

## OTHER APPLICATIONS

Also successfully conducted were year-long trials to determine the suitability of MMA mortars for anchoring steel retaining bolts in concrete construction members for new high-speed [400 km/h (250 mph)] rail systems.

## CONCLUSIONS

1. Eighteen years of experience working with polymers in concrete have shown that early rehabilitation of concrete roadways with polymer concrete will prevent major deterioration problems.
2. Overlays on existing concrete roadways and bridge deck rehabilitation with polymer concrete result in a durable, highly skid-resistant road surface.

3. The use of polymer concrete is cost effective if all factors are taken into consideration.

4. From the information in the instruction manual of the GDR Federal Highway Administration, laboratory and field tests can now be performed to determine the true suitability of any proposed polymer concrete material to be used for rehabilitating concrete roads and bridge decks as well as for the existing substrate.

## ACKNOWLEDGMENT

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*Abridgment*

# Field Evaluation of the Gamma Scientific Model 910B Retroreflectometer

Gerald J. Malasheskie and Frank W. O'Block, Bureau of Materials, Testing, and Research, Pennsylvania Department of Transportation

To ensure that the Gamma Scientific model 910B retroreflectometer will perform satisfactorily in the field environment, the instrument was tested for performance, durability, and ease of operation under the following parameters:

1. Temperature range of 0-38°C (32-100°F),
2. Low and high relative humidity, and
3. Bright sunlight and cloudy lighting conditions.

In addition to the environmental parameters, the device was tested to determine whether it could be referenced to an optical tunnel. Since the device will be used to determine the compliance of reflective sheeting with Pennsylvania Department of Transportation (PennDOT) specifications, it is logical that measurements taken with it should produce the same results that the optical tunnel would provide.

If proved acceptable for use by PennDOT, the retroreflectometer will be used by both the bureau of materials and the sign shop to measure the initial specific luminance values of the sheeting material for compliance with the PennDOT specification for sheet-reflective materials. It will also be used in the field to determine when signs should be replaced. Evaluation for this use included measuring the specific luminance of signs taken from the field while still dirty and measuring them again after cleaning.

## OPERATION OF EQUIPMENT

The retroreflectometer consists of two units, the 910B retroreflectometer head (a pistol-shaped as-

sembly) and the 910 control unit (a rectangular assembly). A set of calibration standards supplied by the manufacturer was used throughout the testing sequence.

The retroreflectometer head contains all of the optics, the lamp source, and the detector. In use, the head is pressed against the surface of the sheeting to be measured. A small white plunger is then depressed flush with the front surface of the head. The depressing of this plunger turns on the lamp source and uncovers the detector, and a reading is then displayed. The head also contains the range switch.

The control unit contains the operating controls, the display, and the batteries. Before taking measurements, the unit was calibrated according to the color of the sheeting to be tested with the calibration standards supplied.

The 910B is designed for use in the field. Extended use throughout the evaluation has proved it to be rugged and built with high-quality components for long life and high reliability. However, like any instrument containing precision optics and sensitive electronics, it should be treated carefully. It should not be dropped or handled roughly. For field use the control unit may be carried on the hip by means of the shoulder strap supplied. The retroreflectometer head can then be pressured against the surface to be measured. If the surface to be measured is elevated, the head can be attached to a short pole for lifting it up against the surface.

A shielded hood has been attached to the digital display so that it may be read in full sunlight. The only precaution necessary is to keep the direct rays of the sun from striking the display. If they do, the display will be unreadable. When the control unit is on the

hip, it is a simple matter for the operator to turn his or her body so that the sunlight is kept off the display.

The duration of the field evaluation was one year. During that time, the instrument operated without flaw. Warm-up time is approximately 60 s and calibration

drift is minimal. If the Plexiglas ring for probe-to-sign alignment is used, the operation of this instrument is extremely simple.

It was noted that the equipment maintains its zero and set calibration reading best if the 0.1 multiplier

Figure 1. Gamma standard luminance at 0°C (32°F).

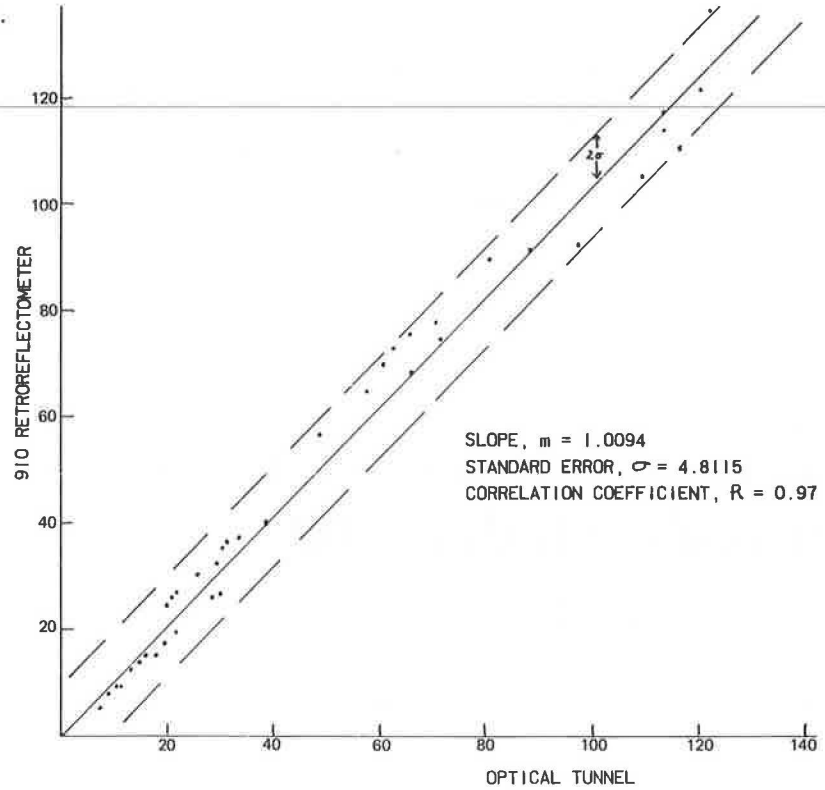
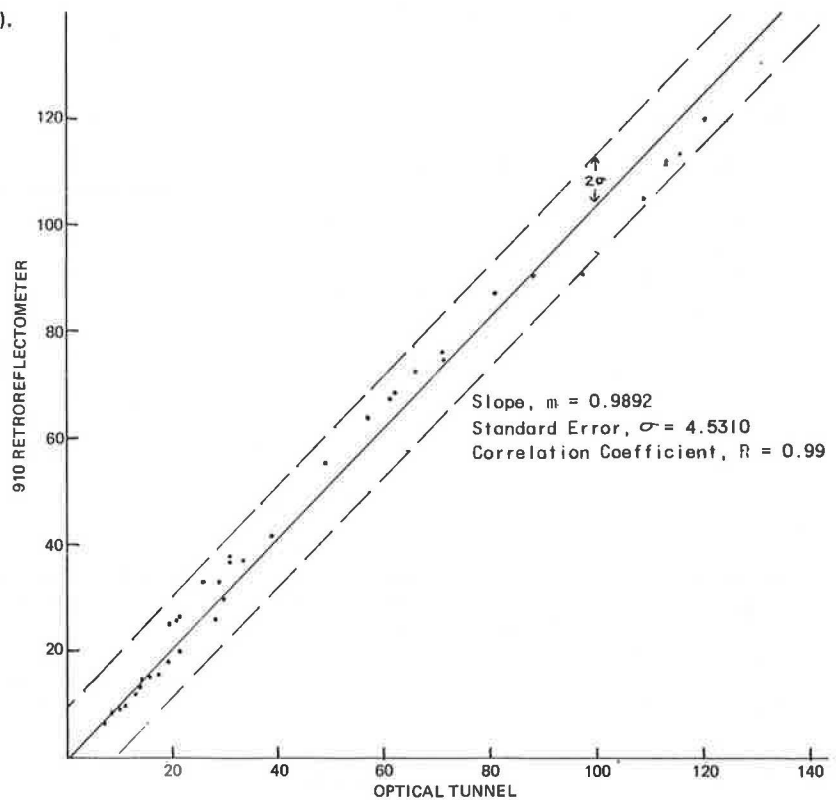


Figure 2. Gamma standard luminance at 21°C (70°F).



range setting is not used. The sensitivity of the equipment at this setting makes it virtually impossible to obtain a stable reading.

# TEST PROCEDURE

To test the performance of this instrument under the range of temperatures commonly found in Pennsylvania, specific luminance measurements were taken at 0°,

Figure 3. Gamma standard luminance at 38°C (100°F).

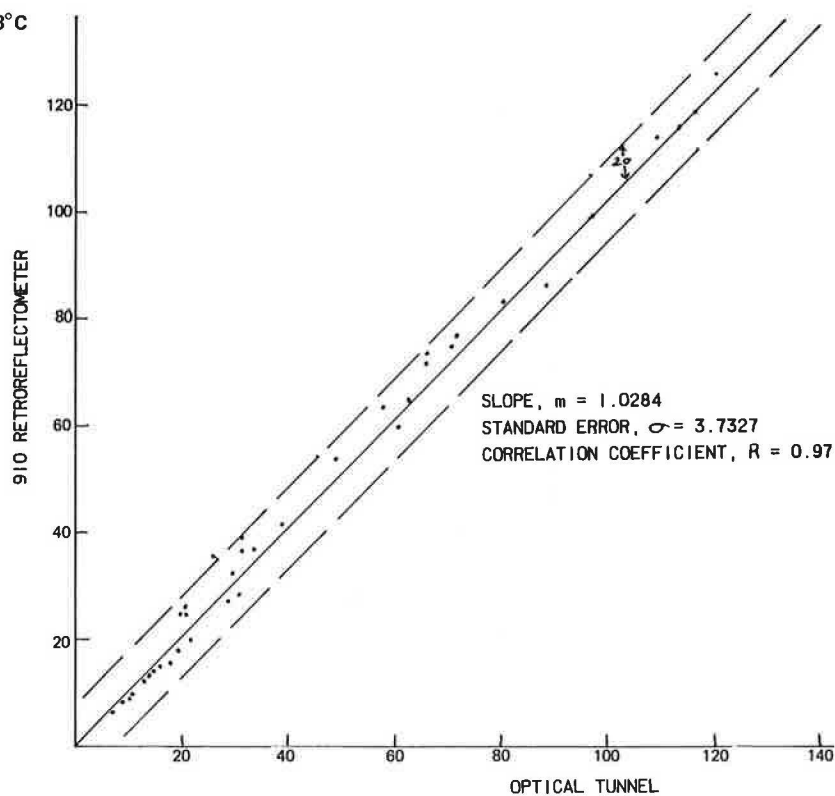
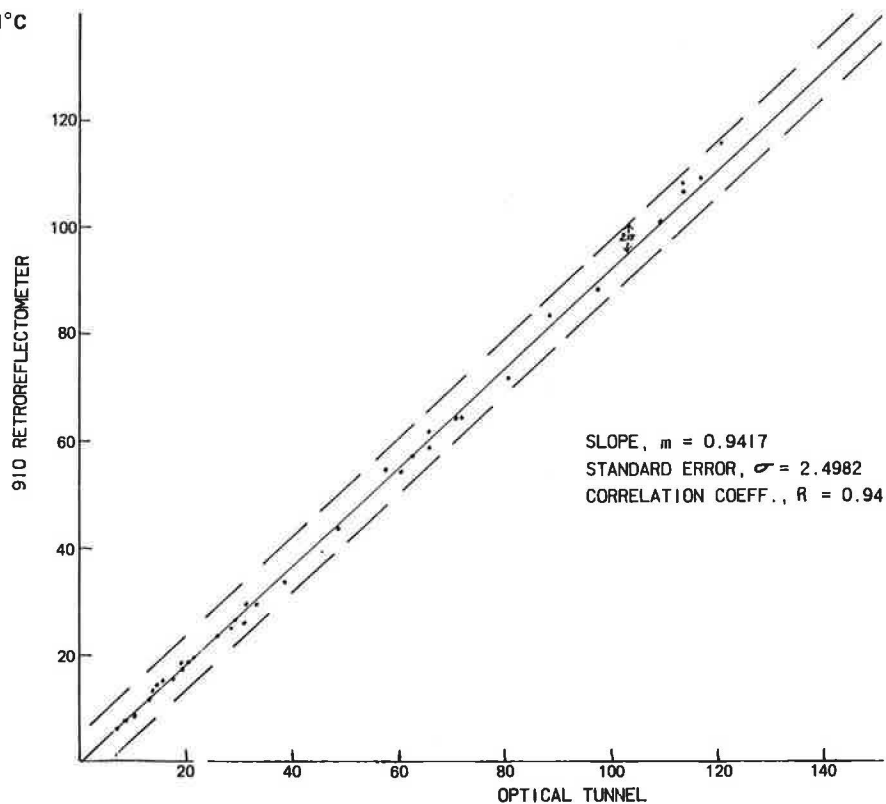


Figure 4. Tunnel standard luminance at 21°C (70°F).



21°, and 38°C (32°, 70°, and 100°F), respectively. The instrument, calibration standards, and test samples were placed in each temperature condition for a period of 90 min before the power switch was activated. The instrument was then activated and allowed to warm up for 60 s. Three readings were taken, averaged, and

recorded on 114 class 1 samples of colors silver-white, orange, yellow, blue, green, and red. The results were then compared to those obtained by the optical tunnel on the same sample plates.

Performance testing for various lighting conditions was accomplished by measuring the specific luminance

Figure 5. Gamma standard luminance of soiled old signs at 21°C (70°F).

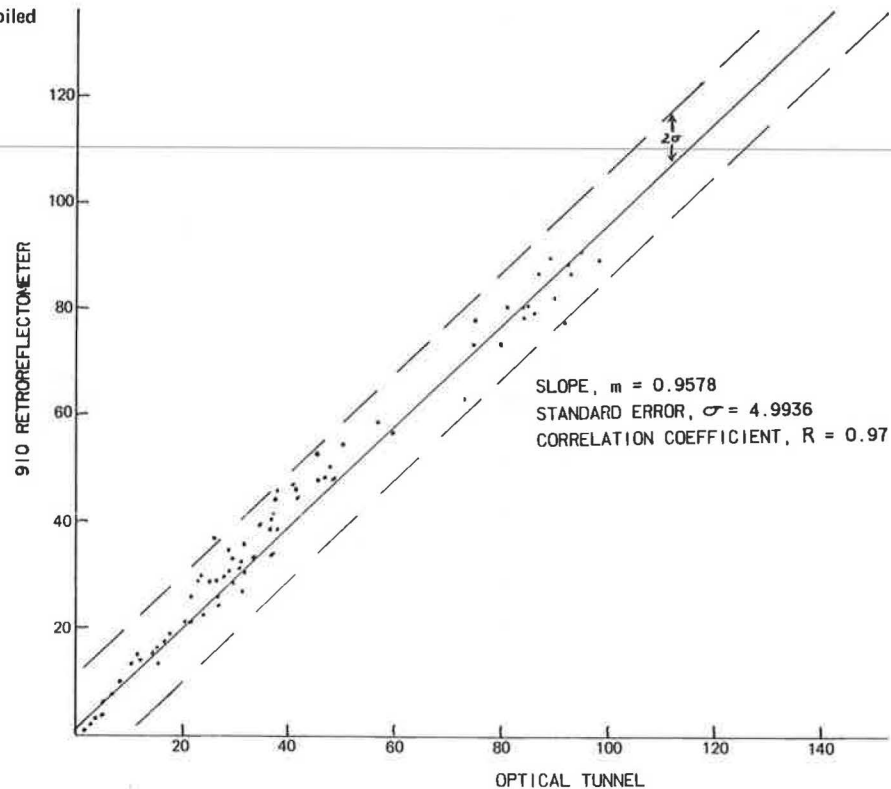
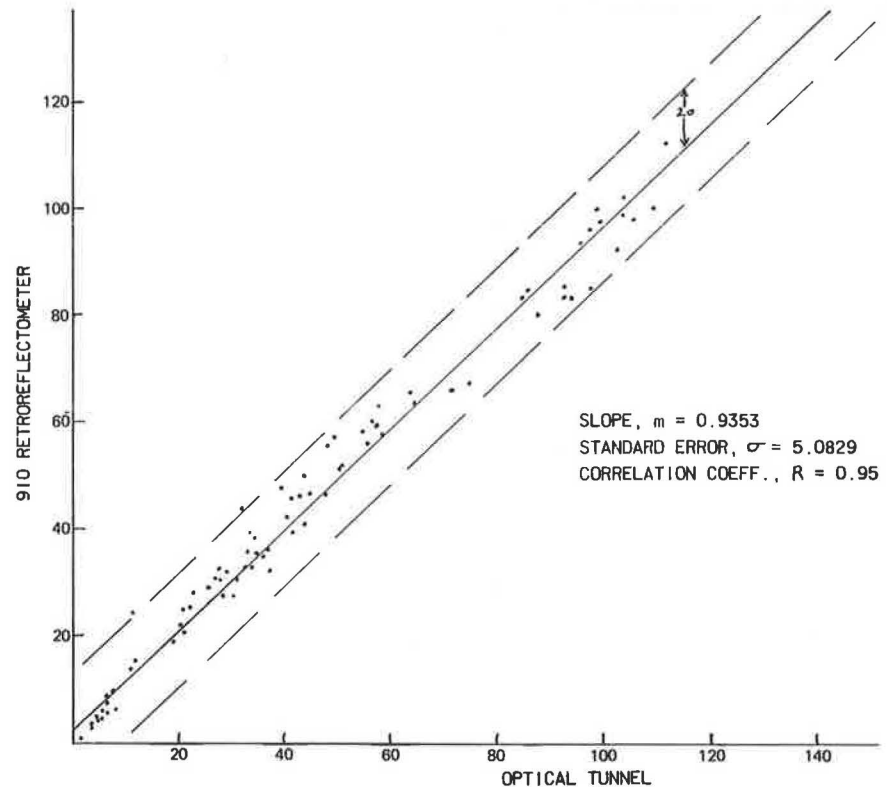


Figure 6. Gamma standard luminance of cleaned old signs at 21°C (70°F).



of sample plates while in bright sunlight and then repeating the readings under cloudy skies. Testing for performance under conditions of varying relative humidity consisted of a random check of measurements taken while it was very cold and while humidity was extremely low and produced results identical to readings taken indoors while it was raining (relative humidity approaching or equaling 100 percent).

## RESULTS

Because the object of this study was to determine the possible use of the instrument for checking performance compliance of reflective materials with PennDOT specifications, measurements taken with the retroreflectometer were compared with the optical tunnel's Gamma Scientific model IC 2000 photometer's readings.

The results are shown graphically for each set of test variables in Figures 1-6. The first point of interest is the slope. In each case the slope of the graph (retroreflectometer versus photometer) approaches the ideal value of 1.00, showing a one-to-one correlation between the two measuring devices.

Second, each figure indicates, via dotted lines, the confidence level of the measurements. Points that fall between the dotted lines are within  $\pm 2$ , or a confidence level of 95 percent.

Finally, from the figures the correlation coefficient (R-value) can be calculated. This correlation defines the usefulness of the relationship as a predictor. The degree of correlation helps one decide whether a set of values can be used to predict the resultant values in a relationship.

Battery life expectancy was not determined. After 8 h of on time, which was measured over a period of several days, the batteries were still operable. Insofar as dry-cell batteries recover voltage if left inoperative after use, the extent of continuous on time creates a wide difference in the duration of useful operating time. Gamma Scientific now offers a rechargeable battery pack for the unit; the problem of battery replacement should no longer exist.

It is noteworthy that all tabulated results reflect measurements taken with the model 910B versus read-

ings obtained in the optical tunnel. In all but one instance, the 910B was calibrated by using the standard values supplied by the manufacturer. For one case (Figure 1) the standards were read first in the optical tunnel, and those new values used in the calibration procedure. Where this was done the correlation between test values was one of the lowest obtained ( $R = 0.94$ ), but the graph of the comparative readings showed a more linear graph with a smaller standard error.

## CONCLUSIONS AND RECOMMENDATIONS

Varying environmental conditions of lighting, temperature, and relative humidity found in Pennsylvania have no adverse effect on the operation or performance of the Gamma Scientific model 910B retroreflectometer.

The retroreflectometer is the only proven method for measuring the specific luminance of reflective sign material in the field. The device can be used to randomly check reflective sheeting materials at the time of manufacture for compliance with current PennDOT specifications. It can be used to ensure performance of the material for the duration of the manufacturer's warranty period, and it can be used as a determinant for replacing worn signs. Calibration standards could be manufactured at PennDOT and calibrated at the bureau's optical tunnel for each unit, for the colors and class deemed necessary.

## ACKNOWLEDGMENT

The contents of this report reflect our views and we are responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of PennDOT or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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