comparison measurements still allow high sampling rates while extending operating range to 30-100 meters.

Other direct range measurement methods include time-of-flight and triangulation. While capable of high accuracy, the time-of-flight method is better suited for range measurements at distances of more than 100 meters, and typically has a slow measurement rate (<75/sec) allowing only coarse images to be generated in a short period. The triangulation technique, is also very accurate, but is best suited for very short-range (<10cm) conditions.

For 3D Vision systems based on phase comparison range measurement, only Holometrics patented scanning laser radar technology allows operation over a wide range versus intensity conditions necessary to support diverse target materials and viewing angles.

Holometrics 3D Vision Systems

Holometrics patented 3D Vision System acquires high-resolution 3-dimensional images in seconds. Direct range measurements using the phase comparison method allows virtually unconstrained scene scanning. Applications include robot navigation and obstacle avoidance, air cargo dimensional-weight measurement, crime scene reconstruction, pavement damage inspection, prosthesis fitting, etc.

Product Family	
Model 300-18 & 300-40	Dual mirror scanning for stationary targets
Model 100	Single mirror scanning for fixed velocity targets

Optical Scanning Unit	
LASER	GaAlAs – 830 nm wavelength
LASER POWER	Amplitude modulated 200- milliwatts (eye safe with interlocks)
DETECTOR	Si:APD
FIELD OF VIEW	
Model 300	160° X 50° Maximum (most applications use 50° X 50°)
Model 100	160°
HORIZONTAL SCAN MIRROR	3000 RPM
VERTICAL MIRROR	1.43 RPM (MODEL 300-18 & 300-40 only)
MODULATION FREQ*	18MHz (Model 300-18), 40MHz (Model 300-40)
AMBIGUITY RANGE	13 ft (Model 300-18) 6 ft (Model 300-40) 100 ft on dual frequency models
DATA RATE	> 500,000 measurements per sec.
X & Y RESOLUTION	0.1 in at 10 ft range
Z AXIS RESOLUTION	±0.2 in at 18MHz, ±0.1 in at 40MHz
RANGE DATA CONN	50Ω RG-174/U Coax
POWER CONN	AMP 23-24 Series 1 Circular Connector
DIMENSIONS	13"x8"x18"
WEIGHT	20 LBS

*Modulation frequency is customizable to user requirements for minimum & maximum range.

Power Supply and Digital Processing Unit	
POWER INPUT	110 VAC, 3 A
OUTPUT	220 VDC, ±9 VDC, ±5 VDC, 12 VDC
A/D CONVERTER	12-bit, 5MHz

Control Terminal	
COMPUTER	Industrial grade Intel Pentium III
OPERATING SYSTEM	Microsoft Windows NT 4.0
FRAME GRABBER	1024x1024, 16-bit

Software*

General Purpose 3D Image Analysis
Air Cargo Automated Measurement System
*Software customizable to user application requirements.

The optical scanner subsystem is the heart of the 3D Vision System, as shown in Figure 1 below.

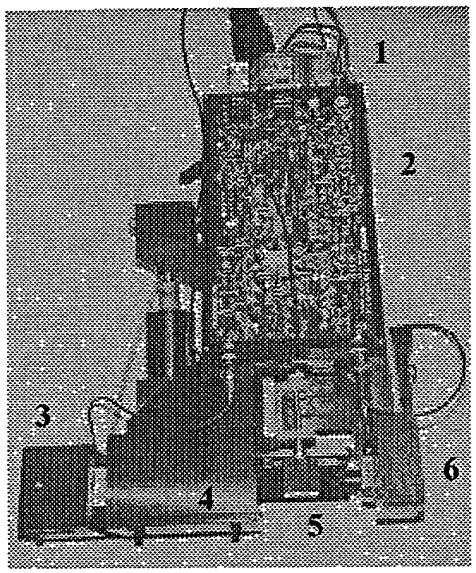


Figure 1: OPTICAL SCANNING SUBSYSTEM

The system is based on laser radar technologies. A collimated laser source (6) is transmitted to two mirrors (5) that scan the laser beam vertically and horizontally. The laser beam is reflected back and directed through the optical receiver (4) to the detector (3), which generates a "range signal". The range signal is then compared with a reference signal in the phase detector board (2), which results in a very accurate range measurement to each point in the scene. In fact, the system measures the 3D features of objects in the scene to an accuracy of 0.1 inch in length, width and height. The entire image acquisition and processing functions are accomplished in less than 9 seconds. The sensor obtains approximately 500,000 individual range measurements per second. The analysis of the resulting 3D image then leads to determination of cargo volume and DIM WT. This capability is about 100 times faster than using a tape measure to obtain dimensions of the cargo item.

The Holometrics 3D Vision System technology is protected under U.S. Patent Number 5,831,719 dated November 3, 1998, Number 5,940,170, dated August 17, 1999 and Number 6,115,114, dated September 5, 2000. Foreign patent protection has been filed. Our filing under Patent Cooperation Treaty procedures has been given the International Application No. PCT/US 98/18684,08/09/1998. Mr. Berg has transferred ownership of the patents to Holometrics.

Company Overview

Holometrics develops 3D Vision technology and products based phase comparison, scanning laser radar systems.

Product Offerings

Holometrics has two 3D-Vision products that are currently in production. Both are single frequency systems targeted at 1-10 meter close range applications. We are currently under contract to develop a dual-frequency system for 30-meter range applications. All product versions are available with single or dual axis scanning capability.

Target Market

Holometrics is initially focused on industrial market opportunities where 3D-Vision systems have direct revenue generation impact that justifies high value products. As production costs are reduced, Holometrics will introduce differentiated products targeted at commercial market segments where purchasing decisions can be made by a broader range of managers without long-term budget planning cycles. Enabling 3D Vision products for the consumer market will require forming a strategic alliance with a company with leading edge technology and manufacturing capabilities in cost reduction and high volume production.

Business Model

Holometrics is pursuing direct sales, distribution partners and OEM opportunities. Holometrics recently secured a contract to provide 3D Vision systems for surveying applications. Industrial and commercial market segments have sufficiently high margins to allow Holometrics to build up infrastructure to maintain a technology advantage over potential competitors and develop cost reduction techniques.

Holometrics is seeking venture capital funding from a firm publicly known as a technology leader, in part to provide reassurance to potential customers that depend on name recognition.

Management

President/CEO: Johnny L. Berg has 36 years of experience in the design and development of electro-optic and laser radar based sensor systems, and 11 years director level experience at the Lockheed California Company as Director of Advanced Avionics, Advanced Development Projects (SKUNK WORKS) and the Perkin-Elmer Corporation as Director of Defense Programs. Previously, Johnny Berg served as an officer in the United States Air Force with 1,100 hours of night combat time over Laos and North Viet Nam and three separate Distinguished Flying Cross awards for heroism. Mr. Berg is co-inventor on all U.S. patents awarded Holometrics.

Co-inventor: Mr. Frank Gerhard is named on all the U.S. patents granted on the Holometrics 3-D Vision System. Mr. Gerhard has over 37-years of experience in analog electronics design. He is the founder of Gerhard Engineering located in Mission Viejo, CA. Mr. Gerhard is a member of Holometrics Technical Support Management Team.

Mr. Thomas Silva is an Engineering Department Manager responsible for maintaining ISO-9001 types of standards for product quality and documentation. Mr. Silva also provides electronic designs for new or modified 3-D Vision System Products.

Ms. Peggy Steward is an electronics technician who handles all board soldering operations within the company.

The Technical Management Team at Holometrics also includes Mr. Norman Walker, a retired college professor in Digital electronics, Dr. Mano Goharlaee, software engineer.

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Holometrics, Inc.

Fax

To:	Jamie Rettenath	**From:**	Johnny L. Berg
Fax:	952-401-3292	**Pages:**	10
Phone:	612-396-1151	**Date:**	1/25/01
Re:	3-D Vision System Proposal	**CC:**	

x **Urgent** ☐ **For Review** ☐ **Please Comment** x **Please Reply** ☐ **Please Recycle**

• **Comments:**

Jamie:

Here is the proposal that you requested. Would you give me a call and let me know that you received this document. The fax area code is different than the telephone area code so I am not sure if there hasn't been a mistake on the numbers.

Hope this is what you are looking for.

Respectfully, Johnny L. Berg, President/CEO

Johnny L Berg

Holometrics Private Information

Proposal To
Facet Technology Corporation
January 25, 2001

INTRODUCTION:

This proposal defines the work required to modify an existing Holometrics 3-D Vision System in order to give it the capability to accomplish the functions outlined by Mr. Jamie Retterath of Facet Technology Corporation. The functions defined to Holometrics involved obtaining 3-D imagery of highway resources (signs, posts, guard rails, etc) in order to verify that the resource was located and oriented properly with respect to the road.

OPERATIONAL REQUIREMENTS:

5

1. Scan a 40° horizontal field-of-view (FOV) by 35° vertical FOV in order to acquire imagery on objects as high as 20-feet above the ground at ranges between 30 and 75-feet from the camera.
2. With appropriate processing of the 3-D imagery, Facet personnel will determine the location, dimensions and orientation of objects located beside the road.
3. Determine angular orientation of an objects surface to an accuracy of ± 2° with respect to the centerline of the road. In other words a vector normal to the surface of a sign should be parallel to the center-line of the road to within ± 2°. ?
4. Maximum distance between the sensor and objects of interest is 75-feet.
5. Objects of interest will have surfaces covered with retroreflective paint Sheeting 3
6. The maximum velocity of the Facet vehicle will be 50 mph.
7. The Facet Technology vehicle will provide a source of 110 volt, 60-cycle electrical power.
8. Facet Technology will provide the computer used to receive and store the 3-D imagery.
9. Facet Technology will provide the means to record vehicle velocity to support image-processing functions.
10. All imagery will be recorded on Facet Technology storage media. The Facet recording device will accept a continuous stream of 3-D data from the 3-D sensor.
11. Facet Technology will accept imagery that has alternating frames of imagery where the first line of a frame starts at the top of the image (scan down), and on the next frame the first line will be at the bottom of the frame (scan up).
12. The sensor must be enclosed in an appropriate container for protection from the elements when not in use.
13. When the sensor is to be used, Facet personnel will manually open a scan-port to allow the sensor to scan the laser beam, unimpeded, through the required 40° FOV.

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SENSOR REQUIREMENTS

The sensor that will be modified on this program is the Holometrics 300-18 3-D Vision System. Figure 1 below depicts the optical scanning head of this sensor.

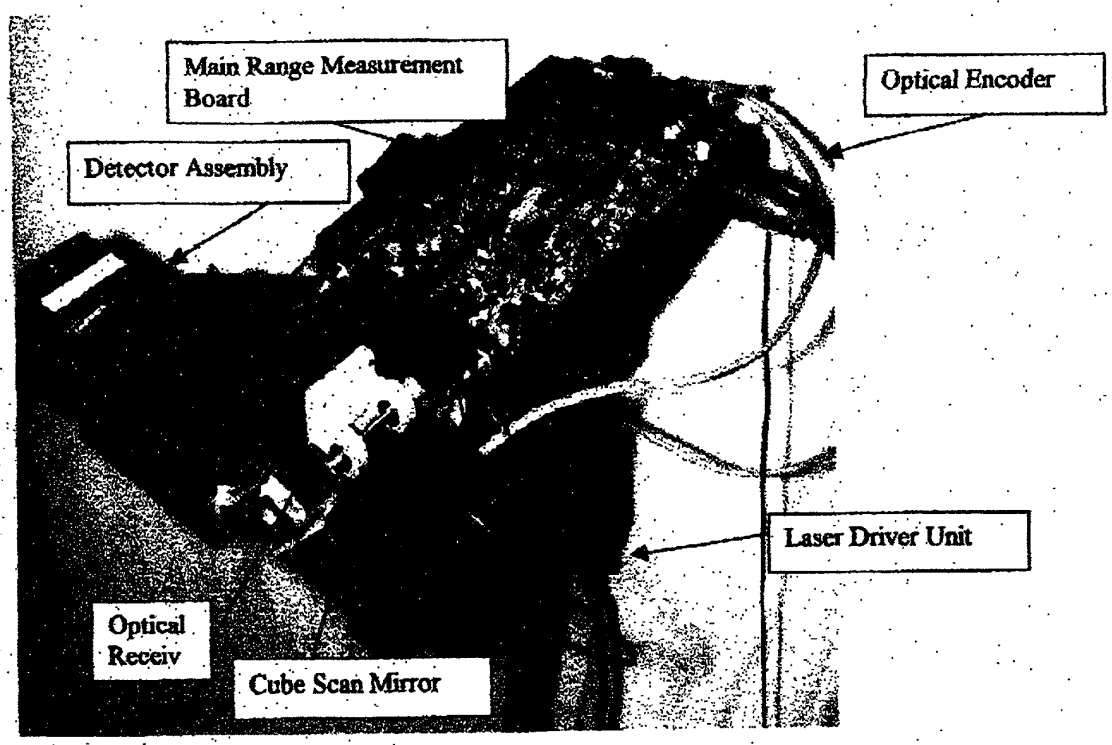

Figure 1: Holometrics Model 300-18 3D Vision System

1. An eye safe, 500 milliwatt laser is used to acquire the range data. The laser is a InGaAs diode laser with an 800-nanometer wavelength. The laser modulation wavelength will be as required to provide unambiguous range data over the required 75-foot interval.
2. Scan rates will be 200 lines per second. The scan line length will contain the pixels required to provide full coverage of the 40° FOV.
3. Distance between scan lines will be not less than 10-inches at a 50-foot slant range.
4. Range data will be collected at a rate of 500,000 measurements per second.
5. Ranging accuracy will be 0.2-inches or better at a slant range of 75-feet.
6. The horizontal scan will be accomplished with a 1-inch cube mirror.
7. The vertical scan will be accomplished by mechanically rotating the scan head with a stepper motor that will provide the correct positioning of the head for each line at the 200-line per second scan rate.

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8. The 3-D sensor will derive electrical power from a Facet supplied 120-volt, 60-cycle electrical source.
9. The 3-D sensor will provide 3-D imagery over a vehicle velocity range of 5 to 50 mph.
10. The 3-D imagery will be made available to the Facet computer via an image grabber board to be provided by Holometrics.

RADIOMETRY

1. We will modulate the diode laser at a frequency of 3.281 MHz that will provide for a 75-foot measurement interval.
2. A 500-milliwatt diode laser modulated at 3.281 MHz will have an average power of 250 milliwatts.
3. Assume a lambertian sign reflectivity of 0.99. Even though the signs utilize retroreflective paint, we assume a lambertian reflector for a margin of safety.
4. With the conditions described in 1,2 and 3 above, the typical Signal-to-Noise (S/N) for this environment will be 2,612 at the 75-foot range point. This will provide for a 1-sigma uncertainty in the range measurements of less than 0.061-inches.
5. The number of range pixels across a 3-foot wide sign will be 95.
6. The spacing between scan lines will be at least 10-inches at 50-feet.
7. The distance that the vehicle will move during one scan cycle is about 0.17 inches. Thus, the 1-sigma range uncertainty value of 0.061-inches is about 1/3 that of the distance moved and will, therefore, be able to provide accurate data under dynamic travel of the vehicle.
8. The data rate from the sensor will be 500,000 measurements/second.
9. The stepper motor for the sensor will allow for selectable line spacing and frame rates.

Statement of Work

The Holometrics Model 300-18 3-D Vision System will be modified to accommodate the specific technical requirements for the Facet Technology Highway scanning application. Appendix A summarizes the Top Level Tasks for this modification effort. As shown in this Appendix, there are 13 major tasks to be accomplished in order to accomplish the new sensor design. Appendix B is the schedule for accomplishing each of the 13 tasks. The effort to be accomplished on each task is described below.

Task 1 – **Remove Large Mirror and Yoke**: The ACAMS configuration will be changed to eliminate the large scan mirror and associated mechanical components. Since we are going to use a stepper motor for the vertical scan driver, this mirror is not required. Eight person-hours will be required for this task.

Task 2 – **Design, Fabricate, and Install a mount and the stepper motor:** A mount will be designed and fabricated which will provide the means to mount the stepper motor to the sensor head. This mount will also provide a mounting point for the stepper motor driver and driver power supply. After installing the mount, the stepper motor will be integrated into the scan head. Eighty person-hours will be required for this task.

Task 3 – **Install a 500-milliwatt laser in the 3-D scanner:** In order to increase the measurement interval from 15-feet to 75-feet, we will install a more powerful 500-milliwatt laser into the scanner. This will entail installation of a new mounting laser drive box, driver, collimator and the laser. Twenty-four person-hours will be required for this task.

Task 4 - **Design, Fabricate, and install system electrical power cable.** This cable is required to connect the sensor to the vehicle electrical AC power supply. This task will require 8 person-hours.

Task 5 - **Change to 75 foot measurement interval.** The ACAMS measurement interval will be extended from 15-feet to 75-feet. This requires that the highly stable crystal oscillator in the laser drive be changed to 3.281 MHz. The local oscillator in the sensor main board will be changed to 1.281 MHz. The local oscillator will reduce the 3.281 MHz frequency of the reference signal and the detector signal to 2 MHz which are then used to make the range measurement. This task requires 40 person-hours.

Task 6 - **Enable ripple circuit.** This circuit provides the means to sample the range voltage at the same point with respect to our reference frequency. This improves the measurement accuracy of the main board phase measurement electronics. This task will require 16 person-hours.

Task 7 - **Design Sensor Enclosure and Window:** In order to protect the sensor from the elements when it is not being used and during transport, an enclosure will be designed and fabricated to protect the system. A small, manually opened and closed window will be included which will be opened when the sensor laser beam is scanning. This task requires 80 person-hours.

Task 8 - **Fabricate a 15-foot RS-422 data link.** This data link connects the scanner head to the image grabber board in the computer. At this point the exact configuration is not known. However, a 15-foot length will be able to accommodate any specific configuration. This task requires 80 person-hours.

Task 9 - **Assemble the system.** After tasks 1 – 8 have been completed, the scanner will be completely assembled and prepared for system testing. This task requires32 person-hours.

Task 10 - **Software Development:** This task will result in the software required to control the sensor, provide for proper formatting and capture of 3-D images, and placing the 3-D images in the computer

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memory. This step also includes setting up a sensor "Parameter File", programming the CPLD chip which provides the clock, start-of-frame, start-of-line, end-of-line, and end-of-frame signals required for proper formatting of the 3-D images. This task requires 120 person-hours.

Task 11 - **System Final Test:** After the software has been developed and inserted into the Holometrics computer system, the sensor will then be thoroughly evaluated over a 10-day (160 person-hour) period.

Task 12 - **Documentation and Report Preparation:** Once the system test has been satisfactorily concluded, then Holometrics will prepare an operating document, routine maintenance document, and a final test report. This task is spread over the life of this effort and will require about 131 secretarial hours.

Task 13 - **Ship sensor FOB Escondido to customer facility:** The system will be packed and shipped FOB Escondido, CA to the Facet Technology facility.

DEVELOPMENT PROGRAM COST:

Appendix C provides the labor costs for the tasks described above. At the completion of this effort, Unit Number One will be complete.

The total labor costs is:	**$44,754.00**
The cost for materials for the sensor is:	**$19,450.00**
The total program costs are:	**$64,204.00**

MULTIPLE ORDER UNIT COST:

If Facet Technology places an order for multiple units, the unit production costs will decrease as summarized below:

QUANTITY ORDERED	UNIT COST
5	$33,750.00
10	$30,480.00

The remaining $34,204.00 will be made upon successful completion of the final test of the first article.

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1. Development Program: Holometrics requires a $30,000.00 advance payment for component purchase and initial labor costs.

2. Quantity Orders:

   a. Holometrics requires **$15,000.00** advance payment, per unit, for the quantity 5 order. This equates to **a total advance of $75,000.00.**
   b. Holometrics requires **$11,500.00** advance payment, per unit, for the quantity 10 order. This equates to a total advance of $115,000.00.

The remaining sum on each of the quantity orders will be made upon shipment of the systems to Facet Technology.

WARRANTEE: The Holometrics systems will be warranted for 6-months from the date of shipment from Holometrics.

Holometrics has contract services for on-going preventative maintenance. Please contact Holometrics for pricing.

This proposal is valid for 45 days.

For Holometrics, Inc.

Johnny L. Berg, President/CEO

Top Level Tasks as of 1/25/01

ID	Task Name	Duration	Start	Finish	% Comp.	Cost	Work
1	Remove Large Mirror/Yoke	1d	6/1/01	6/1/01	0%	$560.00	8h
2	Des/Fab/Install Stepper Mtr & Mnt	10d	6/4/01	6/15/01	0%	$5,600.00	80h
3	Install 500-mw laser unit	3d	6/18/01	6/20/01	0%	$1,176.96	24h
4	Des/Fab Power Supply Cable	1d	6/21/01	6/21/01	0%	$392.32	8h
5	Change to 60-foot amb. Interval	5d	6/22/01	6/28/01	0%	$1,961.60	40h
6	Enable Ripple Circuit	2d	6/29/01	7/2/01	0%	$784.64	16h
7	Design Sensor Enclosure/Window	10d	6/19/01	7/2/01	0%	$5,600.00	80h
8	Fabricate 15' Data Link	10d	6/1/01	6/14/01	0%	$2,400.00	60h
9	Assemble System	4d	7/10/01	7/13/01	0%	$4,000.00	32h
10	Software	15d	6/20/01	7/10/01	0%	$9,000.00	120h
11	System Final Test	10d	7/16/01	7/27/01	0%	$10,000.00	80h
12	Documentation/Report Preparation	41d	6/1/01	7/27/01	0%	$2,888.40	131.2h
13	Ship FOB Escondido	1d	8/1/01	8/1/01	0%	$392.32	8h

Appendix A 7

APPENDIX B

1/25/01

Modification Program
for
Facet Technology Corporation Proposal

Holometrics, Inc.

ID	Task Name	
1	Remove Large Mirror/Yoke	$850.00 Berg
2	Des/Fab/Install Stepper Mtr & Mnt	[illegible] Berg
3	Install 500-mw laser unit	$1,176.96 [illegible] Silva
4	Des/Fab Power Supply Cable	$392.32 [illegible] Silva
5	Change to 50-foot amb. interval	$1,961.60 Silva
6	Enable Ripple Circuit	$784.64 Silva
7	Design Sensor Enclosure/Window	[illegible] Berg
8	Fabricate 15' Data Link	[illegible] Peggy
9	Assemble System	$4,000.00 Team
10	Software	$9,000.00 Mano
11	System Final Test	[illegible] Team
12	Documentation/Report Preparation	[illegible] Allison[0.4]
13	Ship FOB Escondido	$392.32 Silva

Jun '01 | Jul '01 | Aug '01

5/27 6/3 6/10 6/17 6/24 7/1 7/8 7/15 7/22 7/29 8/5 8/12

Project:
Date: 1/25/01

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress

Company Private

Page 1

Company Private

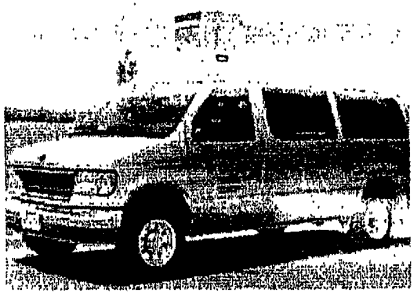
Budget Report as of 1/25/01

ID	Task Name	Fixed Cost	Total Cost	Baseline	Variance	Actual	Remaining
11	System Final Test	$0.00	$10,000.00	$10,000.00	$0.00	$0.00	$10,000.00
10	Software	$0.00	$9,000.00	$9,000.00	$0.00	$0.00	$9,000.00
2	Des/Fab/Install Stepper Mtr & Mnt	$0.00	$5,600.00	$5,600.00	$0.00	$0.00	$5,600.00
7	Design Sensor Enclosure/Window	$0.00	$5,600.00	$5,600.00	$0.00	$0.00	$5,600.00
9	Assemble System	$0.00	$4,000.00	$4,000.00	$0.00	$0.00	$4,000.00
12	Documentation/Report Preparation	$0.00	$2,886.40	$2,886.40	$0.00	$0.00	$2,886.40
8	Fabricate 15" Data Link	$0.00	$2,400.00	$2,400.00	$0.00	$0.00	$2,400.00
5	Change to 50-foot amb. Interval	$0.00	$1,961.60	$1,961.60	$0.00	$0.00	$1,961.60
3	Install 500-mw laser unit	$0.00	$1,176.96	$1,176.96	$0.00	$0.00	$1,176.96
6	Enable Ripple Circuit	$0.00	$784.64	$784.64	$0.00	$0.00	$784.64
1	Remove Large Mirror/Yoke	$0.00	$560.00	$560.00	$0.00	$0.00	$560.00
4	Des/Fab Power Supply Cable	$0.00	$392.32	$392.32	$0.00	$0.00	$392.32
13	Ship FOB Escondido	$0.00	$392.32	$392.32	$0.00	$0.00	$392.32
		$0.00	$44,764.24	$44,764.24	$0.00	$0.00	$44,764.24

Appendix C 9

Mobile Sign Retroreflectometer Van

The van uses a calibrated strobe lamp, mounted on top, to bounce light off highway signs. The returned light is processed by computer to account for observation, angle, and distance, and is then measured and compared to guidelines.



Mobile Sign Retroreflectometer Van

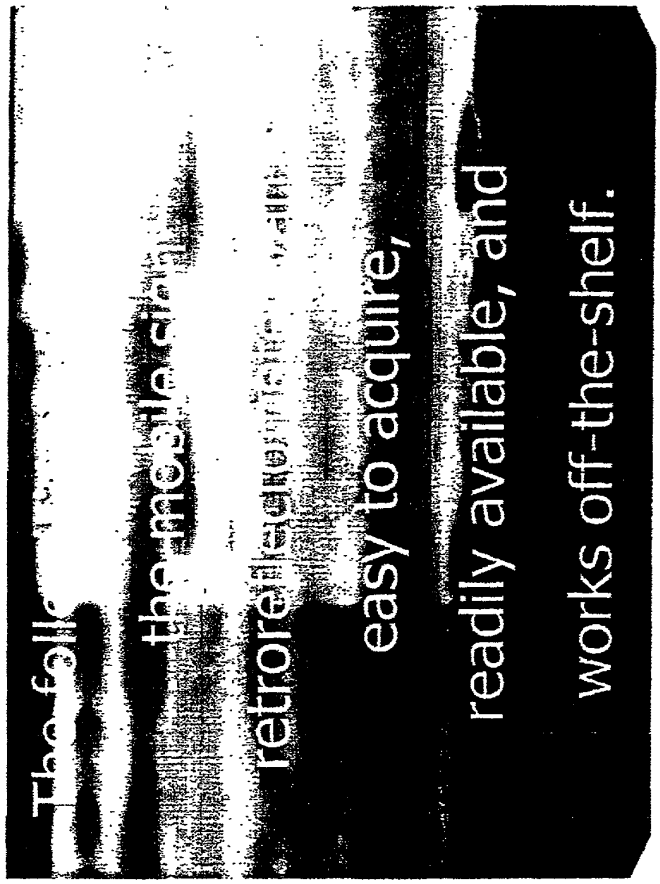
Equipment

The mobile sign retroreflectometer van is a prototype system. It can measure the retroreflectance of traffic signs during daylight hours at highway speeds. It effectively and economically measures the retroreflectivity of the signs.

The system will track the designated sign and, at 200 feet, will flash the sign and perform retroreflectivity calculation. This information along with the GPS coordinates and other data associated with that particular sign will be stored in the systems database. The data will be used to evaluate the sign, and will be the beginning of a sign inventory.

The equipment consists of a laser range finders, a color video aiming camera, two B&W video cameras, a high-intensity xenon flash unit, a pan tilt mount (to rotate the flash unit), a system computer and monitor, image processing and image capture cards, and a van vehicle equipped with GPS.

The equipment is readily available off-the-shelf.


easy to acquire,
readily available, and
works off-the-shelf.

Laser Range Finder

Laser Sys[illegible]

- 1,000 ft range on 20% reflective surface
- 5cm accuracy
- 8kHz sampling rate
- 6 ft beamwith at 200 ft (approximately)
- Naked Eye Safe
- Class 1 laser product

Color Camera

Pulnix TM-7

- 768 (H) x 494 (V) Resolution
- 1/2 inch CCD
- Shutter Speed for 1/60 to 1/10,000 sec
- 50mm Lens

B&W Cameras 1 & 2

Pulnix - 72EX

- 768 (H) x 494 (V) Resolution
- 2/3 inch CCD
- Shutter Speed for 1/60 to 1/10,000 sec
- Camera #1 has a 50 mm Lens, while Camera #2 has a 75mm Lens

Flash Unit

Hughey & Phi[illegible]
(modified)

- Xenon Flash Tube
- 270,000 Candelas of light intensity
- 1 second flash recharge time
- Daytime use ONLY

Pan Tilt Mount

Rotating Precision Mechanisms, Inc.

- 25 deg/sec maximum velocity in azimuth and elevation
- 40 deg/sec☒ maximum acceleration
- Full computer control of azimuth and elevation

System Computer

- Dual- processor Intel Pentium 200 MHz System
- 2 Gigabyte internal HD
- 2 Gigabyte removable HD for data
- SCSI interface for HD, Zip drive & CD ROM
- Windows NT 4.0 Operating System

Monitor

Computer Dynamics Inc

- 13.8" LCD Flat Panel Display
- 1024 x 768 resolution
- 5"total depth of monitor and enclosure

Image Processing & Capture

Processing

SHARP GPB-2

- 25 MHz, 40 ns/pixel processing rate

Capture

VGX 4 Megabyte Frame Grabber

- 8-bit resolution

Vehicle

Ford Motor Corporation

- Regular length Club Wagon
- Heavy duty suspension and alternator
- 2,000-watt inverter installed for AC power
- Racks installed to house associated equipment

GPS Unit

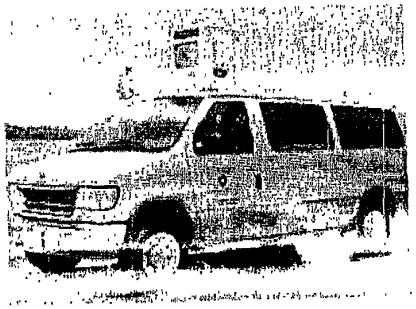
Magellan System Corporation

- 10 Channel GPS Sensor
- 100 meter resolution
- Differential GPS ready (1- meter resolution)

Mobile Sign Retroreflectometer Van

Operation

A driver and a operator are needed to use the system. While the driver maneuvers the vehicle, the operator aims the optical head toward an oncoming traffic sign using a computer mouse and [illegible] tracking [illegible]. This locates and tracks the sign by way of the color video camera.



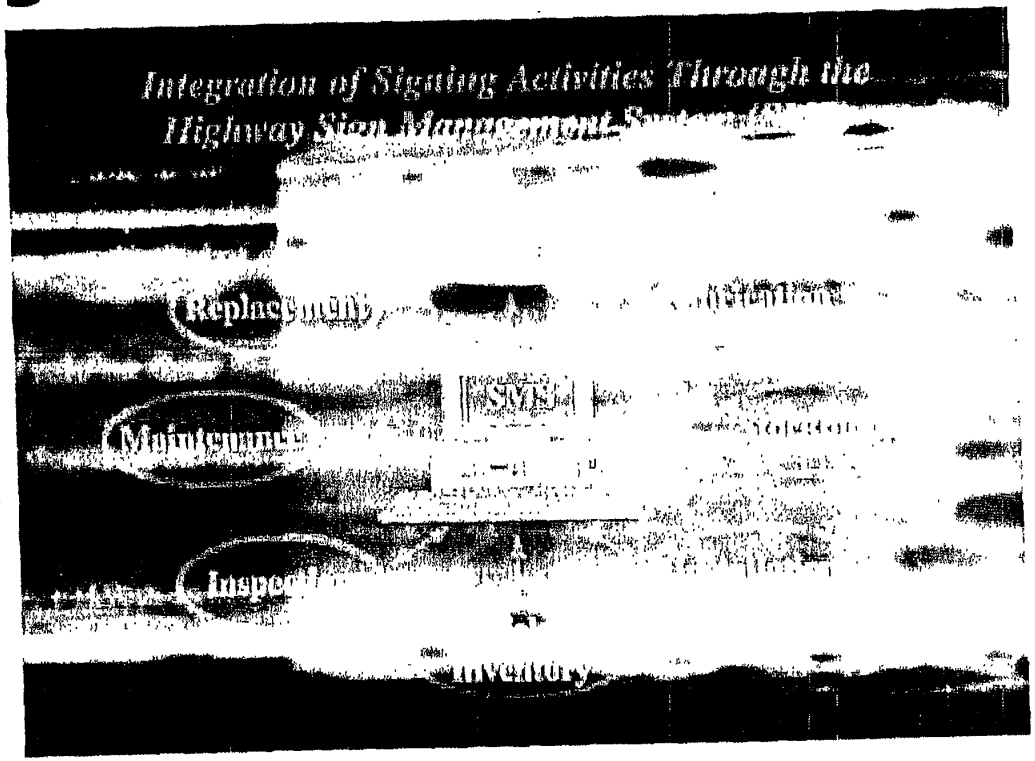
When the system is at the required distance from the sign (200 feet), the range finder fires the xenon flash, and the sign image is captured by the appropriate B&W video camera. A histogram is produced of the sign's legend and background, which is used to calculate retroreflectivity of each in cd/lux/m^2.

This information, along with the GPS coordinates, sign images--color image of sign, B&W, and histogram--is recorded in the sign management system's data base. The data exists in a raw format that can be inputted into a database management system.

Sign Management

At FHWA, we believe that highway agencies should provide signs that are detectable and legible at the required distance for the vast majority of drivers, both day and night.

For signs that rely on their retroreflectivity properties, it is paramount that they do not degrade to a level that cannot achieve this objective. Consequently, FHWA is [illegible] of a sign management program.

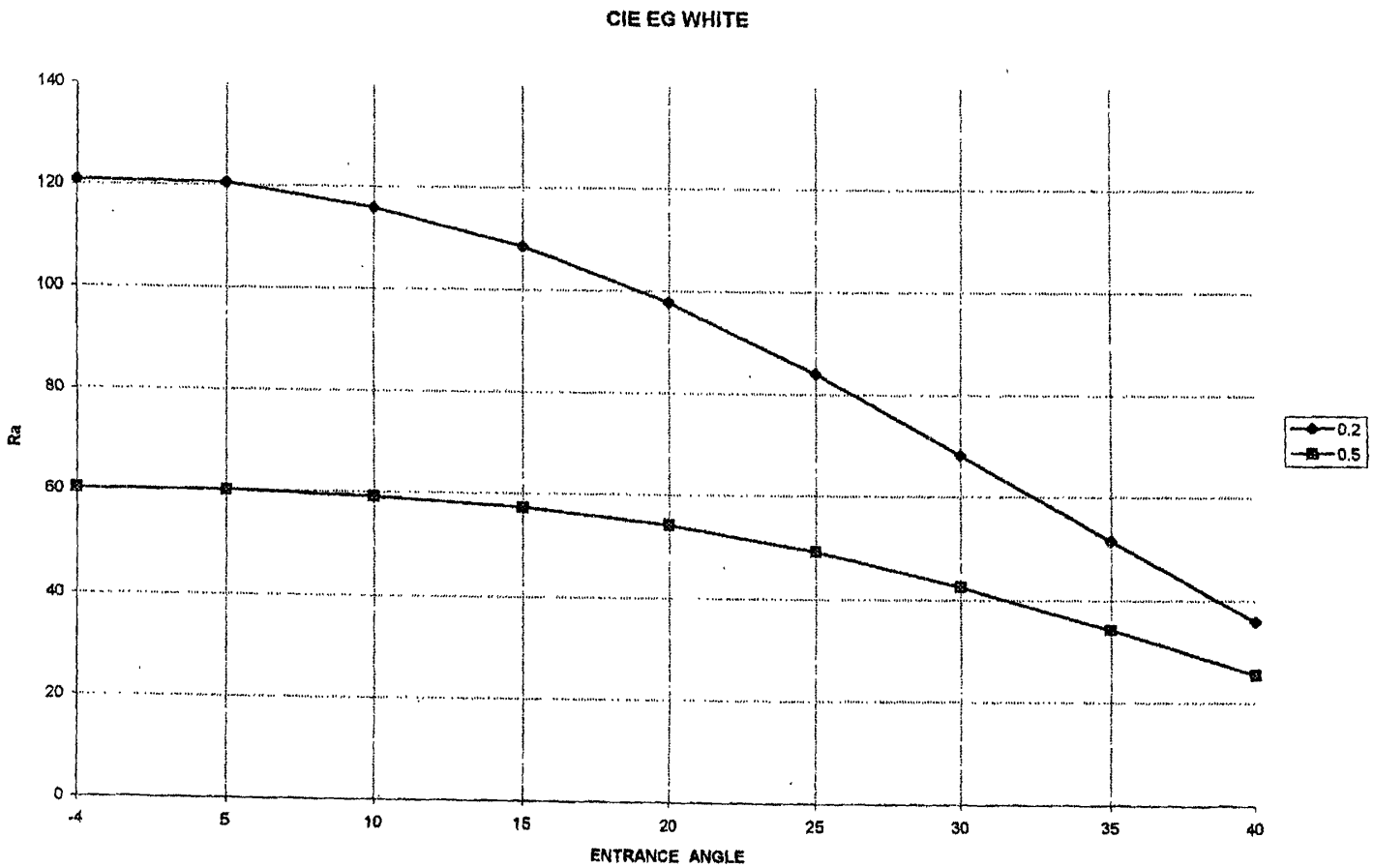


FHWA is currently preparing an Advance Notice of Proposed Rulemaking regarding the minimum retroreflectivity guidelines. The rulemaking process provides an opportunity for all interested parties to comment on the proposal.

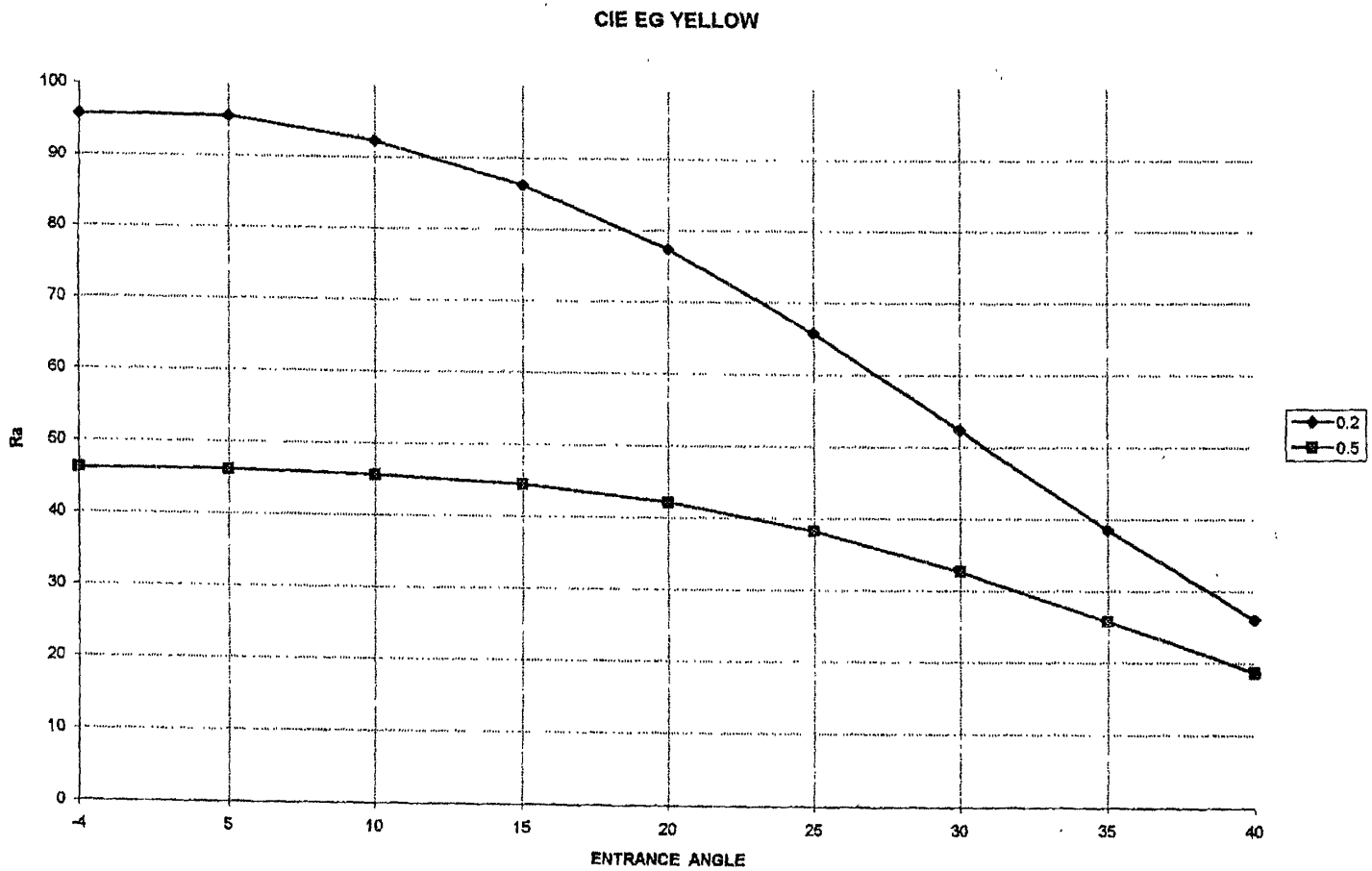
For More Information

For more information about Retroreflectivity, contact:

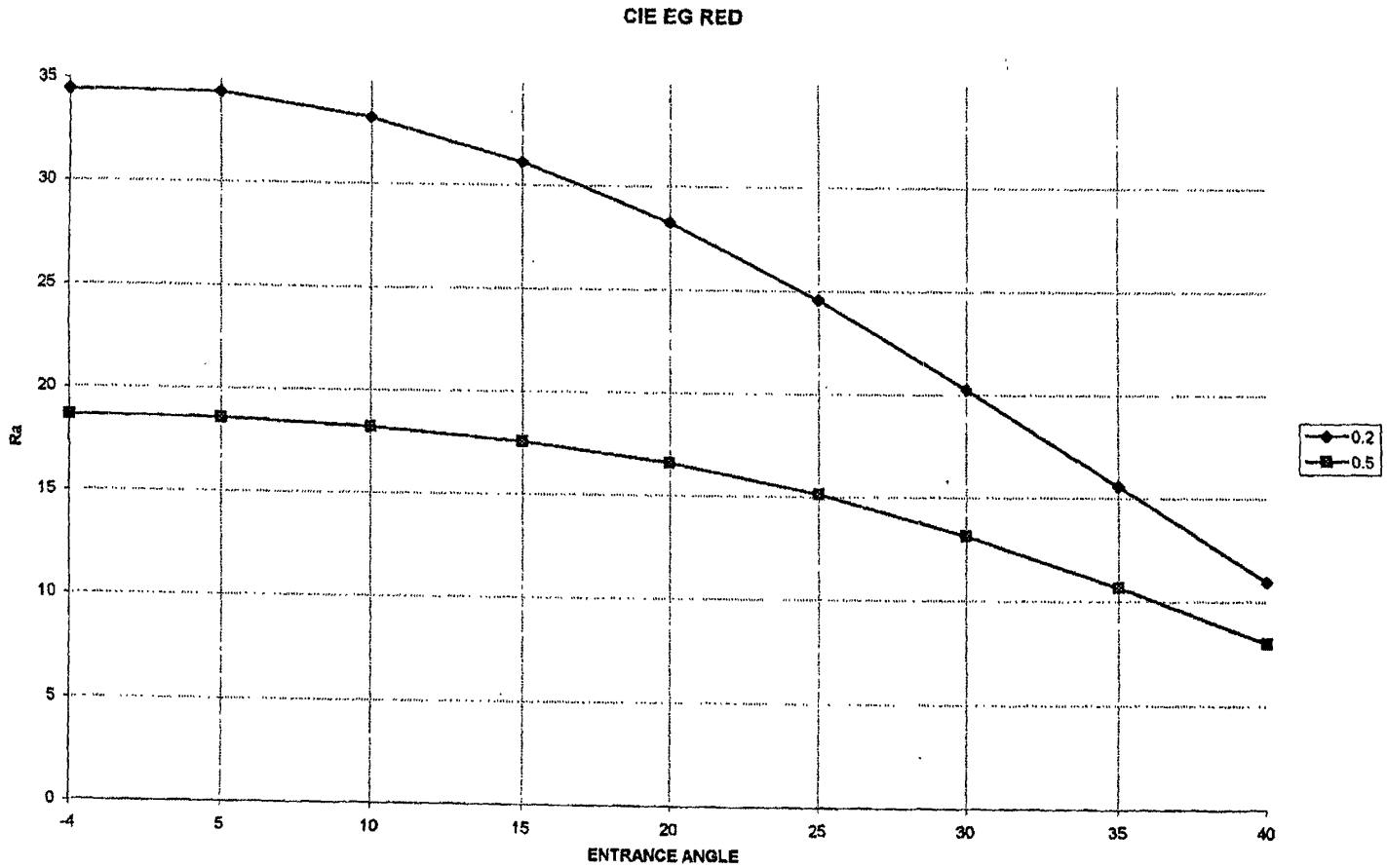
Peter J. Hatzi
FHWA/Safety HSA-1
(202) 366-8095
Federal Highway Administration



RETROREFLECTANCE (R_A) AS A FUNCTION OF OBSERVATION AND ENTRANCE ANGLES



RETROREFLECTANCE (R_A) AS A FUNCTION OF OBSERVATION AND ENTRANCE ANGLES



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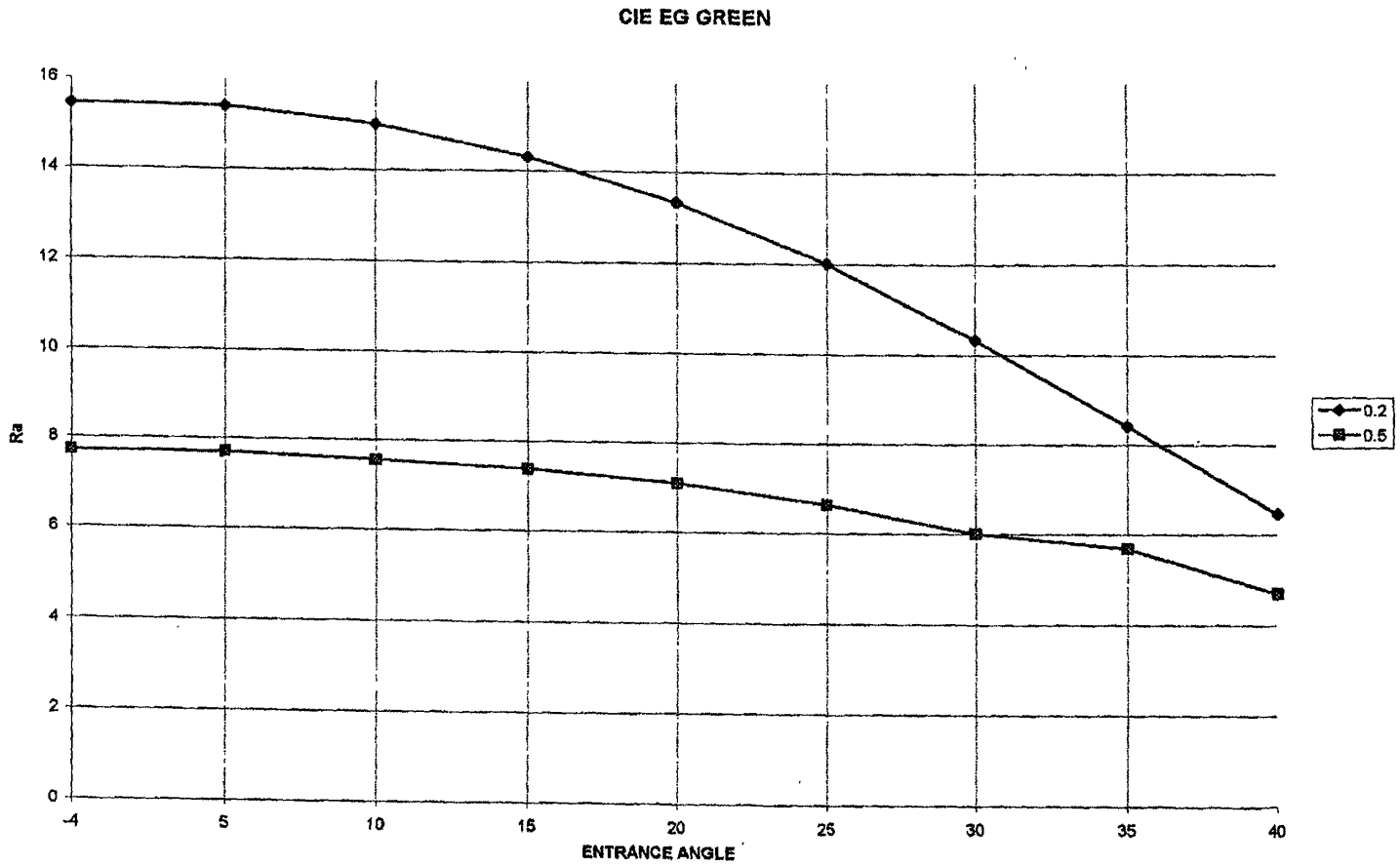

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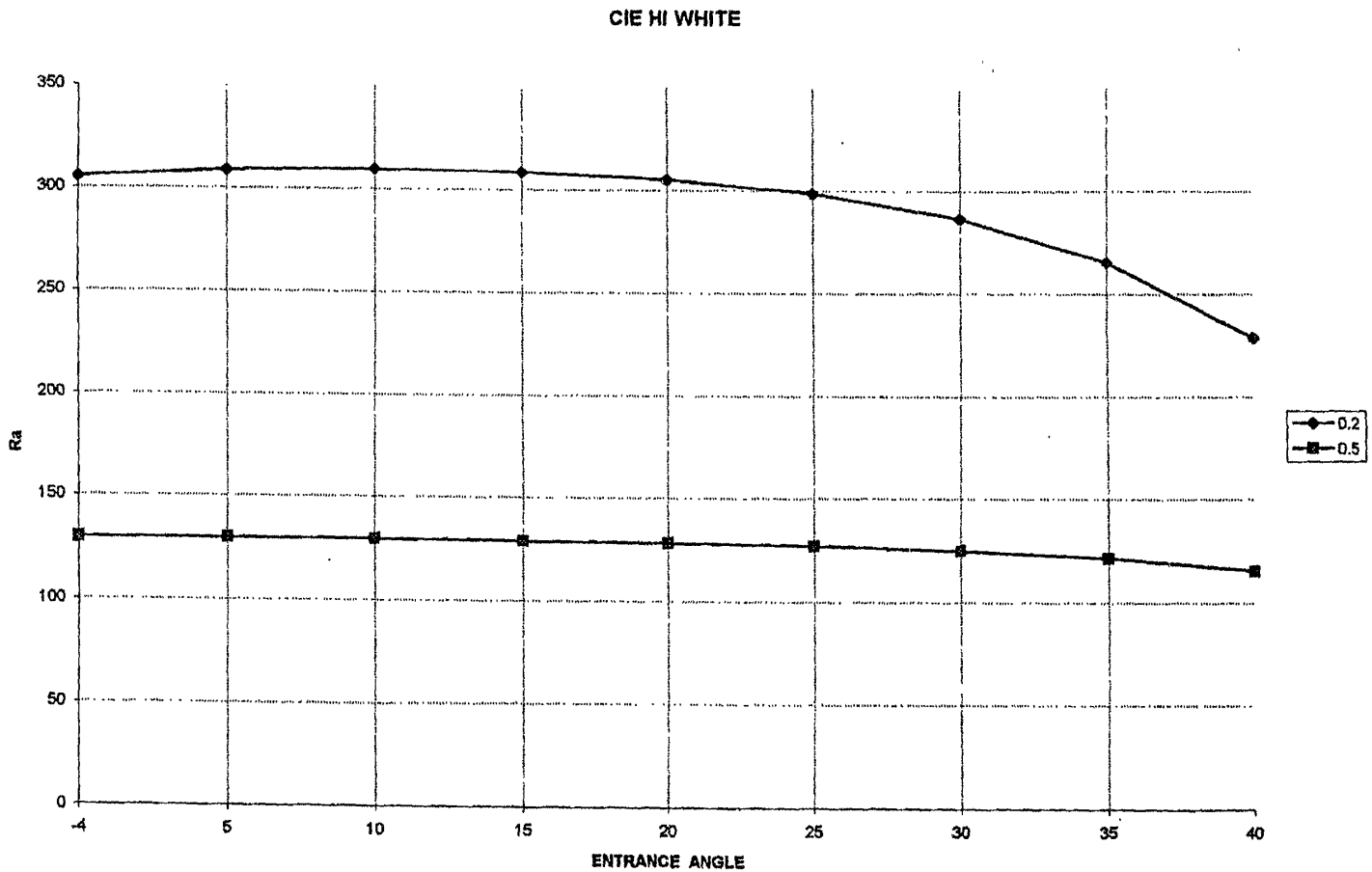
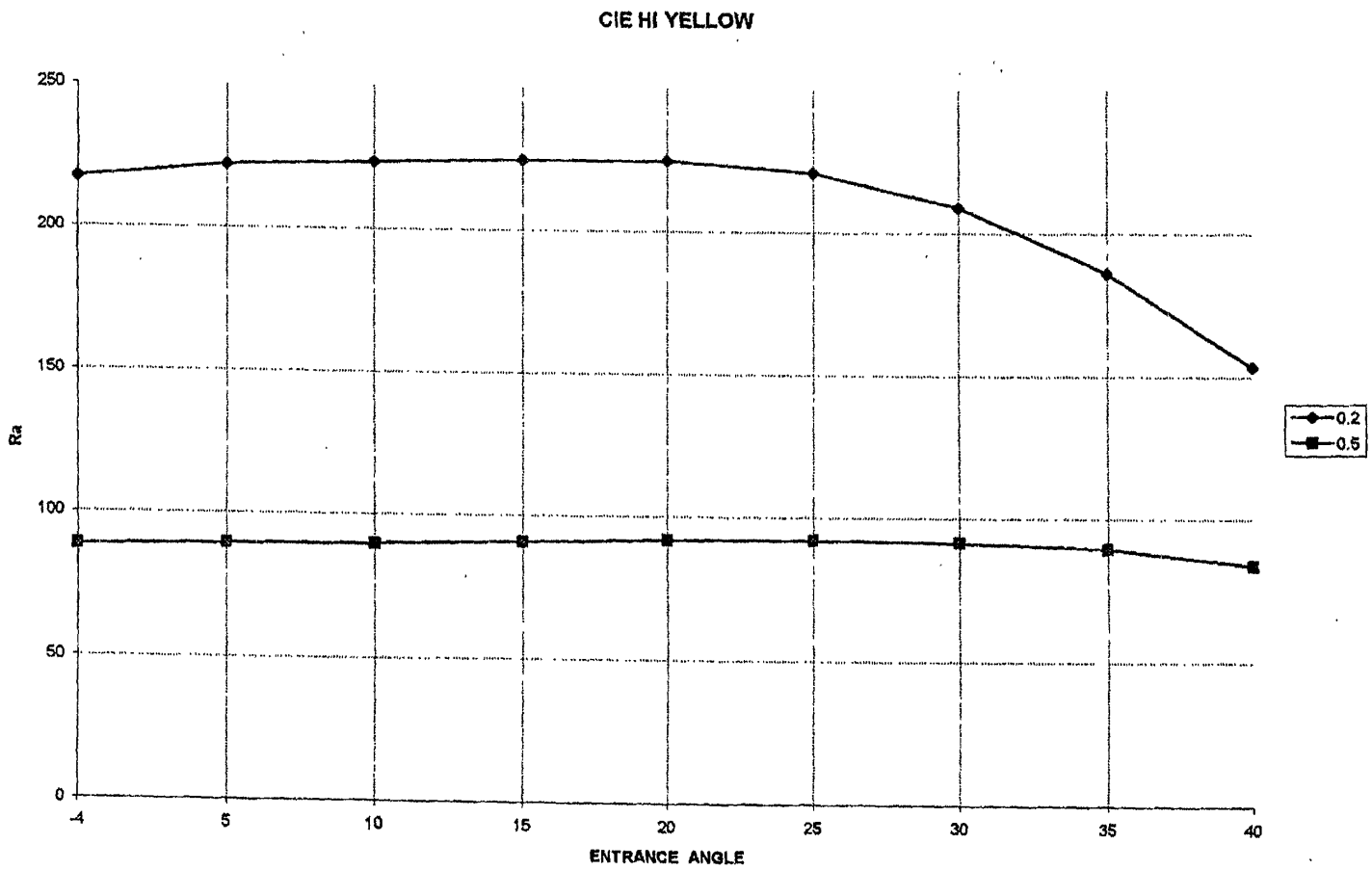


RETROREFLECTANCE (R_A) AS A FUNCTION OF OBSERVATION AND ENTRANCE ANGLES



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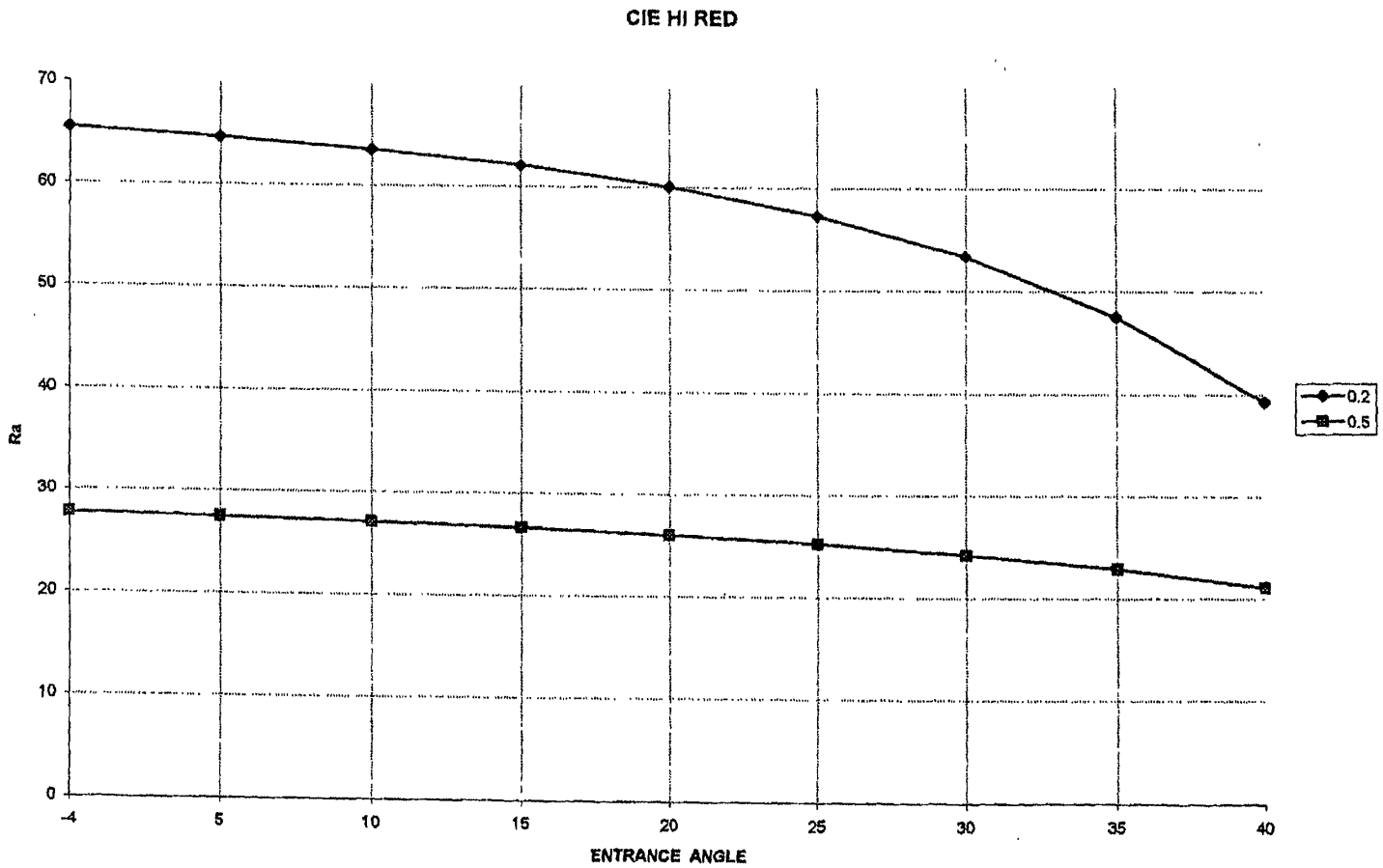

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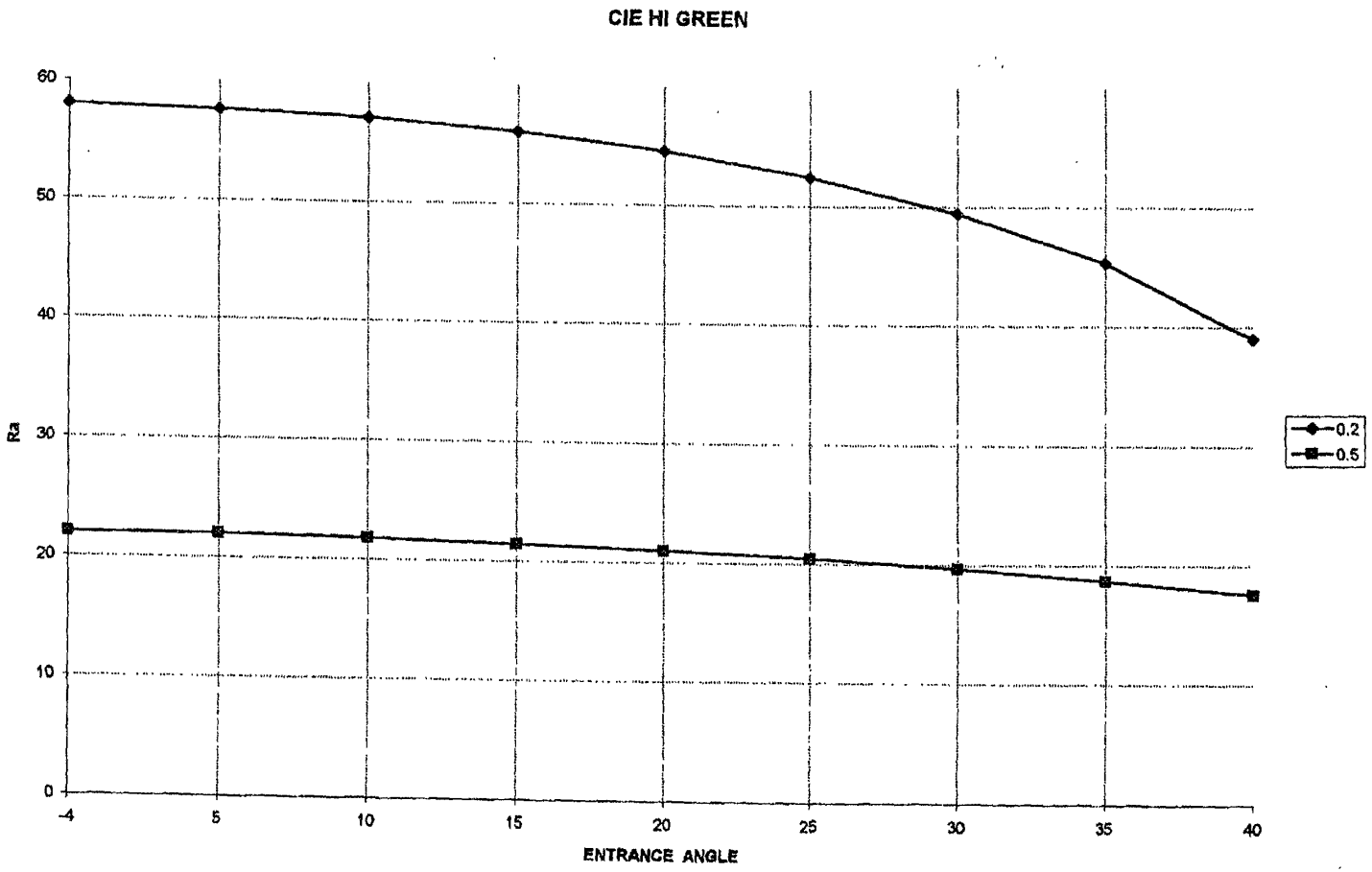

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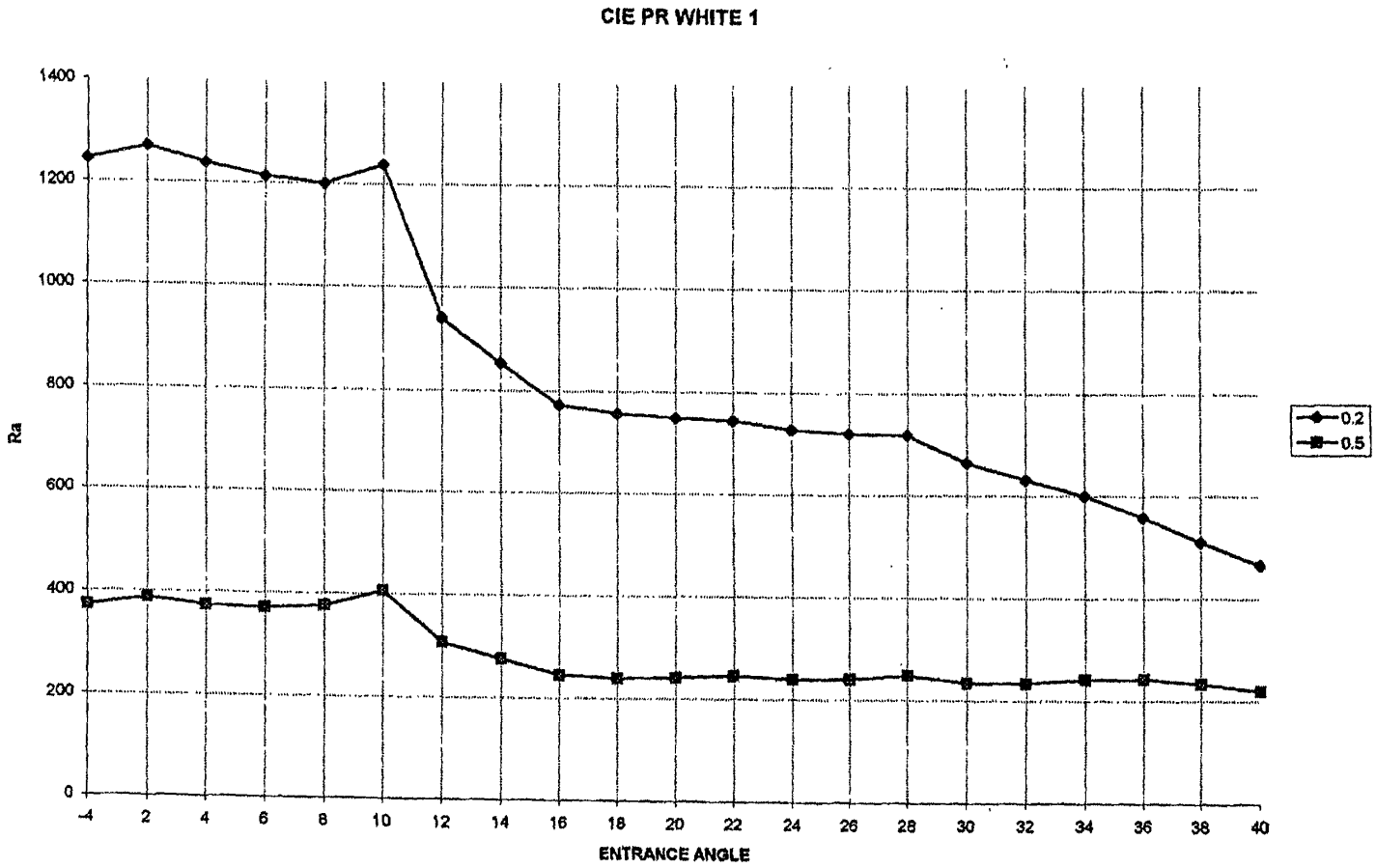

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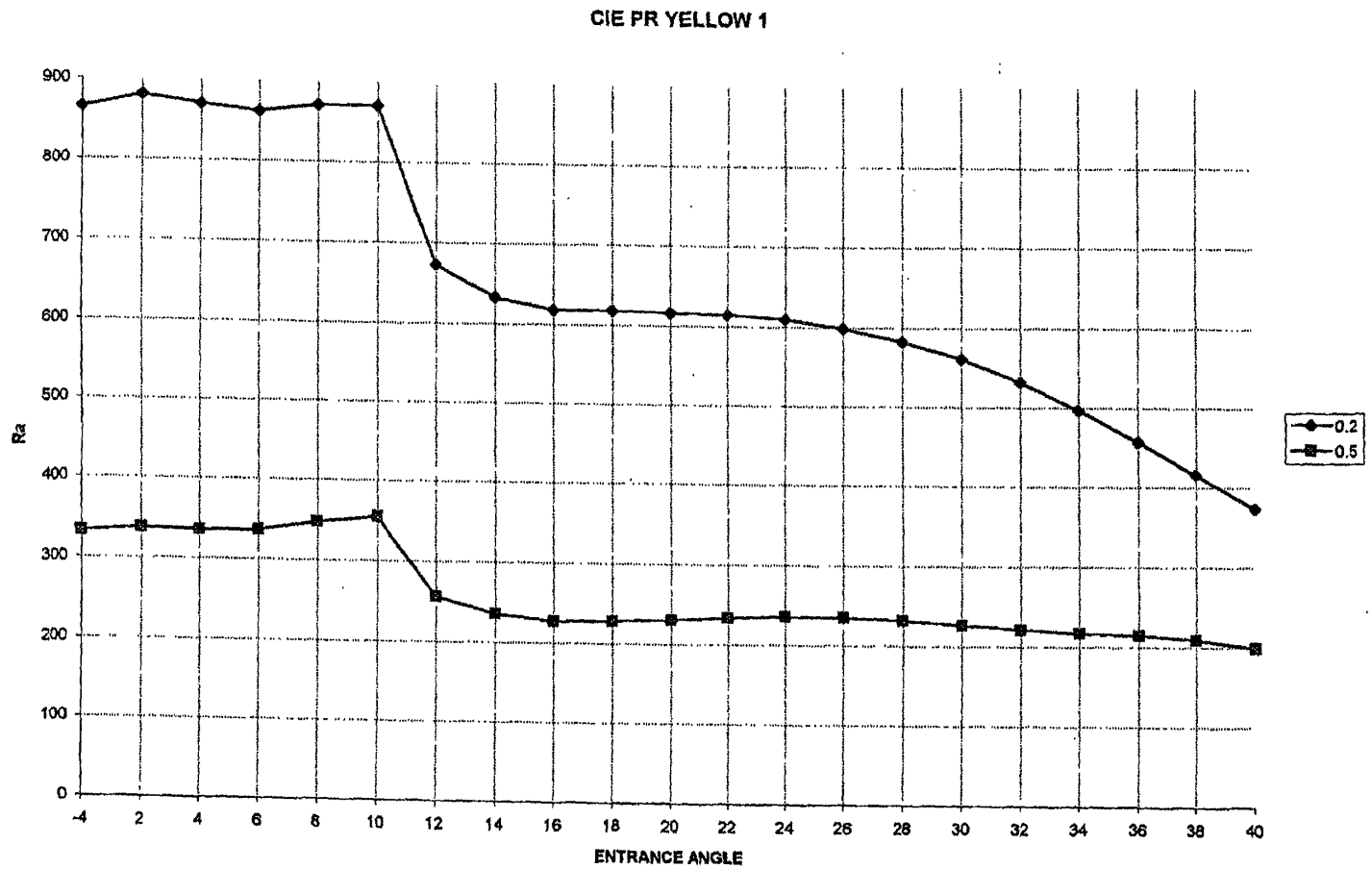

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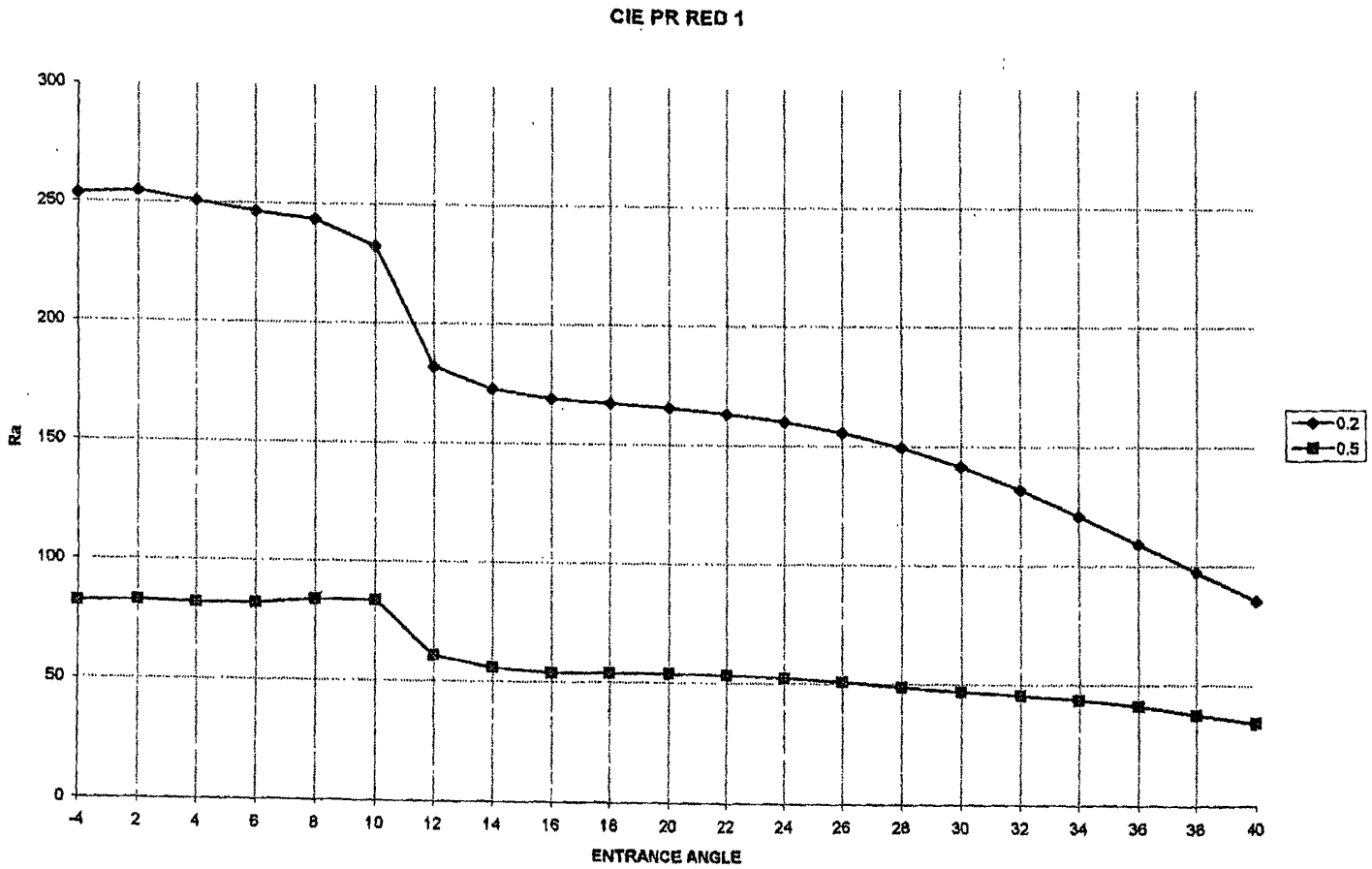
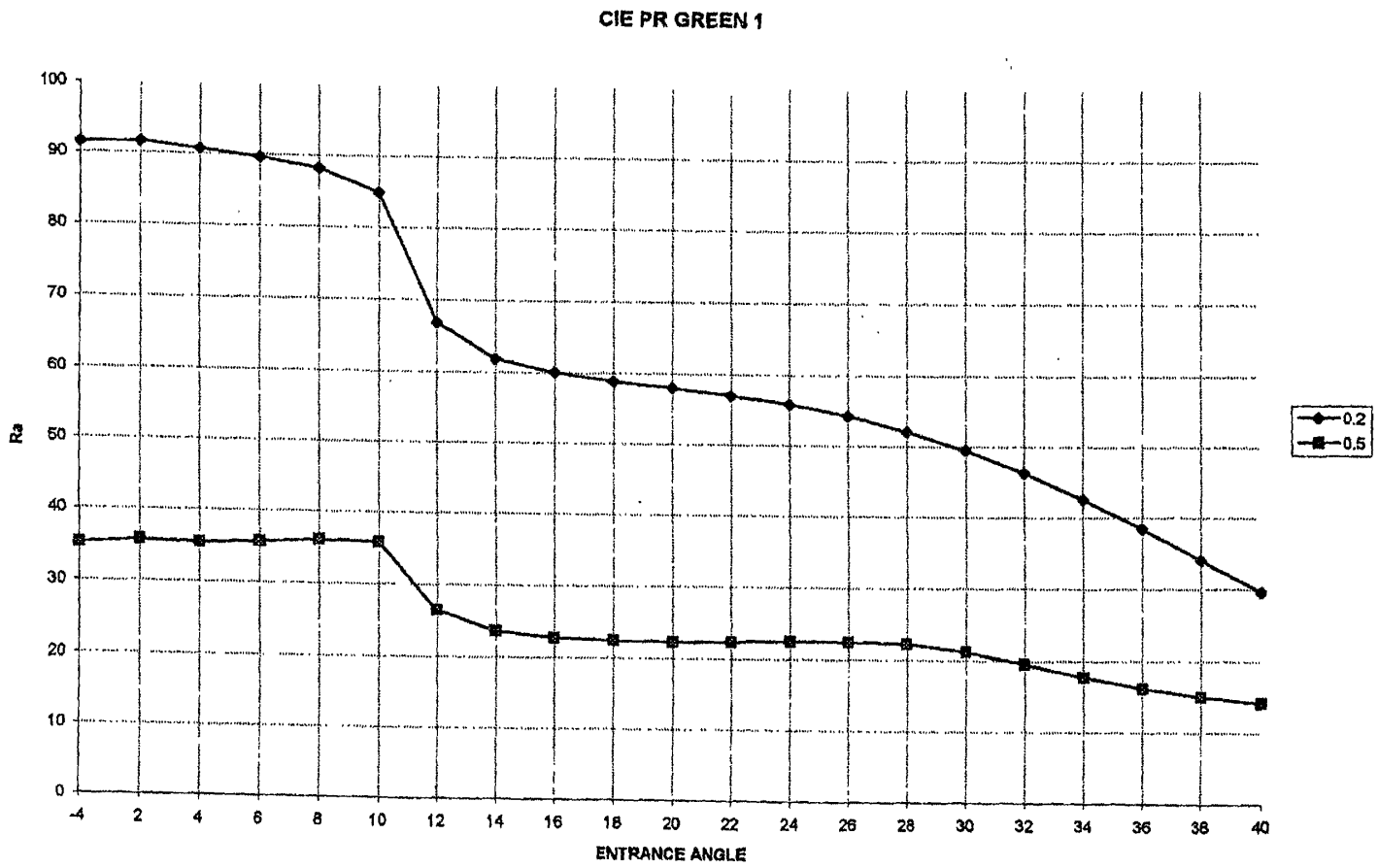


RETROREFLECTANCE (R_A) AS A FUNCTION OF OBSERVATION AND ENTRANCE ANGLES



RETROREFLECTANCE (R_A) AS A FUNCTION OF OBSERVATION AND ENTRANCE ANGLES

Honeywell

INSTALLATION AND OPERATION GUIDE FOR

HIGH INTENSITY OBSTRUCTION LIGHTING SYSTEM

MODEL NO. - SG-60

MANUAL I.D. 81ESG60

SERIAL NO.: _____

WORK ORDER NO.: _____

DATE of MFG.: _____

BY: DON QUACH DATE: 30 JULY 99

APPR.: SEE PAGE 2

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Mobileye v Facet, IPR2024-01110

HISTORY OF REVISIONS

REV	DATE	COMMENT	APPROVAL
A	7/30/99	FIRST RELEASE	D.QUACH
B	02/03.00	ECO 1500, GENERAL REVISION	H.T. SMITH

WARNING!

Modifications to the Power Supply are required for certain applications. Documentation to describe these changes may be found at the end of the manual.

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- 1.2 General Description
- 1.3 Safety Precautions
- 1.4 Specifications

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- 2.2 Mounting and Preparation
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SECTION 1.0 - GENERAL INFORMATION

1.1 Scope

This manual provides information about the installation, operation, and maintenance of the StrobeGuard* High Intensity Obstruction Lighting Systems manufactured by HONEYWELL, 2162 Union Place, Simi Valley, California 93065, tel. (805) 581-5591, FAX (805) 581-5032. The lighting systems described in this manual are FAA types L-856, for use as high intensity aviation obstruction warning systems.

1.2 General Description

The SG-60 Lighting System is a capacitor discharge, xenon flash strobe light system of Flashhead/Power Supply units manufactured to comply with Federal Aviation Administration Advisory Circular 150/5345-43E and hereinafter referred to as Obstruction Warning Lights (OWLs). The master controller system, and an ambient light sensor (photocell) supply the various control functions for all the lights on a single installation with an interconnecting cable (up to 2500 feet in length). System components are shown in Figures 1-1 and 1-2. Modifications may be made to suit different applications.

The flashhead portion of the SG-60 system consists of a flashtube, SGF-60, a reflector and a high voltage trigger transformer. The same enclosure also contains the power supply control circuits (relays, fuses, switches, etc..) for the strobe, a high voltage circuit (power transformer, rectifiers, energy storage capacitors, discharge relays and resistors), a micro-controller controlling flash interval and timing, mode monitoring, and a trigger generator. The Controller, SGC-60, contains flash interval and timing circuits, intensity selection controls, and monitoring all flashhead power supplies as well as status indicators of all flashhead power supplies.

The SGC-60 master controller system consists of a micro-controller for controlling flash interval and timing circuits, intensity selection controls, and monitoring the status of SGF-60. There are relays for alarming and LEDs to display as status indicator. Also attached to the controller system is the ambient light sensor (photocell).

*Registered HONEYWELL Trademark

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1.3 Safety Precautions

The following general safety precautions must be observed during all phases of operation, service, and repair of this equipment. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of this equipment. HONEYWELL assumes no liability for the customer's failure to comply with these requirements.

1. Any interruption of the protective (grounding) conductor (inside or outside the instrument) or disconnecting the protective earth terminal is likely to make this equipment dangerous. Intentional interruption is prohibited.

2. Whenever it is likely that the protection has been impaired, the equipment must be made inoperative and be secured against any unintended operation.

3. Ensure that only fuses with the required rated current and of the specified type (normal blow, time delay, etc.) are used for replacement. The use of repaired fuses and the short-circuiting of fuseholders must be avoided.

4. Adjustments described in the manual are performed with power supplied to the equipment while protective covers are removed. Energy available at many points may, if contacted, result in personal injury.

5. Any adjustment, maintenance, and repair of the opened equipment under voltage should be avoided as much as possible, and when inevitable, should be carried out only by a skilled person who is aware of the hazard involved. Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present. Do not replace components with power cable connected.

6. Do not install substitute parts or perform any unauthorized modification to the equipment.

7. Capacitors inside the equipment may still be charged even if the instrument has been disconnected from its source of supply.

WARNING!

The WARNING sign denotes a hazard. It calls attention to a procedure or pratice which, if not correctly performed or adhered to, could result in injury or loss of life. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

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WARNING!

This system uses lethal voltages in the flashhead power supply. Do not attempt to service or adjust the equipment with line power applied.

Interlock switches are provided in the controller, the flashhead power supply enclosures to interrupt main power to the power supply. These switches are activated when the flashhead power supply door assembly is opened in a conventional manner. No interlock is provided when other means of access are used. Never tamper with (remove, short circuit) the interlocks in any way.

LINE VOLTAGE IS STILL PRESENT WHEN INTERLOCKS ARE ACTIVATED. DISCONNECT POWER BEFORE INSPECTING OR SERVICING.

WARNING!

Flashlamps in this lighting system produce brilliant flashes of light containing some ultraviolet radiation which can result in temporary or permanent eye damage. DO NOT LOOK DIRECTLY AT THE FLASHHEAD WHILE IT IS IN OPERATION.

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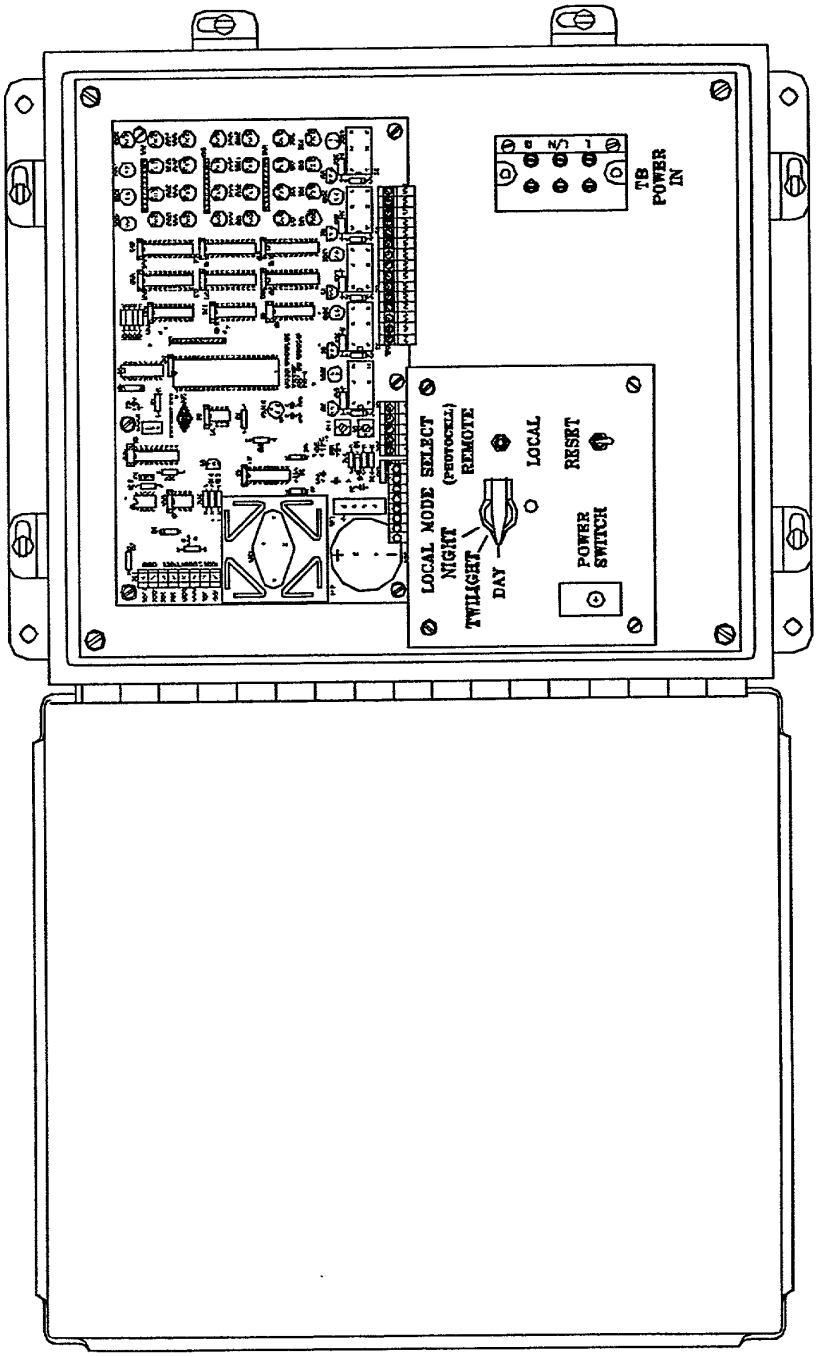

Figure 1-1 Master Controller component Locations
From File 30E00350RevB.dwg

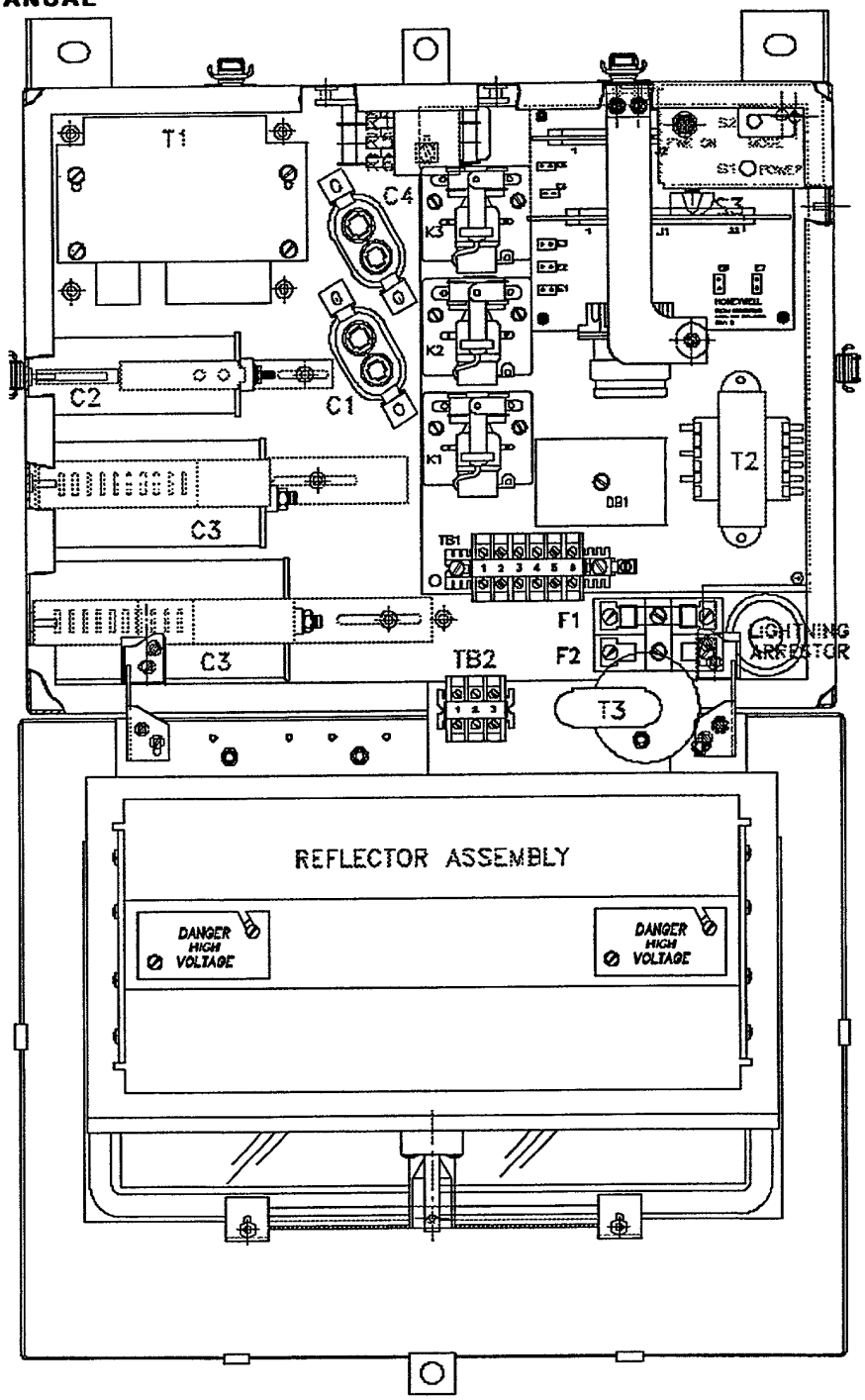

Figure 1-2 Flashhead Component Locations
From File Fig1-2.dwg

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1.4 SPECIFICATIONS

1.4.1 LIGHT OUTPUT

Day Intensity ..... 270,000 ±25% effective candelas, single flash
Twilight Intensity ..... 20,000 ±25% effective candelas, single flash
Night Intensity ..... 2,000 ±25% effective candelas, burst of flashes
Beam Pattern ..... 360° horizontally; 3° min. vertically; max. intensity of 3% of peak @-10°
Flash Rate: Day ..... 40 fpm - single white flash
Twilight ..... 40 fpm - single white flash
Night ..... 40 fpm - white burst of flashes
Master/Slave Operation ..... up to 24 slave units may share a common sync and photocell circuit.

1.4.2 ELECTRICAL INPUT

Master Controller ..... 120,208,240,277,380,480 VAC. 50,60HZ
Flashhead/Power Supply ..... 120,208,240,277,380,480 VAC. 50,60HZ

1.4.3 MECHANICAL PROPERTIES

Flashhead/Power Supply
Weight ..... (37.2 Kg) or 82 pounds
Dimensions ..... 18.88w (479.4) x 15.25h (387.4) x 10.75d (273.1)
Surface Area ..... 1.89 square feet
Wind Load ..... 100 pounds at 150 mph (240kph)

Master Controller
Weight ..... (10.89 Kg) 24 pounds
Dimensions ..... 14w (356) x 12h (305) x 6d (152)

1.4.4 OPERATING ENVIRONMENT

Operating Temperature ..... -55°C to +55°C
Humidity ..... 95% relative humidity

1.4.5 SYSTEM OPERATING STATUS INDICATORS

Neon Lamps ..... Power line and high voltage indicators

Fault Indication
Controller ..... Relay closure, contact ratings of 3A at 120VAC
Controller ..... Flashhead Fail, Relay K1 de-energized and LED (DS29) Off
Controller ..... Photocell Fail, Relay K2 de-energized and LED (DS30) Off
Controller ..... Power Fail, Relay K3 de-energized and LED (DS31) Off

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SECTION 2.0 - INSTALLATION

2.1 Unpacking

Carefully unpack each item and remove any internal packing material from the master controller, and the flashhead/power supply. Examine each item for obvious physical damage. Report any claims to the carrier immediately. Pertinent data such as installation drawings, schematics, interconnection drawings, and operation manuals are included in the power supply carton. The flashtube is packaged inside the flashhead.

2.2 Mounting and Preparation

Detailed drawings for mounting the flashhead/power supply are shown in Figures 2-1 (page 11).

2.2.1 Flashhead/Power Supply SGF-60

Normally the flashhead/power supply is mounted at the uppermost point on the structure. It must be mounted level to assure proper light output. The power supply is connected to its master controller via the cable provided by HONEYWELL. The length of this cable (up to 2500 feet) determines how far from the master controller the flashhead/power supply can be mounted.

The vent hole on the bottom surface of the power supply is covered with a solid plug prior to shipping. Optional screened plugs are furnished separately.

The user should determine that the power line voltage selector, located on the transformer board inside the power supply enclosure is set to the main voltage being used.

2.2.2 Cables and Junction Boxes

The cables shall be properly supported and terminated in the junction boxes per the detailed description provided in the installation kit documentation. Particular attention should be paid to assure that the shields are isolated from the junction box housing. Refer to figure 5-1C for a description of the measurement procedure to assure data line integrity

2.2.3 Master Controller SGC-60

The master controller is connected to power supply(ies) via the cable provided by HONEYWELL. The length of this cable (up to 2500 feet) determines how far from the power supply(ies) the controller can be mounted.

2.2.4 Ambient Light Sensor

The ambient light sensor, when supplied with the system, should be mounted upright, away from artificial light (eg., floodlights), and in a location that will enable its sensor window to have an unobstructed view of the polar sky (eg., pointed north in the northern hemisphere).

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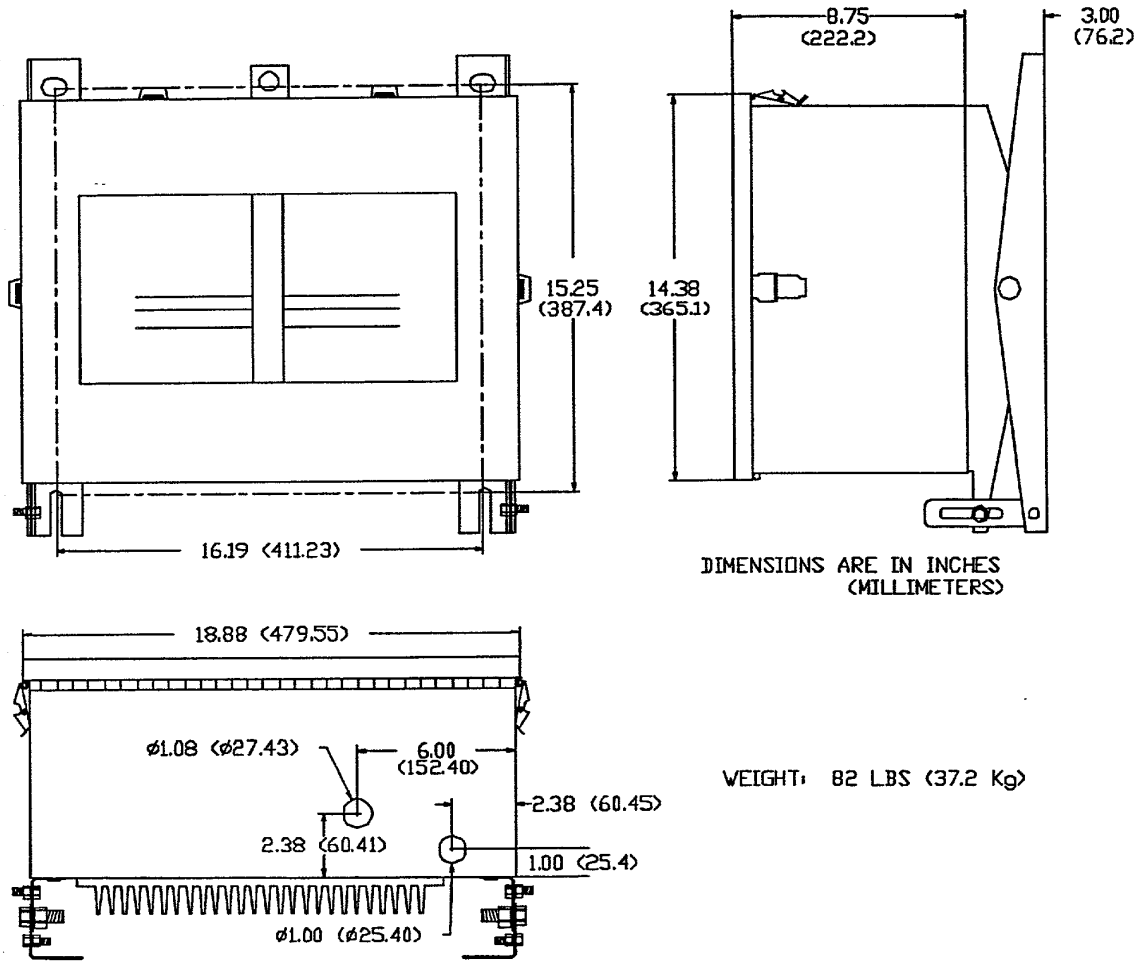

Figure 2-1. OUTLINE AND MOUNTING DIMENSIONS

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2.3 Installation Wiring

STEP1 - Make the interconnects between the master controller and the flashhead/power supply using the HONEYWELL supplied cable (twisted and shielded cable). The wires in this cable are connected from **TB2 in the master controller** to **TB1 in the power supply.**

* **Blue Wire of Cable from TB2 Terminal B in Controller to TB1 Terminal #5 in the power supply**
* **White Wire of Cable from TB2 Terminal A in Controller to TB1 Terminal #4 in the power supply**
* **The shielded wire of Cable from GND Lug of Controller to TB1 Terminal #6 in the power supply**

STEP2 - Make the interconnects between the external photocell and the controller. The wires in this cable are connected to **TB2 in the controller.**

* **White Wire of Cable to TB2 Terminal W, *Chassis ground***
* **Red Wire of Cable to TB2 Terminal R**
* **Black Wire of Cable to TB2 Terminal B**

STEP3 - Make the connections for incoming power to **TB1 in the Master Controller** per *Figure* 2-2 as follows. The wires or cable needed are NOT supplied.

* **Black Wire or conductor of Cable to *TB1* Labled L, Phase or Hi.**
* **White Wire or conductor of Cable to *TB1* Labled L/N, Phase or *Neutral.***
* **Green Wire or conductor of Cable to TB1 Labled G, Ground.**

STEP4 - Make the connections for incoming power to **TB1 in the Flashhead/Power Supply** per *Figure 2-2* as follows. The wires or cable needed are NOT supplied.

* **Black Wire or conductor of Cable to *TB1* Terminal #2, Phase or Hi.**
* **White Wire or conductor of Cable to *TB1* Terminal #3, Phase or Neutral.**
* **Green Wire or conductor of Cable to *TB1* Terminal #1, Equip. GND.**

STEP5 - For structures with two (2) or more systems make the interconnects between the master controller and the power supply (s) using the HONEYWELL supplied cable (twisted and shielded cable). The wires in this cable are connected to) **TB1 in the Power Supply(s) Terminal #4, #5 and #6** as described in *STEP1*.

2.4 Final Check

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Before applying power to the equipment, check all relays and printed circuit boards to ensure that they are properly seated in their sockets. Check to ensure that any user-installed wiring does not interfere with relay operation when covers are closed.

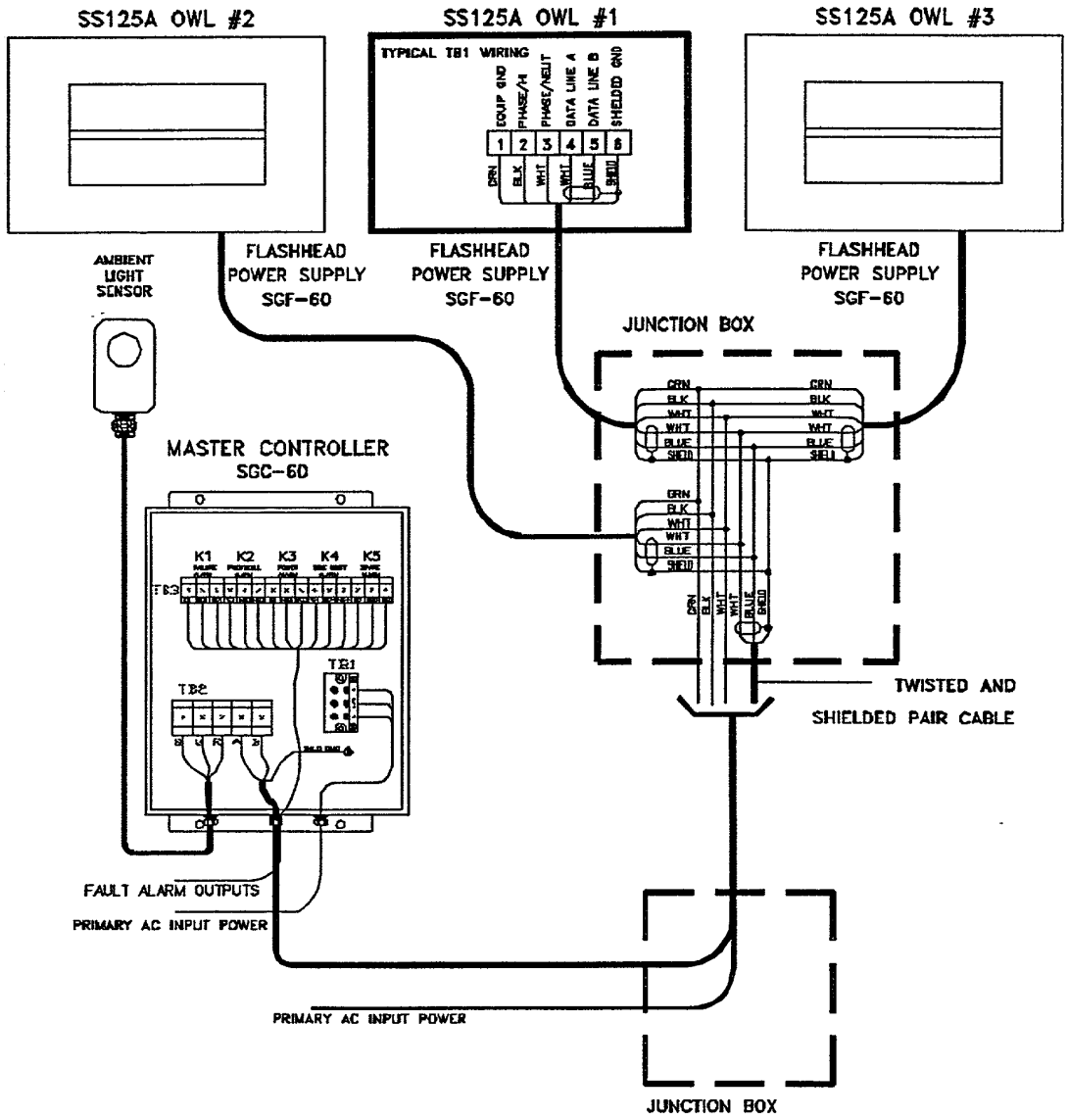

Figure 2-2, Installation Wiring For Typical Lighting System.

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SECTION 3.0 - OPERATION

3.1 Operating Considerations

The standard main power input to the SGC-60 Controller is dependent on the voltage setting of the transformer.

The SGF-60 Obstruction Warning Light (OWL), as standard, may be operated at various voltages dependent on the setting of the transformer. The source of power may be the same as that supplied to the Controller.

3.2 Controls and Indicators

This section contains descriptive information and figures to locate and identify the operating controls and indicators of the High Intensity Obstruction Lighting System.

3.2.1 SGC-60 Master Controller (Figure 1-1)

On/Off Power Switch: Toggle switch that interrupts input power.

Reset Switch: Momentary push-button resets the system and relay when a fault has been repaired.

Mode Switch (Remote/Local): Two-pole, two-position toggle switch that permits manual (local) selection of the intensity levels with switch or automatic (Remote Photocell) operation through the Ambient Light Sensor.

Local Intensity Select Switch: Two-pole, three-position rotary switch that allows manual selection of three light intensities of the system (DAY/high, TWILIGHT/intermediate, and NIGHT/low) when, Mode Switch, switch is in the local position.

Failure Indicators: Bi-color LEDs. One LED for each light in the system. The LED that corresponding to the light will change from green to red when that light experiences failure.

DS25 Indicator: Illuminates only when the Controller is in the DAY mode.

DS26 Indicator: Illuminates only when the Controller is in the TWILIGHT mode.

DS27 Indicator: Illuminates only when the Controller is in the NIGHT mode.

DS28 Indicator: Bi-color LED. It is green in normal operation, and turns red when photocell fails.

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TB Main Terminal Block: For main power input.

TB1 DC Terminal Block: This terminal block is on the board. It is the main power input for the board.

TB2 Data and Photocell Terminal Block: For data line and Ambient Light Sensor connections.

TB3 Alarm Terminal Block: For remote alarming.

3.2.2 SGF-60 Obstruction Warning Light (Figure 1-2)

REF. COMPONENT

S1 Interlock Switch: When the OWL door is opened, S1 interrupts the control power to relay K1, causing the high voltage to be shut off and the energy storage capacitors to discharge.

S2 Interlock Switch: Transfers intensity select lines from remote operation (by SGC-60 Controller) to local control by switch S3 when the OWL door is opened.

S3 Test Switch: Allows local intensity selection for the individual OWL of interest, while not affecting the operation of any other light in the system.

F1 Main Power Line Fuse: Value varies with input line voltage. Manufacturer will supply the correct fuse for the customer.

TB1 Main Terminal Block: For power input and control functions to the system.

3.3 Normal Operation

After the system has been wired according to the instructions in section 2, it is ready for normal operation. When the cover of the flashhead / power supply (SGF-60)is closed so that the interlock switch is engaged and power is applied, the system will begin to operate randomly. However, when the cover of the controller (SGC-60) is closed, the system will begin to synchronize. . If the controller is set to remote, and there is sufficient light and the ambient light sensor is mounted correctly, the system will automatically switch to the correct mode after a 30-second delay. The delay protects against unwarranted switching due to momentary changes in the light reaching the sensor.

If the system is not operating correctly, review the installation instructions in Section 2 or consult the troubleshooting information in Section 5.

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SECTION 4.0 - PRINCIPLES OF OPERATION

4.1 Overall Description

The Type L-856 and L-857, High Intensity Obstruction Lighting System meets the requirements of the FAA. All the lights at a given installation flash synchronously.

The AC main power input to the flashhead/power supply is converted to approximately 2000 VDC to bias the flashtubes and to charge the energy storage capacitors. The ambient light sensor sends control signals to the master controller. The master controller then processes the signals and transmits a string of data to the power supply to automatically change the intensity of the flashhead.

The main power to the flashhead/power supply is applied to the control and logic circuitry, thereby activating relays which determine the intensity of the flashhead. Logic circuits in the flashhead/power supply receive its command signals from the master controller. However, in the absence of command signals, the power supply will generate its own timing signal which controls the rate of flash.

Test switches located on the switch board allow the system to operate in either day, twilight or night mode. These switches will change to **remote** when the flashhead door is closed . See figure 1-2, (page 8).

4.2 Functional Description of Subsystems

4.2.1 Controller, and Flashhead/Power Supply

The main AC input power to the master controller is transformed to 5VDC to drive relays and LEDs as well as all the chips on the master controller board. The master controller sends out all the necessary control commands to the flashhead/power supply. The flashhead/power supply main AC input is transformed to high voltage DC and stored in capacitors. The flashtube, in parallel with the capacitors, is fired by the trigger circuit. This discharges the capacitors, producing a flash of light. The intensity of the light is varied by changing the capacity for energy stored between flashes. The flashtube extinguishes when the current from the capacitors is too low to support the arc. The flashhead/power supply short circuit current is set below the minimum tube current to prevent continuous conduction. The capacitors then recharge for the next flash.

Input power is applied to the primary of the ferroresonant power transformer (T1) when the flashhead and cover interlocks are closed. The high voltage output of T1 is rectified and charges the energy storage capacitors.

In the day mode (high intensity), normal operation has the interlock relay (K3) energized while the mode relay (K2) is de-energized and relay (K1) is de-energized. This keeps capacitors C1, C2, and C3 in the high energy circuit. With this amount of capacitance in the circuit and DC voltage provided, sufficient energy is discharged through flashtube V1, will yield an effective intensity of approximately 270,000 candelas.

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In the twilight mode (intermediate intensity), the mode relay (K2) is energized and relay (K3) is de-energized. When K2 is energized, its contacts remove C3 from the circuit and prevent it from being charged. Capacitors C1 and C2 are still in the high energy circuit and their energy, discharged through flashtube V1, will yield an effective intensity of approximately 20,000 candelas.

In the night mode (low intensity), the mode relay (K2) is energized as well as relay (K3). When K3 is energized, its contacts will remove C2 from the circuit to the flashtube, circuit and prevent it from being charged. Capacitor C1 is the only one still in the high energy circuit. This provides the energy required to produce the effective intensity of approximately 2000 candelas.

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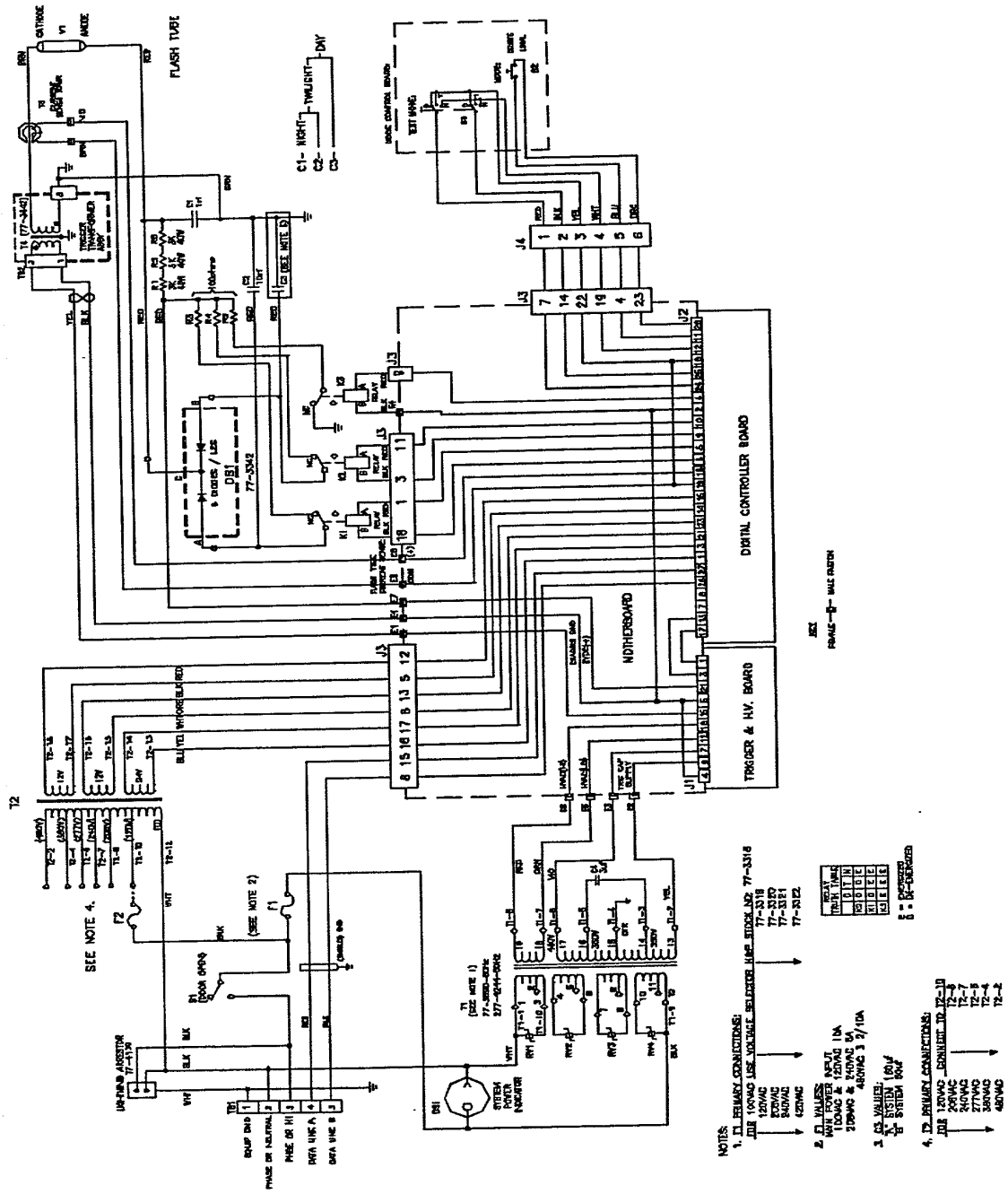

Figure 4-1, Schematic, SG-60

4.2.1.1 Master Controller Printed Circuit Board

The function of the master controller is to provide command to the flashhead power supply, display system status and alarm system failure. The master controller board consists of a micro-controller, relays, and LEDs as shown in Figure 4-2a.

The input power is supplied by the transformer to the master controller board TB1. The voltage is then rectified by (DB1), filtered by (C19), and regulated by (VR1). The regulated 5VDC is used throughout the board.

The ambient light sensor sends out a resistive value to TB2 of the master controller board. The resistive value goes through U6, a Pic, which is then converted to digital signals for input to the micro-controller. The digital signals are processed and modulated into a string of code which then sends out serially to U2 Differential line transceiver which is then transmitted to all flashhead power supplies via a twisted pair data line.

The master controller transmits a string of data every 1.5 sec. to all flashhead power supplies. Within the string of data, there is the address of a flashhead power supply. Only the flashhead power supply that contains this address can respond, the rest will not respond. The master controller expects the addressed flashhead power supply to respond every time it transmits a string of data. Failure to respond will be considered as a bad flashhead power supply.

The master controller is constantly monitoring and updating all the flashhead power supplies. With a fully loaded system, the master controller can monitor and identify 1 to 24 flashhead power supplies. The 24 bicolor LEDs will be green in normal operation. However, if one of the flashhead power supplies is bad its corresponding LED changes from green to red and a green LED (DS29) from on to off and at the same time de-energizes an alarm relay (K1).

The master controller is constantly updating the mode to all flashhead power supplies, thus if the ambient light sensor is damaged, the master controller will issue a photocell alarm failure. That is, photocell LED indicator (DS28) changes from green to red and photocell relay (K2) is de-energized and turns (DS30) off. At the same time the master controller sends a default mode (DAY) to all flashhead power supplies.

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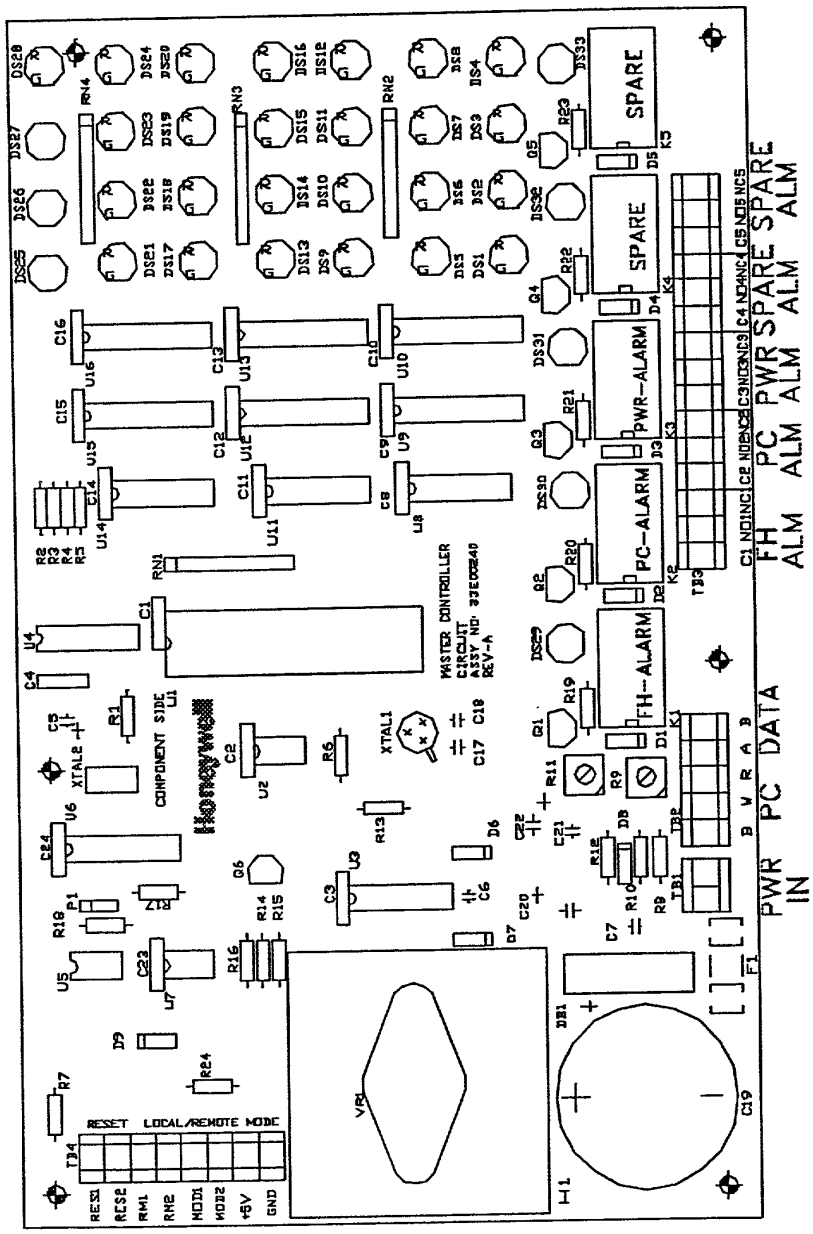

Figure 4-2a, Master Controller Board

HIGH INTENSITY OBSTRUCTION LIGHTING SYSTEM

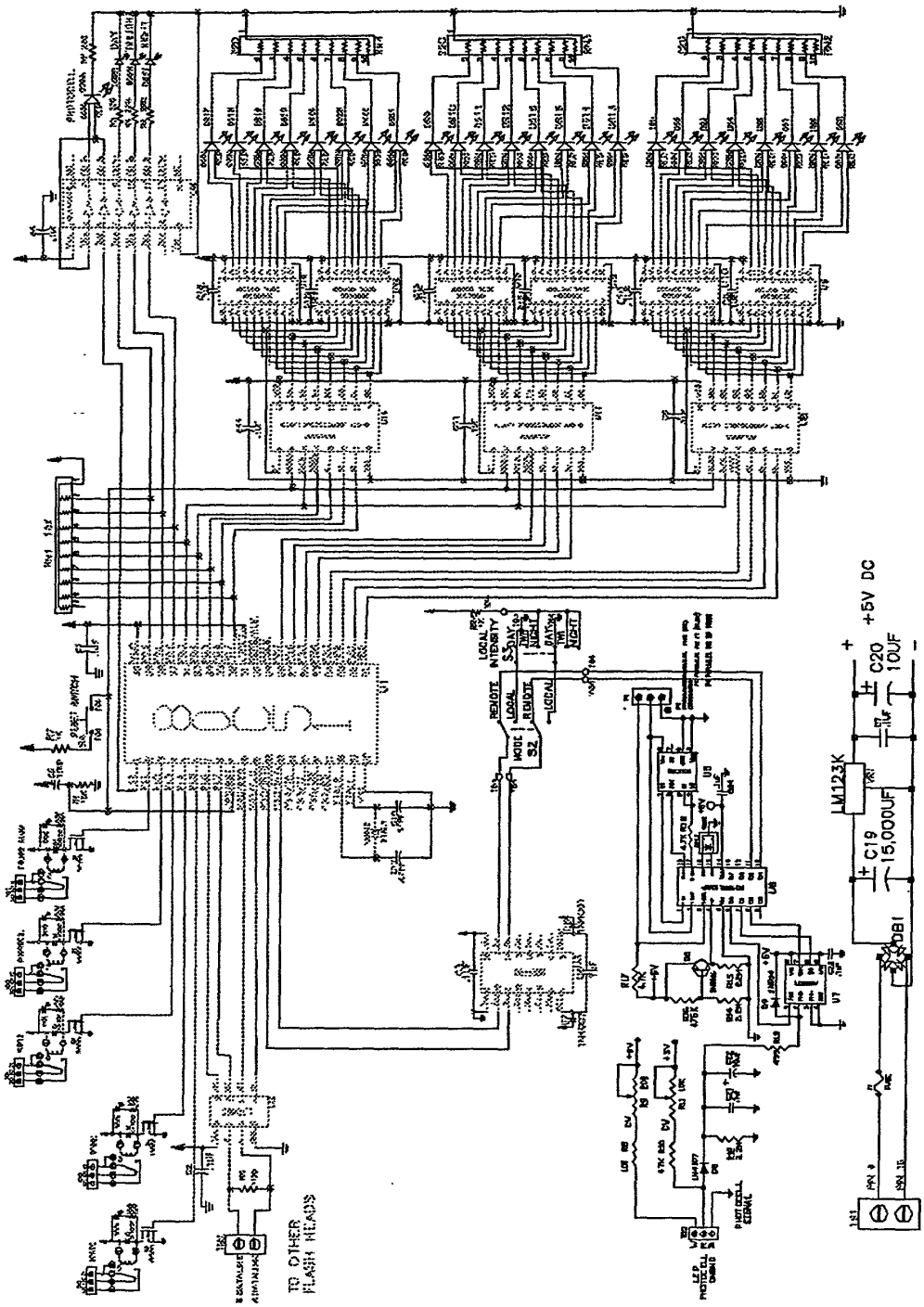

Figure 4-2b, Master Controller Board Schematic
From File 36E00240RevB.dwg

4.2.1.2 Flashhead Controller Printed Circuit Board

The flashhead controller printed circuit board consists of three logical sections: High Voltage, Trigger Control, and Digital Control.

High Voltage

The high voltage section consists of a three-diode-per-leg bridge and two 3-diode circuits. The high voltage AC from the ferroresonant power transformer T1 pins T1-7 and T1-8to flashhead Motherboard pins E5 and E6, respectively. This high AC voltage is full wave bridge rectified by the bridge circuits. This in turn is fed to E7 (pos.) and E4 (gnd.). Voltage divider circuit R6 through R10, with a series neon lamp, is connected to the bridge output. DS1 lights whenever high voltage is present.

WARNING!

HIGH VOLTAGE is still on the energy storage capacitors when this indicator is lit!

The bridge network is used for a night mode energy capacitor charging. In night mode, when full charge is reached, the voltage is nominally 2 KV DC on C1. In the night mode burst operation, only C1 is being charged. All triggering occurs at zero crossing of the HV AC. The night capacitor (C1) recharge begins with current from the transformer (T1). This completes the charge cycle for one flash in a burst. In AC-powered systems, night flashing occurs at twice the line frequency rate. The first few flashes in the burst establishes the steady state operating conditions of the circuit for the remaining flashes of the burst. At the full charge, the voltage on C1 is normally 2 KV DC.

Trigger Control

The trigger control section consists of a trigger capacitor (C4), SCR (Q4), unijunction transistor (Q3), and line driver transformer. The function of the Trigger Control is to provide a synchronized trigger pulse to flashtube V1, singularly in the DAY and TWILIGHT modes, and in a "burst" in the NIGHT mode.

Line voltage coming into T2 is stepped down to 24V with respect to chassis ground. The 24 volts is half wave rectified and filtered by C7 and regulated by VR2. The regulated 15 volts provides the power to SCR (Q4) gate drive.

The trigger circuit energy is derived from terminals T1-6 and T1-2 of T1 through a rectifier circuit in the Trigger Control section. This trigger energy is stored in a 0.5μF capacitor C4 whose charge path is through the primary of the high voltage trigger transformer T2 to ground.

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The signal coming out of optoisolator U10 pin 5 is a pulse. This pulse will stay low for 500µsec. which is long enough to cause CR1 to conduct. This in turn forces the gate of Q3 below the anode of Q3 triggering Q3 - a "snap-action" unijunction switch. A fast rising current is developed, driving the gate of Q4. SCR Q4 then turns on, switching C4, charged to 450 volts, into the primary of the series trigger transformer, located on the flashtube assembly. This series trigger transformer steps the pulse to approximately 15 KV, flashing the flashtube (V1). The recharge current for the 0.5µF capacitor is limited by a series resistor to a value below the hold in current of the SCR so that it turns off, allowing the 0.5µF capacitor to charge again in time for the next flash.

For a burst in night mode, there will be multiple pulses coming out of optoisolator. The pulses are separated by half-cycle of the line frequency; for example, if 60HZ is the line frequency, then 8.33msec would be the separation between each pulse. Also, the pulse only occurs at zero crossing.

Digital Control

This section consists of a micro-controller, current sensor and logical circuits. The function of this section is to generate a sync pulse for the trigger control circuit, to provide the correct mode, communicate to the controller and detect zero-crossing.

The AC main power input to the flashhead motherboard J3 is converted to 5VDC. The 120VAC input to the primary of T2, located on the board, is stepped down to approximately 18VAC. One secondary winding of T2 is rectified by DB1 and voltage divided by R6 and R8, then goes to pin 1 of U4 for zero-crossing detection. The other secondary winding of T1 is rectified by DB2, filtered by C11 and regulated by VR2 to 5VDC which is then used throughout the board.

The micro-controller (U1) is the main processing unit of the flashhead power supply. It receives the information from the master controller via serial link. It gets its zero-detect from microprocessor supervisory circuit (U4), and it senses the flashhead current from the current sensor (T3) and 8-bit A/D converters (U5). The micro-controller receives the local mode status from Hex contact bounce eliminator (U3). Within 1.5 seconds, all information must be processed, as well as commands sent out.

The micro-controller receives the sync and mode status from the master controller via the data line. The information comes as a string of code to TB1 then to the transceiver (U2) before it reaches the micro-controller for processing. After the micro-controller processes the data it received, it then switches the relays, and sends out one pulse (in day) or multiple pulses (in night), according to the commands. The micro-controller sends out a pulse only when it receives a zero-detect signal from U4 pin 6. The pulse coming out from pin 22 of (U1) goes to optoisolator pin 2 (U7) which is optically linked to the trigger circuit.

Failure to receive a string of code from the master controller will activate the micro-controller to use its own 1.5 seconds internal clock. When this happens, the micro-controller will switch to a default mode, which is day mode and alarming will occur also.

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Flashtube current is sensed by a current transformer (T2) located in the ground side, or cathode return side of the capacitor bank. Whenever the flashlamp fires, a pulse current appears at E8 (+) and E9 (-) ground, which rapidly charges C14 to about 7.5 volts. This voltage is divided down by R43 and R44 to about 5 volts and clipped by D10 and D11 before going to U5 pin 3 for conversion.

The voltage on C14 will decay with a time constant of about 68msec. This is long enough for the A/D converter to convert the analog signal to an 8-bit digital signal for the micro-controller to process.

System failure: (Alarms)

Fail detection during any mode operation causes the micro-controller to transmit a fault code to the master controller so alarming can occur. The fault alarm relay K1, located in the master controller board, will de-energize. The fault alarm will continue until the system has been serviced. The fault relay will close whenever normal operation is restored.

Default DAY operation occurs when photocell fails. The failure of the photocell will cause the master controller to transmit a default code to all the flashhead power supplies. Once the flashhead power supply receives the default code, it will turn to DAY mode operation. The DAY mode operation continues to run 24-hours a day until the system has been serviced.

Beside providing default code to all flashhead power supplies, the master controller also provides photocell failure alarm relay K2, and photocell failure LED. The alarm relay K2, located on the master controller board, will de-energize and the green LED (DS30) will turn off. The bi-color photocell LED will switch from green to red.

The flashhead power supply will default to day mode when there is a failure in any operation mode, or communication failure. When mode failure occurs, the flashhead power supply will send a failure data to the master controller so alarming can occur accordingly. When communication failure occurs, the master controller will generate an alarm.

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SECTION 5.0 - TROUBLESHOOTING (Figures 5-1a and b)

WARNING!

1. Always turn off power when changing any component or printed circuit board.
2. High voltage is present in the flashhead power supply. Do not cheat the interlocks.
3. Do not put hands or tools in the flashhead power supply until the neon lamp on the high voltage board is extinguished.
4. Do not look directly into the flashhead at close range when it is flashing.
5. Replace components in the order stated, keeping track of those replaced.
6. The following procedures presume that all fuses, interlocks, and controls are functioning properly.
7. The components and assemblies in this system were designed by HONEYWELL to handle the high voltages which are present. We do not recommend substituting components or assemblies which might be available through other vendors.

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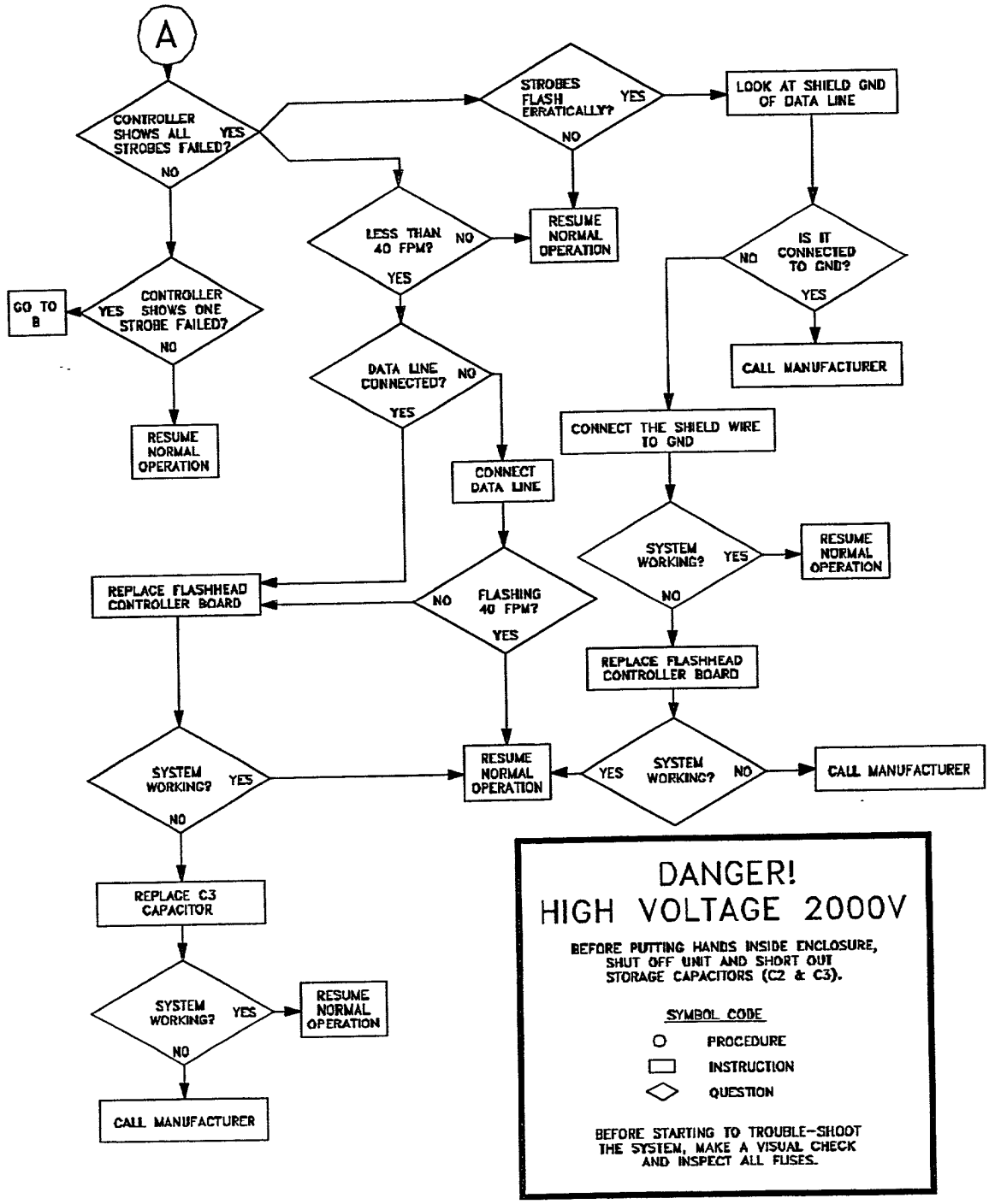

Figure 5-1a. TROUBLE-SHOOTING PROCEDURE

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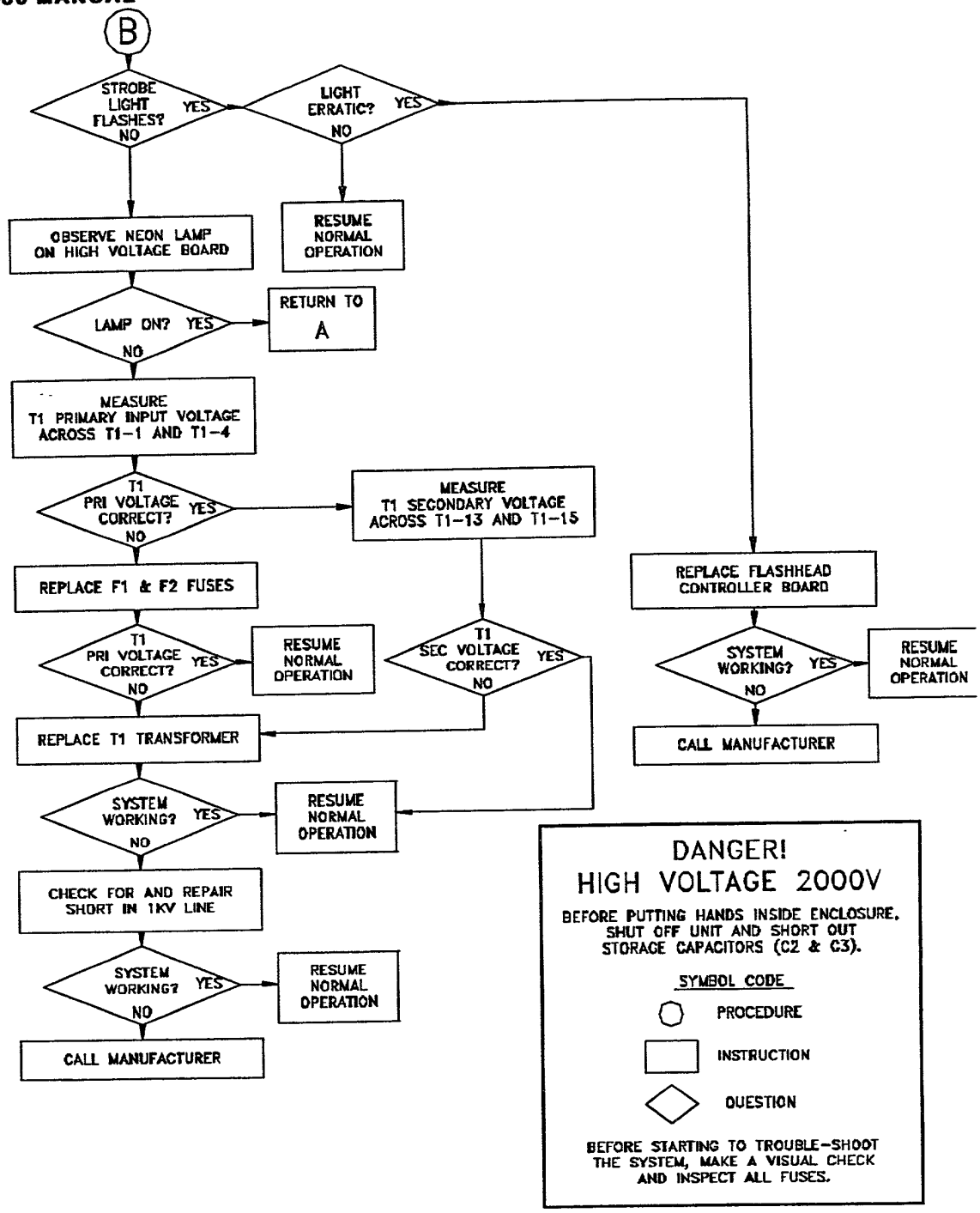

Figure 5-1b. TROUBLE-SHOOTING PROCEDURE

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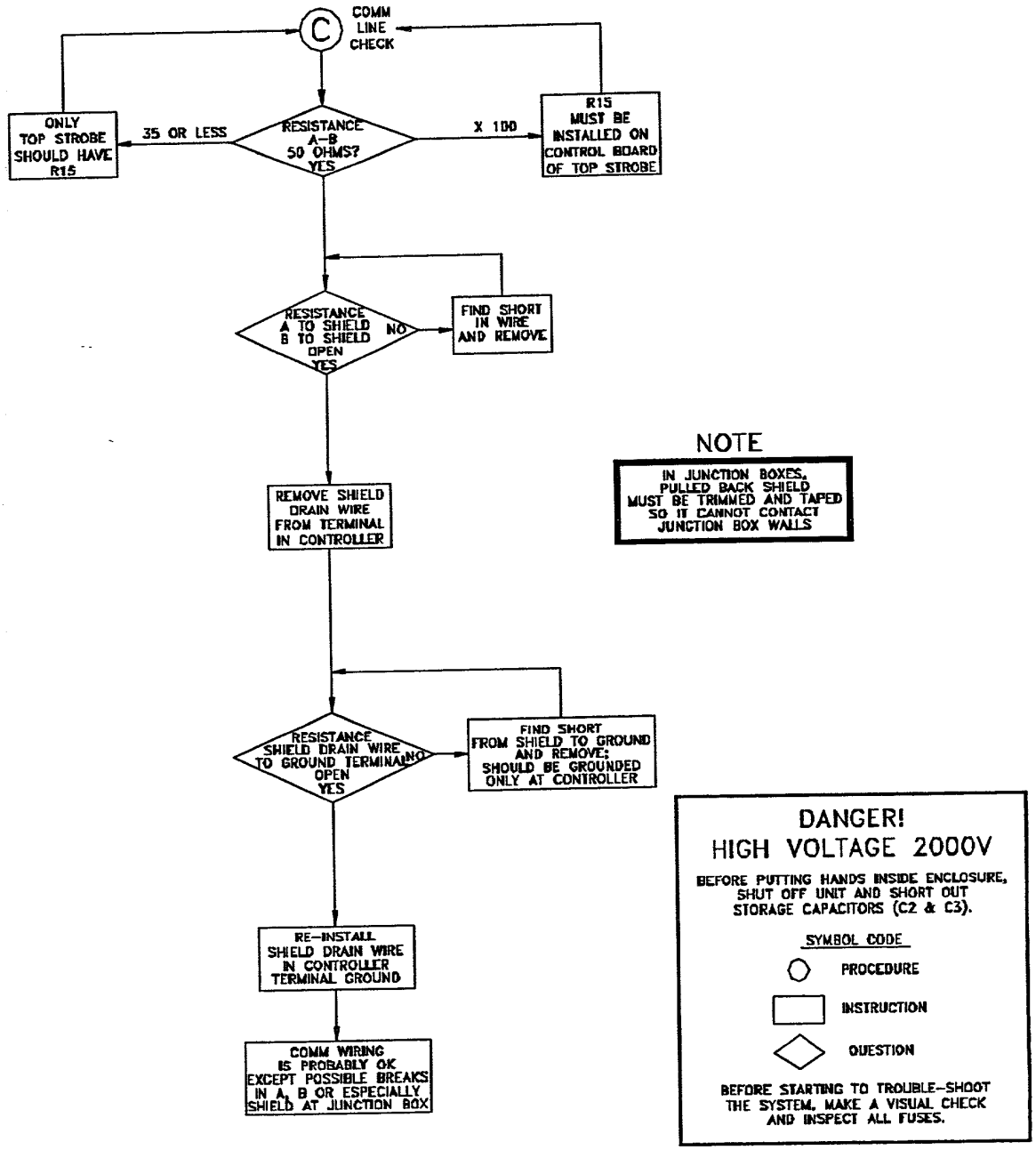

Figure 5-1c. TROUBLE-SHOOTING PROCEDURE

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6.1 SG-60 Obstruction Warning Light (OWL)

Normal maintenance of the OWL requires periodic cleaning of the window with a non abrasive soap.

WARNING!
Ensure that the power is **OFF** and the capacitor bank has been discharged before opening the OWL.

6.1.1 Flashtube Replacement

Flashtubes which are faulty or degraded in performance by aging should be replaced by the following procedure:

1. Shut off the power.
2. Release the OWL cover.
3. Swing the cover open, exercising caution not to damage the glass face or the gasket.
4. Release the old flashtube by disconnecting the electrode wire fastons at each end and carefully snapping the tube from its holders.
5. Unpack the new flashtube, being careful not to touch the glass envelope.
6. Holding the flashtube by its metal ends, center it in the reflector assembly and snap it into place, making sure the red mark on the flashtube matches the red mark on the socket assembly.
7. Attach the faston connector at each end of the flashtube to each socket assembly.

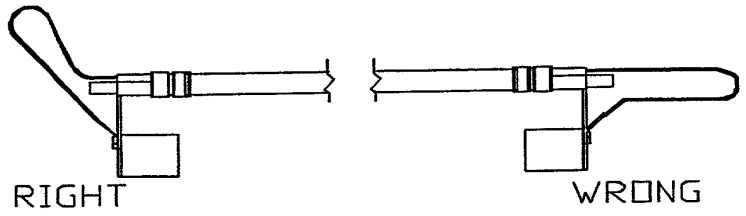

Figure 6-1. FLASHTUBE REPLACEMENT

8. Dress the electrode wires up and away from the sides of the reflector.

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9. Close and fasten the OWL cover.

6.2 Ambient Light Sensor

The only maintenance required for this unit is the periodic cleaning of the Photocells. Frequency of cleaning will depend on the enviroment to which they are exposed.

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SECTION 7.0 - REPLACEMENT PARTS

SGF-60 (OWL)	part no.
Capacitor, 1µF C1	77-3310
Capacitor, 3µF C4	77-3311
Capacitor, 12.5µF C2	AC000003
Capacitor, 110µF C3	77-4133
Capacitor, 50µF C3	AC000002
Diode Block Assembly DB1	277-3342
Flashtube Assembly V1	77-3295
Fuse, FNQ, 3.2A (for 480VAC) F1	77-2041
Fuse, FNQ, 6A (240VAC) F1	77-1167
Fuse, FNQ, 10A (120VAC) F1	77-2040
Fuse, FLA, 1/4A (for 120VAC) F2	FU000003
Fuse, FLM, 1/10A (240VAC) F2	FU000005
Fuse, FLQ, 1/10A (480VAC) F2	
PC Board, Motherboard	277-5053
PC Board, Digital Controller	33E00030
PCBoard, Trigger & H.V	33E00010
Relay K1, K2, K3	77-3870
Transformer, T1 (60HZ)	77-3890
Transformer, T1 (50HZ)	77-3765
Transformer, T2 (50HZ / 60HZ)	TP000005

SGC-60, MASTER CONTROLLER	part no.
PC Board, Master Controller	33E00240
Transformer, T1 (50HZ / 60HZ)	TP000006
Photocell	12H00107

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NOTICE

The integrity and reliability of HONEYWELL aviation obstruction lighting systems are dependent on the use of HONEYWELL parts and components. To ensure the optimum performance and reliability of your HONEYWELL system, it is strongly advised that only components and modules manufactured by HONEYWELL be used.

WARRANTY

HONEYWELL warrants the equipment described in this instruction manual and sold to the purchaser to be free from defects in material and workmanship at the time of shipment. HONEYWELL's liability under this warranty being limited to repairing or replacing, at HONEYWELL's option, items which are returned to it prepaid within twenty four (24) months from shipment to the original Purchaser and found, to HONEYWELL's satisfaction, to have been defective. In no event shall HONEYWELL be liable for consequential damages. NO PRODUCT IS WARRANTED AS BEING FIT FOR A PARTICULAR PURPOSE AND THERE IS NO WARRANTY OF MERCHANTABILITY. This warranty applies only if: (I) the items are used solely under the operating conditions and in the manner recommended in HONEYWELL's instruction manual, specifications, or other literature; (II) the items have not been misused or abused in any manner or repairs attempted thereon; (III) written notice of the failure within the warranty period is forwarded to HONEYWELL and the directions received for properly identifying items returned under warranty are followed; and (IV) such return notice authorizes HONEYWELL to examine and disassemble returned products to the extent HONEYWELL deems necessary to ascertain the cause of failure. The warranties stated herein are exclusive. THERE ARE NO OTHER WARRANTIES, EITHER EXPRESSED OR IMPLIED, BEYOND THOSE SET FORTH HEREIN, and HONEYWELL does not assume, nor does HONEYWELL authorize anyone else to assume for it, any other obligation or liability in connection with the sale or use of said products. HONEYWELL's liability on any claim of any kind, including negligence, for loss or damages arising out of or connected with the manufacture, sale, delivery, repair or use of any equipment or services provided by HONEYWELL shall in no case exceed the price allocable to the item or service or part thereof which gives rise to the claim.

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