Proposed Revision for Specification for Reflex-Reflective Materials for Highway Signs

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MEMO TO: H. R. Creal, Chairman
Specifications Committee

SUBJECT: Recommended Special Specification No. 50-R
On Reflex-Reflective Sign Materials

For the past two years the Division of Traffic and the Research Laboratory have recognized a need for changing Special Specification No. 50 in order to simplify the requirements for reflex-reflective sign materials, facilitate the testing, and provide a broader scope to include more materials that are commercially available. Within the past few months a great deal of effort has been concentrated on the testing of all types of materials under different conditions so that changes offering the greatest advantage could be recommended to the Specifications Committee.

The attached Recommended Special Specification No. 50-R is offered as a replacement for the one now in effect. It should be noted that while this does include a wider range of materials, it contains no provisions for plain enameled sign surfaces since they are not considered reflex-reflective. For that reason, it will be necessary to reinstate Article 7.23.8-B of the 1945 Standard Specifications if this is adopted.

The Memorandum Report from J. H. Havens, which accompanies the recommended specification explains a number of the significant points, and it will be of interest to the Committee. Several copies of both the report and the specification are being sent on the assumption that you will want to distribute them to the Committee Members.

LE: ddc
Attached
cc: C. P. Brown
Division of Traffic

L. E. Gregg
Assistant Director of Research
MEMO TO: L. E. Gregg  
Assistant Director of Research  


There are several pertinent factors and considerations that have a direct bearing on the requirements contained in the attached Recommended Special Specification No. 50-R, and it seems appropriate to record them here as reference material either in support of the specification or as information.

Angularity requirements are based on the practical geometry associated with a driver’s view of a sign. The calculations assume:

1. That a driver’s eyes are 5 feet behind and 2 feet above the headlamps of his car and that the distance between his eyes and his right-hand headlamp is 6.7 feet.

2. That a sign is positioned 4 feet off the edge of the pavement and 4 feet up and that the right headlamp, when the car is in its normal position in the lane, is 3 feet from the edge of the pavement. This means that the perpendicular to the plane of the sign and the perpendicular to the headlamp are separated laterally by 7 feet.

Incidence angles are then calculated as the angle whose tangent is equal to 7 feet divided by the perpendicular distance from the sign to the headlamp.
The length of the "line of light" is calculated as the hypotenuse of a right triangle, \( L^2 = D^2 + (7)^2 \).

The length of \( S \), the "line of sight," is calculated as \( S^2 = (D + 5)^2 + (11.2)^2 \). Knowing \( S \), \( L \) and \( C \), the divergence angle \( a \) is calculated by the law of cosines:

\[
\cos a = \frac{L^2 + S^2 - C^2}{2LS}
\]

Values calculated in this manner are tabulated below:

<table>
<thead>
<tr>
<th>Perpendicular Viewing Distances in Feet</th>
<th>Incidence Angle (( \Theta ))</th>
<th>Divergence Angle (( \alpha ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>24°</td>
<td>13.7°</td>
</tr>
<tr>
<td>500</td>
<td>48°</td>
<td>27.0°</td>
</tr>
<tr>
<td>400</td>
<td>1°00'</td>
<td>36.9°</td>
</tr>
<tr>
<td>300</td>
<td>1°20'</td>
<td>48.2°</td>
</tr>
<tr>
<td>200</td>
<td>2°00'</td>
<td>1°12'</td>
</tr>
<tr>
<td>150</td>
<td>2°40'</td>
<td>1°34'</td>
</tr>
<tr>
<td>100</td>
<td>4°00'</td>
<td>2°16'</td>
</tr>
<tr>
<td>75</td>
<td>5°20'</td>
<td>2°52'</td>
</tr>
<tr>
<td>50</td>
<td>7°58'</td>
<td>3°55'</td>
</tr>
<tr>
<td>25</td>
<td>15°39'</td>
<td>5°42'</td>
</tr>
<tr>
<td>15</td>
<td>Approx. 25°</td>
<td>Approx. 6°</td>
</tr>
</tbody>
</table>

A divergence of 0° to 1-1/2° embraces all viewing distances beyond 150 feet. The range in divergence from 1-1/2° to 4° embraces all viewing distances between 150 feet and 50 feet. It is worthy of note here that the projected area encompassed by 1-1/2° is only 11.1 percent of the projected area encompassed by 4° of divergence. Therefore, in order to assure adequate long-range reflectivity, at least 11.1 percent of the overall (4°) reflectivity should be appropriated to the smaller angle. Actually for maximum long-range benefit, considerably more than the 11.1 percent would be desirable. For this reason, the specification requires at least 15 percent for Type I materials and 25 percent for the Type II materials in which long-range reflectivity is the particular feature sought.

A perfectly diffusing surface is said to reflect light equally in all directions, and these reflection vectors describe a hemisphere. Assuming unit radius of the hemisphere, a 4° cone whose apex is at the center of the sphere subtends an area equivalent to only 0.282 percent of the hemispherical surface. In other words, a perfectly diffusing surface should have an over-all reflective efficiency (as defined in the specification) of 0.282 percent. A white bond paper, at perpendicular (normal)
incidence, in our Reflex Photometer yielded 0.75 percent. This indicates, of course, that even such a surface is not a perfect diffuser and that the normal or near normal vectors have been reinforced at the expense of higher angle reflections. The 0.75 percent might be thought of as the maximum reflectivity available from ordinary painted non-glossy surfaces. Beads-on-paint systems may range upward from 1.50 percent for a refractive index of 1.52 for the glass to about 4.5 percent for an index of 1.85.

As a result of a previous study*, it was found that the legibility distances of a 4-inch letter on a 24 by 24-inch sign was limited by


Acuity to about a 300-foot viewing distance. A standard curve sign could be recognized as far as 600 feet under the upper beam of headlamps. Attendant to these observations, there seems to be a critical threshold reflectivity (luminous intensity) above which acuity could not be improved. Ordinary painted signs were less than half as effective as reflectorized signs. Beads-on-paint reflectorization (1.52 refractive index glass) seemed to fall just a little short of the threshold to the constant acuity factor. Accordingly, if it is necessary that a sign be read at distances greater than 600 feet, it is necessary for it to be larger than 24 by 24 inches. These observations may also be interpreted as meaning that ordinary beads-on-paint reflectorization is adequate for many non-critical sign applications. The logical exceptions would be "STOP" signs, and other signs warning of impending hazards.

Although the higher extreme of reflectorization has not been studied very extensively, it is possible to foresee that very high reflectivities may actually be a detriment to acuity. The eye sees objects by contrast, but too much contrast in luminous intensity or too high a luminous intensity level, disregarding contrast, is interpreted as glare. Glare works in opposition to acuity and depth perception. In other words, a sign could be too bright for the surrounding scenery and its position be misjudged.

With further reference to specification requirements, the 2 percent diminution tolerance per degree of incidence is intended to compensate for reductions in equivalent normal surface for high-angle incidence and for inherent optical imperfections in the reflectorizing systems. As a matter of interest, the attendant reductions in equivalent normal surface are:
Averaged over the range of incidence, this is equivalent to about 1/2 percent per degree. The remaining 1-1/2 percent per degree represents the tolerance factor. Probably a more realistic alternative would have been to allow 2 percent diminution per degree plus the cosine correction for equivalent normal surface. However, that would provide more tolerance than seems necessary or permissible.

The 6 percent per degree diminution allowance for Type II reflective materials is necessary to cover materials such as Reflexite and Grotelite. They consist of minute hemispherical lenses embossed in a clear plastic sheet overlying aluminum foil or heavier gauge aluminum sheet. Both materials, despite their seemingly narrow angularity, have been installed experimentally by the Traffic Division and they seem to have considerable merit. The Reflexite installation is now 4 or 5 years old and shows no tendency to deteriorate. Actual performance and appearance in service must be considered the final criteria for judgement in these things, and that seems to be about the only justification for including them in the specification. On the other hand, it may be that the high angularity features are not nearly so important as have been previously emphasized or inferred. More light impinges upon a sign the closer a car approaches it, and therefore commensurately less reflectivity should be required in order to preserve a constant brightness throughout the full range of view. Still, there are too many intangible factors involved to attempt to analyze the situation on this basis. Small changes in direction of the vehicle or geometry of the road may throw the main body of the headlight beam onto the sign at one instant and away from it the next. In some cases, this might cause low-angle materials to "flash" or to black out at some critical instant.

If over-head signs should gain wide acceptance in this state, the angularity problem would have to be re-analyzed on that basis. At an assumed elevation of 16 feet the corresponding incidence angles and viewing distances would be:
Distance | Incidence
--- | ---
500 | 1°10'
300 | 2°18'
150 | 4°34'
75 | 9°05'
50 | 13°30'
25 | 25°39'

Obviously, a wider angle material than the two products already mentioned would have to be used.

In order that the specification may be considered in terms of specific cases, I am appending hereto a series of physical analyses, such as might be called a laboratory report sheet, covering each type of material or manufacturers products that we have studied during the past few years and which have been considered in the preparation of the specifications.

James H. Havens
Research Chemist

JHH:ddc
Attached

August 26, 1954
TRADE NAME: Prismo
MANUFACTURER: Prismo Safety Corporation, Huntingdon, Penn.
Specification Type: Type I, beads-on-paint, paint-on
Reflectivity Type: Group I, Class A if 1.52u. glass is used
Durability: Comparable to that of a high-type paint.

Comments: A low-cost, apply-it-yourself material, suitable for many non-critical signs. It is purchased as a kit containing paint binder and glass beads which are dusted onto the wet paint film. Glass beads customarily have a refractive index of 1.52, but the reflectivity of the system could be improved and compare favorably to that of Wide Angle Scotchlite if a more highly refractive glass were used.

The Department could feasibly purchase selected paint binders and glass beads separately in greater bulk at considerable savings.
TRADE NAME: Wide Angle Scotchlite
MANUFACTURER: Minnesota Mining & Manufacturing Company, St. Paul 6, Minn.
Specification Type: Type II
Reflectivity Type: Group I, Class B
Durability: Excellent

Comments: A prefabricated sheet-coating, available in rolls, with or without adhesives. Basically its construction is similar to that of beads-on-paint. It is suitable for application to embossed sign-stock with vacuum envelope, receives roller-applied paint overlays or silk screen overlays, and is also available with precoated, solvent-activated or possibly even pressure-sensitive adhesives. The glass beads are very uniform in size and evenly distributed, they have a refractive index in the order of 1.85 or higher, and to a large extent they exemplify the optimum of the beads-on-paint systems.
Comments: A prefabricated sheet-coating with precoated adhesive, water-soluble or water activated. A sheet is soaked in water until the paper backing is loosened; the coating is then transferred and rolled onto the sign-stock like a decal. The coating itself weathers well, but adhesion to aluminum (the only stock material tried) was not very secure. The coating was easily stripped from the panel, but there was no apparent tendency for it to strip, sag, or peel under its own weight.

The Manufacturer offers a material they call Tranz Luminate consisting of prefabricated sheet of beads and clear plastic binder for use as a reflectorizing overlay for any existing surface such as painted sign stock or aluminum.

The glass beads are not deeply anchored, although there was no apparent loss during weathering.

The manufacturer recommends that the material not be used over embossments. It is available in cut sizes to fit inside embossed edges. It is also available in a wide angle form - which has not yet been studied.
TRADE NAME: Wide Angle Flat Top (Scotchlite)
MANUFACTURER: Minnesota Mining & Manufacturing Company, St. Paul, Minn.
Specification Type: Type II
Reflectivity Type: Group I, Class C; or Group II, Class A
Durability: Excellent

Reflective index of beads may be as high as 2.30

90,000 per sq. in.

Clear plastic or dyed plastic

Aluminum pigment

Paper backing (if any)

Adhesive

Typical Cross-section

Reflectivity Characteristics

Comments: A prefabricated sheet material available in rolls, suitable for use over embossed sign stock. Apparently this material represents the most recent development in the Scotchlite series. An earlier material of similar construction used aluminum foil behind the beads, but apparently that could not be deformed over embossments or to form the spherical reflecting surfaces behind the beads - which is rather essential for wide angle reflectivity. The beads are apparently not a silica glass, they are very soft (actually, they are not much harder than the plastic they are imbedded in) and probably would not be very stable if exposed outside the plastic sheet.

Coloration is imparted either by including a dye in the plastic or by overlaying a coating of dyed plastic on the clear plastic.
TRADE NAME: Grotelite
MANUFACTURER: The Grote Manufacturing Co., Inc., Bellevue, Kentucky
Specification Type: Type II
Reflectivity Type: Group II, Class B
Durability: Excellent

Clear or dyed transparent plastic
Adhesive
Paper backing (if any)

Typical Cross-section

Reflectivity Characteristics

Comments: Grotelite is a prefabricated sheet material very similar to Reflexite, optically and physically. It consists of molded plastic lenses (molded into the surface of a transparent plastic sheet overlying aluminum foil). If the plastic is water-clear, the effective color of the reflecting system is silver white. For colored materials, a dye is incorporated into the plastic material. The fabricated sheet is rather brittle, and is not suitable or recommended by the manufacturer for use over embossed stock. It is available in pre-cut sizes to fit inside embossed edges. Plastic lenses are rather easily marred or abraded, and such materials should be handled carefully.

This material is presently available with precoated adhesive, but the application procedure recommended by the manufacturer is to use additional adhesive, which they supply, to prime the stock and, in a sense, to activate the adhesive. Only pressure is required to affix it to the prepared sign stock.
TRADE NAME: Stimsonite
MANUFACTURER: American Gas Accumulator Co., 1629 Newark Avenue, Elizabeth 3, N. J.; or Stimsonite Plastics, 313 N. Justine Street, Chicago 7, Ill.

Specification Type: Type III-C
Reflectivity Type: Group I, Class D; or Group II, Class B
Durability: Excellent

Comments: A cube-corner reflective system in the form of a circular plaque, usable as reflectorizing inserts for letters affixed to signs or for reflectorizing guard rails. The units are available in several sizes and as letter-units. It is made of molded plastic, presents a smooth outward surface, and has cube-corners molded into the back surface of the front transparent element. Behind the front element is a pigmented plastic surface or a metallic reflecting surface. The units are sealed.
TRADE NAME: Reflexite  
MANUFACTURER: Reflexite Corporation, 39 South Ave., New Canaan, Conn.  
Specification Type: Type III A  
Reflectivity Type: Group II, Class A  
Durability: Excellent

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Comments: A molded lens-sheet of Methacrylate with back coatings of aluminum powder in lacquer; coloration is imparted to the material by inter-mixing pigment with the aluminum powder and lacquer. The sheeting is rather thick and brittle. Presumably, it is available only as prefabricated letter plaques mounted on metal or plywood with adhesives. Although its angular reflectivity is rather narrow, the manufacturers claim to have some control over this by adjusting the thickness of the molded sheet. The focal length of the lenses is approximately .070 inch; and if molded so that the lens is in focus, the product is claimed to have long-range characteristics. If it is molded out of focus, it has much wider divergence characteristics.
COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

RECOMMENDED

SPECIAL SPECIFICATION NO. 50-R

REFLEX-REFLECTIVE SIGN MATERIALS

This Special Specification No. 50-R covers the requirements for Reflex-Reflective Sign Materials. It shall be applicable when indicated on plans, proposals, or bidding invitations, and when applicable, shall supersede and void Special Specification No. 50 adopted March 11, 1949, and re-establish and make valid Article 7.23.8-B of the Department's 1945 Standard Specifications.

REFLEX-REFLECTIVE SIGN MATERIALS

1. GENERAL REQUIREMENTS: The reflective materials specified herein shall preserve the day-light appearance of the sign on which they are placed, comparable to that of a painted sign; and they shall fulfill the intent of sign reflectorization for night-time use. The optical systems shall be functionally faithful to the practical geometry associated with night-time driving and sign viewing conditions. They shall utilize the light incident from automobile headlights, that is otherwise specularly or diffusively scattered, and shall return a substantial percentage of it along the driver's "line of sight" (the relationship represented by a conically divergent angle between the "line of light" from the headlamps and the driver's "line of sight" to the center of the sign).

Materially, the fabricated systems shall be capable of withstand ing a minimum of two years of natural weathering or its equivalent in exposure to artificial sunlight, moisture, and ambient temperatures without showing visible deterioration. Systems containing exposed glass, such as lenses, prisms, or vitreous enamels shall be made of stable glass resistant to thermal shock, corrosion, or dissolution by moisture, mild acid or alkali. Translucent or transparent pigmented or dyed resins or plastics shall be similarly resistant and shall be further resistant to shrinking, cracking, peeling, and other types of premature deterioration. Metallic mirrors or pigments shall be resistant to corrosion, rusting, and similar influences or otherwise shall be sealed against contact with corrosive elements.

All materials procured for fabrication of finished signs by the Department or its agent shall be guaranteed by the vendor to comply with all the requirements attendant to the method and procedures of fabrication as recommended by the manufacturer and/or as prescribed by the Department. Failure of a material to comply, or to render possible the successful fabrication of a finished sign, shall cause the material to be rejected as unsatisfactory for the purpose intended.
2. **OPTICAL DESIGN:** The design of materials covered by this specification shall represent either a lens-mirror optical system or a cube-corner optical system, in the sense that those terms normally apply to basic forms of reflex-reflectors for the purpose of sign reflectorization.

3. **CLASSIFICATION BY METHODS OF APPLICATION TO SIGN STOCK:**

The method or means by which a material is applied to sign stock shall appropriately classify the material in one or more of the following categories:

**Type I:** Paint-on materials suitable for application to prepared metal or wood sign stock by brush or spray. This type is exemplified by the beads-on-paint system. These materials shall present a finished surface suitable for receiving stenciled overlays of paint.

**Type II:** Glue on materials, including prefabricated sheet-coatings, laminates, or decals, suitable for application to prepared sign stock by the use of adhesives. The materials shall present a finished surface suitable for receiving stenciled messages or paint overlays. All materials in this group shall be further classified in accordance with the adhesive required for application, as follows:

- **P. Pressure Sensitive** - Adhesives which secure the sheet material to the sign stock when subjected to pressure by a rubber roller or vacuum envelope.
- **T. Thermo-Sensitive** - Adhesives requiring heat to soften the adhesive prior to or at the time pressure is applied in a manner described above.
- **S. Solvent-Activated** - Adhesives that require solvent to activate and soften the adhesive before pressure is applied in a manner described above.

The method of application for any Type II material shall produce a surface free from cracks or tears, ridges or humps, discolorations, or other objectionable blemishes; and when intended for use on embossed sign stock, as stated in the invitation for bids, the material and method of application in combination shall provide an unblemished and unbroken surface comparable to that obtainable with smooth sign stock.

**Type III:** Screw-on or bolt-on materials, consisting of individual reflectorized units suitable for composing sign messages or for outlining the important features of signs. The materials shall be readily adaptable to painted sign stock or to sign stock surfaced with Type I or Type II materials. All materials in this group shall be further classified in accordance with their physical features as follows:
A. **Bold Face Letters or Symbols** cut or formed in the desired outline of specified size, and having integral reflex-reflective characteristics.

B. **Button Inserts** consisting of glass or similar translucent surfaces combined with other parts of the inserts to form individual reflex-reflective optical systems.

C. **Medallions or Brilliants** of plaque-like construction, having the desired size and outline. Individual plaques shall, in accordance with the bidding invitation, have surfaces either entirely reflectorized or only partially reflectorized within the outline of letters, symbols, or parts of letters or symbols which may be used to compose messages through the combination of two or more plaques.

Means for attaching Type III materials to sign stock are considered part of the materials themselves, to be furnished by the vendor and used in accordance with the vendor's instructions. Failure of the attaching device to fasten a material securely to sign stock shall constitute a basis for rejection of the materials.

4. **OPTICAL EFFICIENCY**: The optical efficiency of materials, as described in the definition of terms (Section 11) and as determined by tests outlined in Section 6B, shall classify materials in groups according to reflectivity and angularity as follows:

**Group I**: Materials having a long-range efficiency value not less than 15 percent of their over-all efficiency value, which display less than 2 percent diminution in over-all reflective efficiency per degree increase in angle of incidence to 30 degrees, and which have an over-all efficiency at "normal" incidence (zero degree angle of incidence) equal to or greater than the minimum specified for the appropriate class designation as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Minimum Over-all Reflective Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>3.0</td>
</tr>
<tr>
<td>C</td>
<td>6.0</td>
</tr>
<tr>
<td>D</td>
<td>15.0</td>
</tr>
</tbody>
</table>
Group II: Materials having a long-range efficiency value not less than 25 percent of their over-all efficiency value, which display less than 6 percent diminution in over-all reflective efficiency per degree increase in angle of incidence to 10 degrees, and which have an over-all efficiency at "normal" incidence (zero degree angle of incidence) equal to or greater than the minimum specified for the appropriate class designation as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Minimum Over-all Reflective Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.0</td>
</tr>
<tr>
<td>B</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Reflectivity classification and requirements shall apply to materials of all colors designated in this specification when light from the illuminating source in the Reflex Photometer (Section 6B) is filtered or the source otherwise corrected to the same apparent chromaticity as the color specified for the material.

5. COLOR: All materials shall conform to one of the following color designations:

White: A pure white visually comparable with white bond paper.

Silver White: A white metallic luster, normally exemplified by aluminum pigment or foil.

Yellow: Standard "Highway Yellow", normally exemplified by chrome yellow. Color saturation shall be visually comparable to that obtained by placing a Kodak Wratten Filter G over white bond paper.

Red: A bright red visually comparable to that obtained by placing a Kodak Wratten Filter A over white bond paper.

Green: A bright chrome green normally obtained by a combination of lead chromate and insoluble Prussian blue. Color saturation shall be visually comparable to that obtained by placing a Kodak Wratten Filter B over white bond paper.

6. SAMPLING: For the purpose of sampling, a shipment shall consist of the total amount of material received in one delivery even though it may represent only partial delivery of the amount contracted. Samplings shall
be made from at least three widely separated and indiscriminately chosen packages included in the shipment. A sampling shall consist of enough material to make representative trial applications to sign stock in accordance with the appropriate method described in Section 3.

Samples to serve the requirements of durability and reflectivity tests shall consist of the following:

Type I & Type II materials: From flat portions of one or more of the signs produced by trial application, sections (panels) 3 inches by 9 inches in size shall be cut in a manner that will not tear the material or leave the edges excessively frayed.

Type III Materials: Three complete letters, buttons, or medallions selected at random. In cases where the units purchased are not of sufficient size to provide a test specimen at least 1-1/2 inches in diameter, the largest size available shall be used in the reflectivity test and the results expanded proportionately to compensate for the reduction in area of reflective material.

7. TESTING: Of the three specimens prepared in accordance with Section 6, one shall serve the combined purpose of reflectivity measurements followed by "sunshine" and freeze-thaw durability exposure. A second specimen shall be used for immersion in mild basic and acid solutions, and the third specimen shall be retained for reference and check.

Test procedures for evaluation of reflectance and durability characteristics shall be as follows:

Reflectivity and Optical Angularity: The apparatus for reflectivity measurements shall consist essentially of a source of incandescent light, a lens to produce converging light, a 1-1/2-inch diameter barrier-layer photocell with a 1/16-inch aperture drilled through its center, a second photocell to measure incident light, a 1-1/2-inch diameter mask to define effective sample area, appropriate meters to measure the electrical output of the photocells, and other appurtenances necessary to effect the optical alignment and arrangement of essential elements illustrated in the Schematic Diagram of the Reflex Photometer included herein.

Over-all reflective efficiency of a material shall be determined by first measuring the electrical output of the incident light photocell, then by placing the
test sample between the incident light photocell and the sample holder face plate, and measuring the electrical output of the reflected light photocell. Over-all reflective efficiency shall be calculated and expressed as the percentage ratio of meter reading for reflected light to that of incident light. It shall be determined and recorded at 5-degree increments in angle of incidence from zero degrees to the maximum angle required to comply with optical efficiency provisions in Section 4.

Long-range efficiency measurements shall be made and values calculated in the same manner except that an aperture mask having an inside diameter of 1/2 inch and an outside diameter of 1-1/2 inch shall be placed over the reflected-light photocell. Measurements shall be made at 0-, 5-, and 10-degree angles of incidence.

For reflectivity measurements on materials having colors other than white or silver white, light from the illuminating source shall be appropriately filtered or otherwise corrected to the same apparent chromaticity as the sample being tested. This may be accomplished by placing corresponding filters described in Section 5 between the lamp and the condensing lens. When filters are placed in the system, values of incident and reflected light shall be measured and calculated as described above.

**Durability:** The accelerated weathering test shall consist of 800 hours exposure of a test specimen in a National Type X-1A weathering unit or its equivalent, using Corex D glass filters, National "Sunshine" carbon electrodes, and an intermittent water spray. Following this exposure, the test specimen shall be submerged in water at room temperature for at least one hour and immediately subjected to one cycle of: freezing in air at 0 degrees F. for not less than 2 hours and thawing in water at 77 degrees F. for at least 1/2 hour.

Resistance to chemical attack shall be determined by immersion of a test specimen in a 1/10 N. sodium hydroxide solution at room temperature for a period of 24 hours, followed by immersion in a 1/10 N. sulfuric acid solution at room temperature for a period of 24 hours.
8. PERFORMANCE: Test panels shall withstand all durability tests without cracking, peeling, fading, dissolving, or otherwise displaying visible evidence of deterioration.

Note: Extended durability testing may be waived when field service and previous tests and observations have substantiated the durability of a particular material or the products of a particular manufacturer; however, the Department may elect to sample and test any and all shipments and, at its discretion, conduct durability tests whenever they are judged necessary to assure compliance with the intent of the specification.

All specimens shall meet the application, reflectivity, and angularity requirements for the Type and Class of material designated in the invitation for bids, with the exception that a 10-percent tolerance on over-all reflective efficiency and long-range reflective efficiency values shall be allowed for materials of all colors other than white and silver white, in order to compensate for minor differences in color saturation.

9. PACKAGING: All materials shall be suitably and substantially packaged; and shall have the name and address of the manufacturer or vendor, contract or purchase order number, kind of material, trade name, and net contents plainly marked on each package or container.

10. MEASUREMENT AND PAYMENT: Sheet materials shall be measured by the square foot, bulk solid materials such as glass beads shall be measured by the pound, and Type III materials shall be measured by the assembled unit. Liquid materials should be measured by the gallon.

11. DEFINITION OF TERMS:

Reflectivity: Percentage of total luminous flux incident upon the surface of the test specimen that is reflected by that surface onto the exposed area of the reflected-light photocell.

Angle of Incidence: The angle encompassed by the axis of the cone of light projected onto the surface of the test specimen and a line perpendicular or normal to the surface of the specimen. (Comparable to the angle between the "line of light" from headlamps of an automobile and the "normal" to the plane of a highway sign).
Angle of Divergence: The angle encompassed by the axis of the cone of light projected onto the surface of the sample and any line projected from the rim of exposed area of the reflected-light photocell to the center of the test specimen. (Comparable to the angle between the "line of light" from the headlamps of an automobile and a driver's "line of sight" intersecting at the center of a highway sign.)

Over-all Reflective Efficiency: An integrated reflectivity measurement of the amount of light reflected by the test specimen within 4 degrees divergence - expressed as a percentage ratio of reflected light to incident light. (Comparable to driver viewing conditions at distances greater than 50 feet from a highway sign.)

Long-range Reflective Efficiency: An integrated reflectivity measurement of the amount of light reflected by the test specimen within 1.5 degrees divergence - expressed as a percentage ratio of reflected light to incident light. (Comparable to driver viewing conditions at distances greater than 150 feet from a highway sign.)
Reflected light photocell, Weston, Model 594, filter glass removed, 1/16" aperture drilled through center.

Incident light photocell, Weston, Model 594

4-degree divergence angle

1-1/2" dia. baffle

Sample holder face plate, 1-1/2" dia. aperture, mounted on pivot with circular scale.

Stabilized voltage source

Large rheostat

Decade scale

Selector switch

Galvanometer

Note: For 4-degree divergence, cell-to-sample distance is 10.7". Effective divergence angle decreased to 1-1/2 degrees by placing 1/8" dia. aperture mask over reflected light photocell.

Schematic Diagram of Reflex Photometer