NIGHTTIME SEEING through HEAT-ABSORBING WINDSHIELDS

Val J. Roper, Illuminating Engineer
General Electric Company

SYNOPSIS

The glass used in heat-absorbing windshields currently available transmits 18 percent less light than ordinary windshields. This reduction in light transmission led to concern about the possibility of a serious reduction in nighttime-seeing distances, which are barely sufficient, at best.

Tests were conducted on an airstrip, using two identical cars equipped with sealed-beam headlamps. Ordinary and heat-absorbing windshields were interchanged in the two cars. Observations were made while driving at 40 mph., half with each type of windshield. Seeing-distance observations were made both against the glare of an approaching car and when the road was clear.

A summary of these observations shows an average reduction in seeing distance of not quite 6 percent for driving with no approaching vehicle and an average reduction of 2 percent when approaching another car on a straight, level road over a distance of almost a mile.

For the most critical portion of the seeing-distance curve, the last 500 ft. before meeting an approaching car, results show the same seeing distances through ordinary and heat-absorbing windshields. This may be explained by the slight reduction in brightness of the approaching headlamps as offsetting the reduction in brightness of the obstacles under observation. Both reductions are caused by the 18-percent additional absorption of light by the heat-absorbing glass.

As a result of these data, it may be argued that unless the driver does practically all of his driving at night, the daytime benefits to be derived from the heat-absorbing glass windshield offset the small reduction in seeing distance at night. This reduction averaged 3 percent over the entire seeing-distance curve obtained in the tests reported as a result of the investigation.

TWO types of heat-absorbing glass windshields are available for installation on motor vehicles. The lower portion of these windshields, through which one normally views the road, is essentially the same in both types. The heat-absorbing glass has relatively high iron content which effects an approximate 50-percent reduction in heat transmission, as compared to ordinary, clear glass windshields. The light transmission through this lower portion is reduced approximately 18 percent, as compared to that of clear glass windshields (see Figure 1).

This latter factor, the reduction in light transmission of 18 percent, caused some state administrators and others to express concern over the possibility of increased hazard in nighttime driving behind heat-absorbing windshields. They feared that seeing distances would be reduced materially, without compensating reduction in car speed.

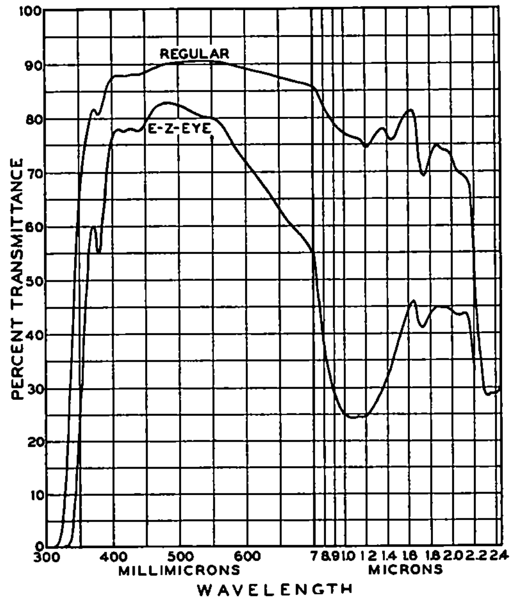

Figure 1. Spectral transmittance L.O.F. laminated plate glass thickness = 0.233 in.

Fortunately, the reduction in seeing distances is much less than the reduction in light transmission. Study of data from previously conducted seeing-distance tests (1), using headlamps of varied light output, indicated that the average reduction in seeing distance through the currently available heat-absorbing glasses should not exceed 5 percent. This is based on the assumption that the reduction in light transmission would have exactly the same effect as an equivalent reduction in beam candlepower from the headlamps.

Because of the general interest in the matter, it was decided to run some seeing-distance tests in the spring of 1951 to compare results with clear and tinted windshields. These were conducted at the General Motors Proving Grounds in April of 1951 by General Electric and Libbey-Owens-Ford. Six observer-drivers were used. The resultant data showed essentially the same seeing distances through heat-absorbing and clear glass windshields. However, it was admitted that an insufficient number of observations were made to be certain of an accurate statistical comparison. That is, the probable error in the observations was greater than the apparent difference in seeing distances through the two different types of windshields.

The increasing general interest of the public in the benefits of daytime driving in cars equipped with the heat-absorbing glass, the still-not-fully-satisfied concern of state administrators over the effects of higher light absorption, and the desire of car manufacturers and the glass manufacturers to resolve the issue, all combined to point to the desirability of conducting additional and conclusive tests.

It was decided that such tests should again be made using observer-drivers and with technique and instrumentation previously employed by

General Electric in seeing distance tests (2) with various types of head-lighting equipment, tests similar to those conducted previously but with more observations. This particular test procedure makes it possible to plot seeing-distance curves for the condition of approaching, meeting, and proceeding beyond another car on a straight,level, two-lane road. To eliminate all influencing variables, excepting that of the windshields (and seeing distances), the tests were conducted on a moonless, clear night with two identical cars, operating at identical speeds (40 mph.), equipped with identical, sealed-beam headlamps, and operated by the same two drivers throughout the tests.

There appears to be no reason to expect any difference in the relation of seeing distances obtained behind the two different windshields with drivers having less than normal visual acuity as compared to drivers having normal visual acuity. However to check this point the two drivers were selected as having 20/20 acuity by the AMA chart (one with spectacles). And additional observations were made with two passenger-observers who had 20/40 acuity.

The test obstacles were 16-in. squares of painted paper board having a reflectance of 7.5 percent. They stimulate the hazard presented by a small animal. Twelve of these were distributed ahead of and behind the meeting point, just off the right edge of the travelled roadway. Eleven of the obstacles on each side were gray in color. The twelfth (last) was red but of essentially the same reflectance (Figure 2).

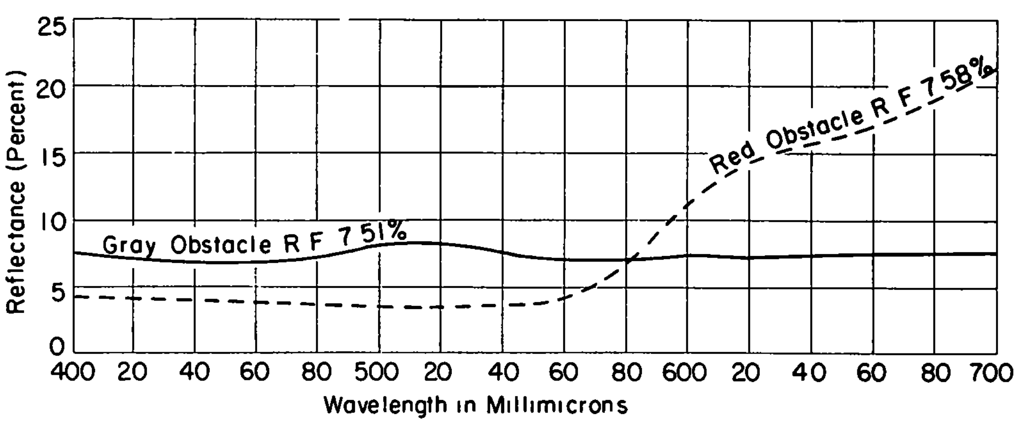

Figure 2. Spectral reflectance curves for 16-in. square obstacle test on heat-absorbing windshields.

Seeing distances were recorded by means of a paper-tape recorder (3) driven by a power takeoff from the transmission. The recorder had three marking pens, one connected through a relay to the horn ring, one to a switch held in the hand of the passenger-observer, and one to a switch held in the hand of a monitor riding in the back seat with the recorder.

The two cars were started at opposite ends of a 1.2-mi. stretch of the roadway. They started upon signal, accelerated to 40 mph. and held that speed for the entire test run. The drivers used the upper beams from their sealed beam headlamps until the two cars were 1,500 ft. apart, then depressed to the lower beams and continued to use the lower beams for the balance of the test run, even after passing the meeting point. This was done to effect a more critical seeing condition and to obtain lower seeing-distance values.

Upon perceiving each obstacle, the observer-driver depressed the horn ring, thus marking the tape on the recorder. (The horn was disconnected). Also, upon perceiving each obstacle, the observer-passenger pressed the switch which he held in his hand and which actuated a second pen on the tape. When the driver came abreast of each obstacle, the test monitor in the back seat pressed the switch he held in his hand, making a third impression on the tape of the recorder. The linear distance between the "pips" made by the driver and passenger and that made by the back seat monitor is the seeing distance. Twelve such seeing distance observations were recorded upon each individual test run, for each observer from each car. After six test runs, the windshields were changed. The purpose of changing so often was to avoid any possible influence of fatigue affecting readings through one of the windshields more than the other.

In order to plot the data in curve form as a function of the distance between the two cars, it is necessary to know exactly the distance between the two cars at the times of making the observations. This required maintaining uniform speed. A good check as to whether or not the uniform speed was maintained in any given test run was whether or not the two cars passed at exactly the half-way point. When they did not pass within approximately a car length of the half-way point, this test run was ignored.

The test location was an Air Force airstrip near Orlando, Florida. The time was late in February 1952. The surface was concrete in excellent condition. Two center lanes were used: the width of the two lanes was 22 ft. 4 in. The test obstacles were positioned at the outside edge of each lane. That is, they were just to the right of the travelled roadway. A total of 60 acceptable test runs were made, 30 for each windshield condition. This gave a total of 30 seeing-distance readings for each of the 12 obstacle positions with each windshield and for four observers: two drivers, two passengers. There were a total of 2,880 seeing-distance observations: 1,440 observations for each windshield condition (See appendix for sample procedure guide.)

All of the individual readings taken are plotted on Figures 3 through 10. Each of these figures also includes a single average curve drawn through the calculated statistical average for each obstacle location.

The 30 observations of each observer at each obstacle location were plotted on probability charts, from which the statistical averages were obtained. The average seeing distance of each obstacle for each observer and with each windshield is given in Table 1. The standard deviation for each is also included. Table 2 gives the percentage seeing distance of each obstacle in terms of 100 percent for the clear windshield.

A composite picture of the comparative results is given in Figures 11 through 14, which have the average curves for the heat-absorbing and clear

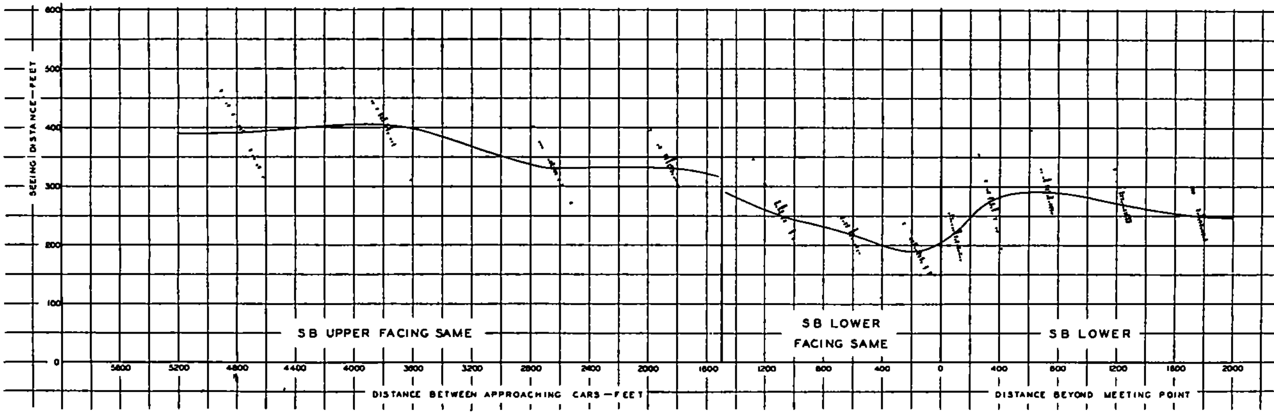

Figure 3. Clear windshield, driver-observer.

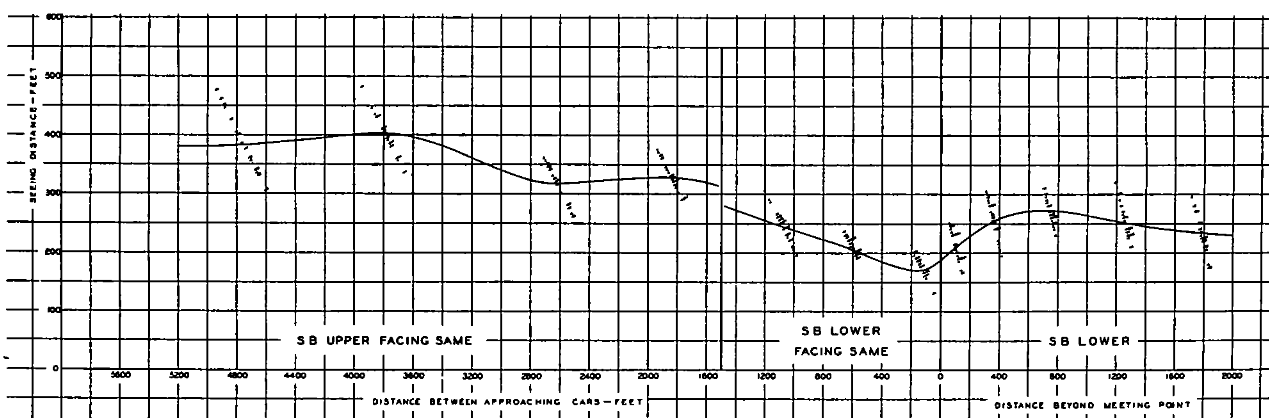

Figure 4. Heat-absorbing windshield, driver-observer.

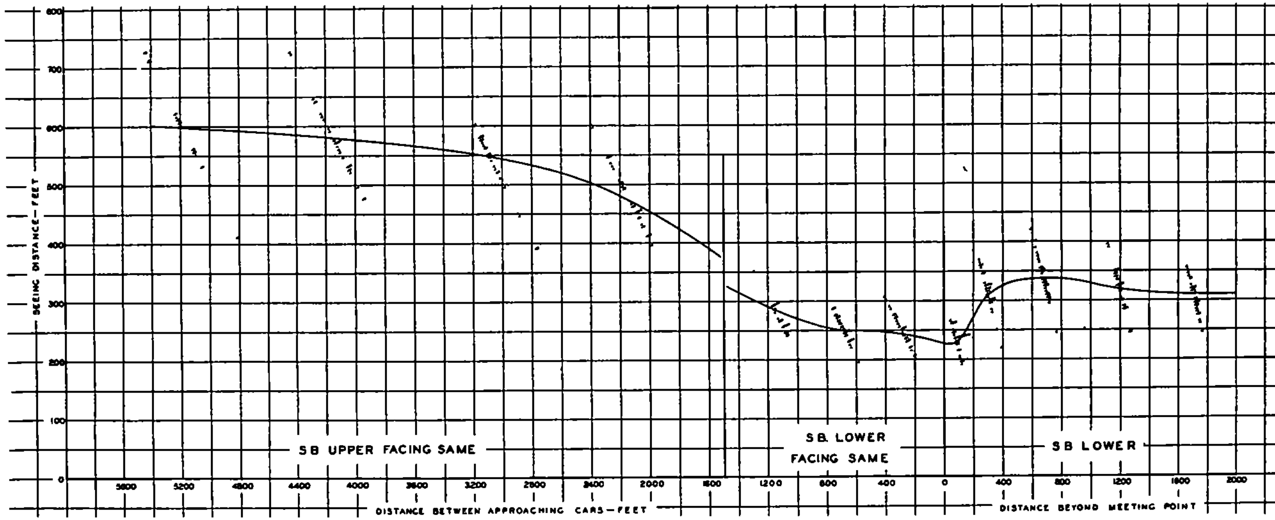

Figure 5. Clear windshield, driver-observer.

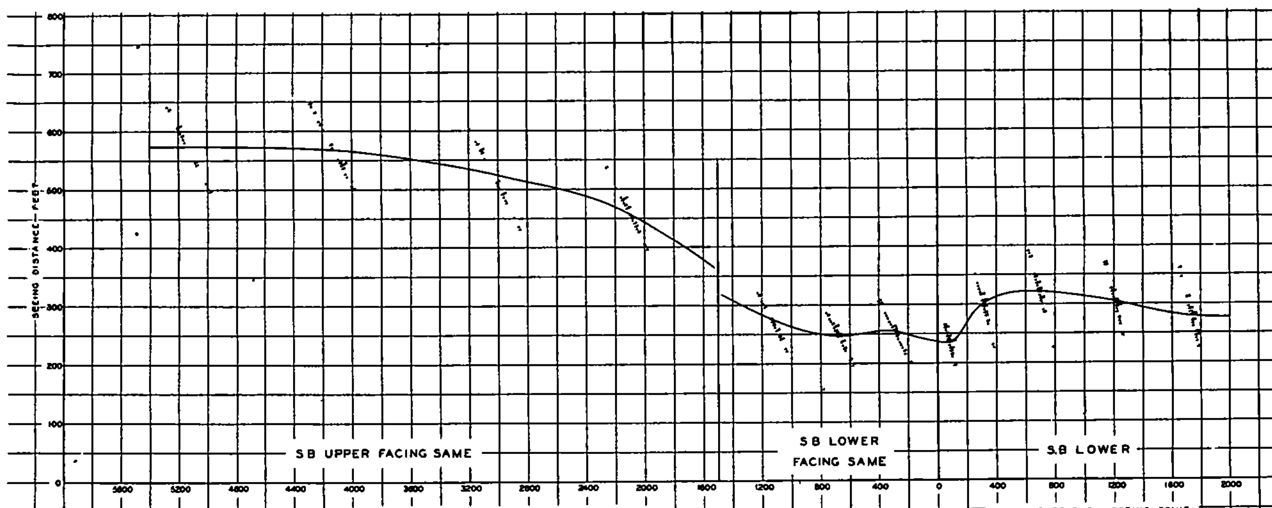

Figure 6. Heat-absorbing windshield, driver-observer.

windshields plotted together on the same graph. In terms of seeing through the clear glass windshield as 100 percent, the seeing distances through the heat-absorbing windshield varied from 90 to 104 percent.

TABLE 1

AVERAGE DISTANCE OF PERCEIVING OBSTACLES ($\bar{X}$)
AND STANDARD DEVIATION OF SUCCESSIVE TRIALS (σ)

		Driver				Passenger			
		Devine		Boylan		Besch		Wagar	
*		$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
20A	Cl.	391	55	599	75	473	58	436	56
	H.A.	382	57	572	72	477	63	402	61
15A	Cl.	405	29	580	62	468	53	412	49
	H.A.	403	45	568	60	468	54	400	42
10A	Cl.	331	32	548	83	429	69	422	83
	H.A.	317	39	526	64	415	66	410	76
6A	Cl.	332	27	474	54	381	46	370	42
	H.A.	328	29	460	42	373	37	337	47
3A	Cl.	251	37	286	47	276	49	244	28
	H.A.	246	27	278	36	278	41	234	26
1A	Cl.	221	21	250	23	247	18	214	15
	H.A.	208	15	246	29	247	20	209	21
1B	Cl.	189	31	244	37	333	32	225	32
	H.A.	170	25	255	33	333	22	240	39
3B	Cl.	217	26	227	25	246	16	215	21
	H.A.	208	32	236	21	244	14	221	19
6B	Cl.	274	46	307	36	303	36	260	28
	H.A.	252	39	299	31	291	32	246	36
10B	Cl.	291	24	337	37	334	45	279	30
	H.A.	273	24	322	35	303	36	262	31
15B	Cl.	269	26	320	38	300	33	270	35
	H.A.	252	31	306	33	287	36	265	37
20B	Cl.	250	28	310	34	288	33	283	45
	H.A.	235	33	280	33	270	30	266	34

*Hundreds of feet ahead and behind meeting point.

There appears to be no significant difference in the comparative results with the driver-observers and passenger-observers, although the data do show a considerable variation in the ability of the individual observers to see at night.

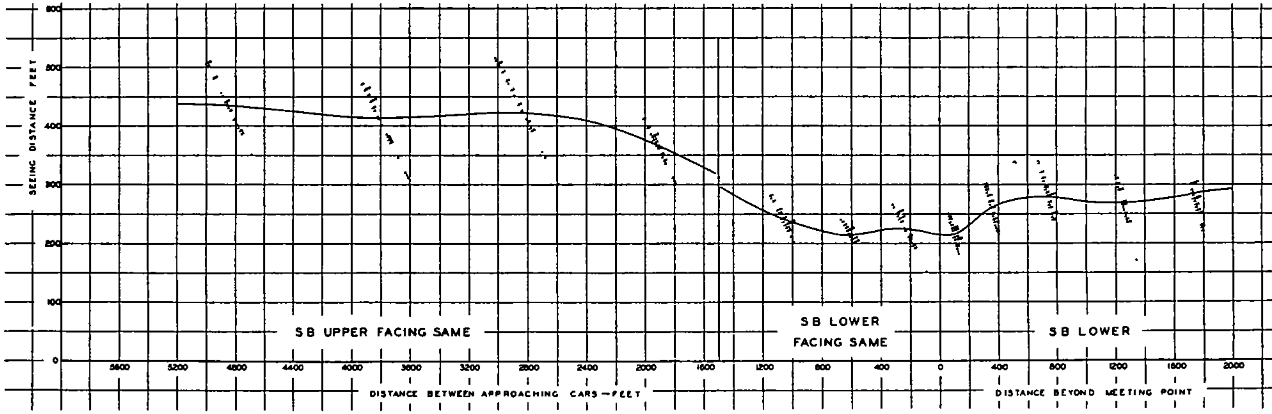

Figure 7. Clear windshield, passenger-observer.

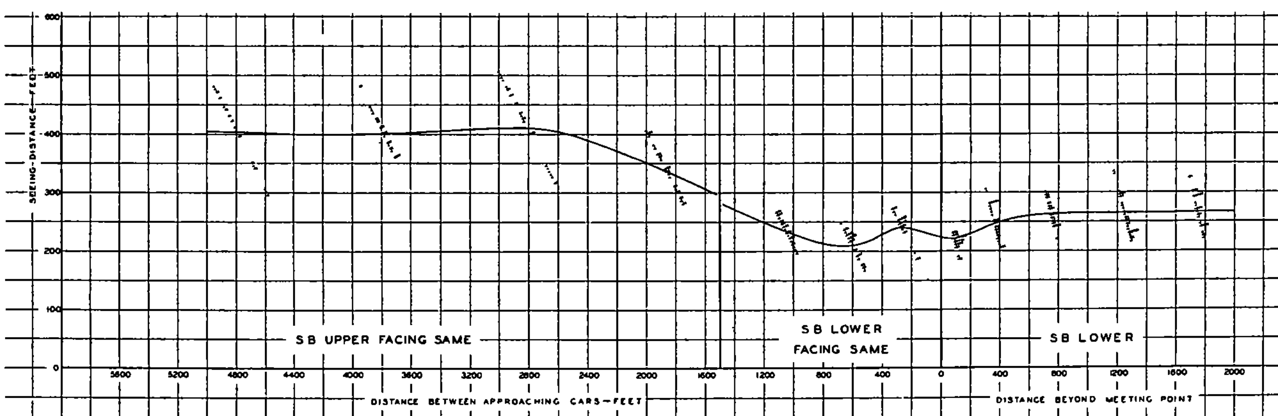

Figure 8. Heat-absorbing windshield, passenger-observer.

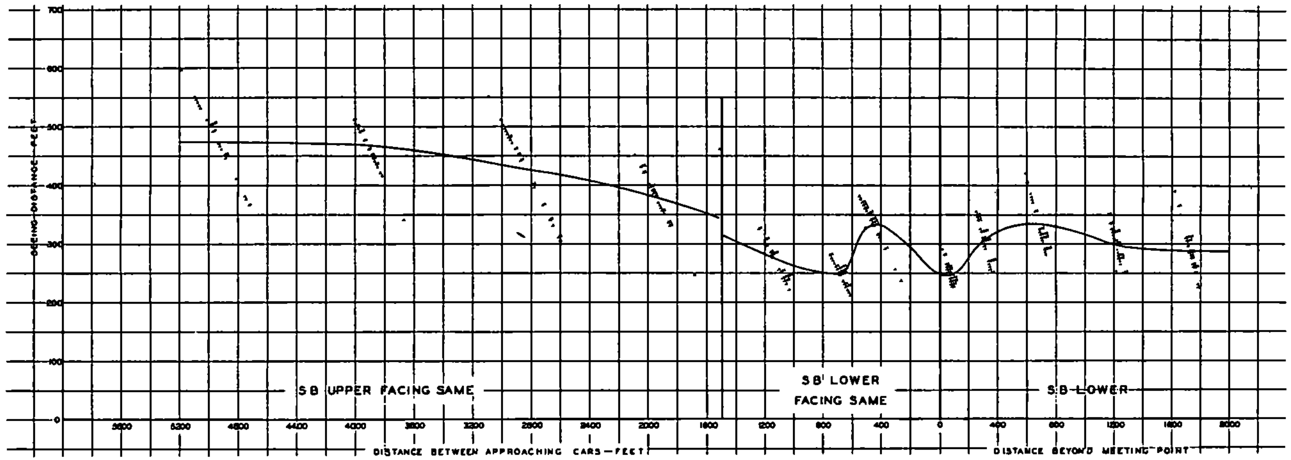

Figure 9. Clear windshield, passenger-observer.

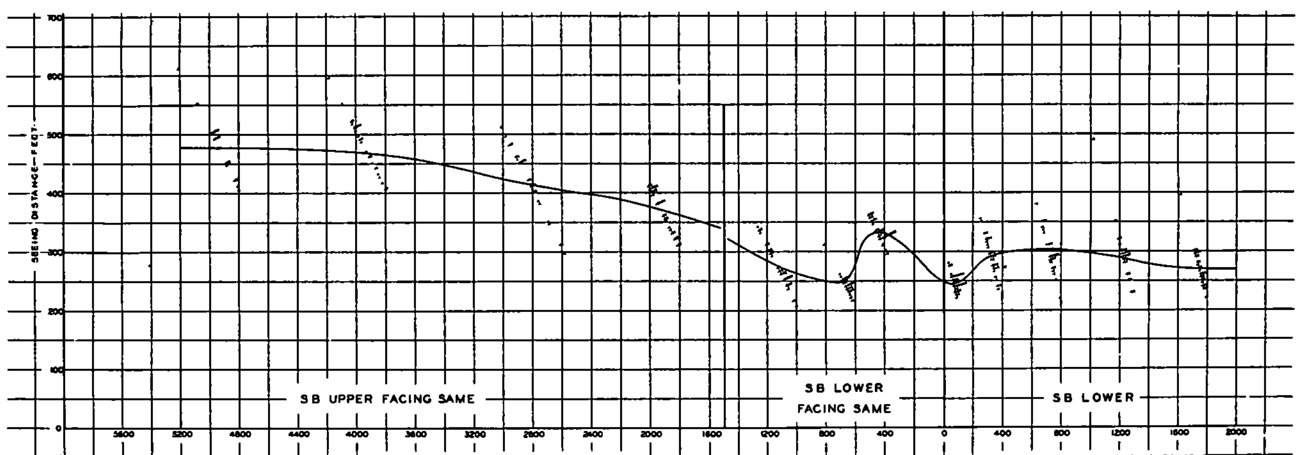

Figure 10. Heat-absorbing windshield, passenger-observer.

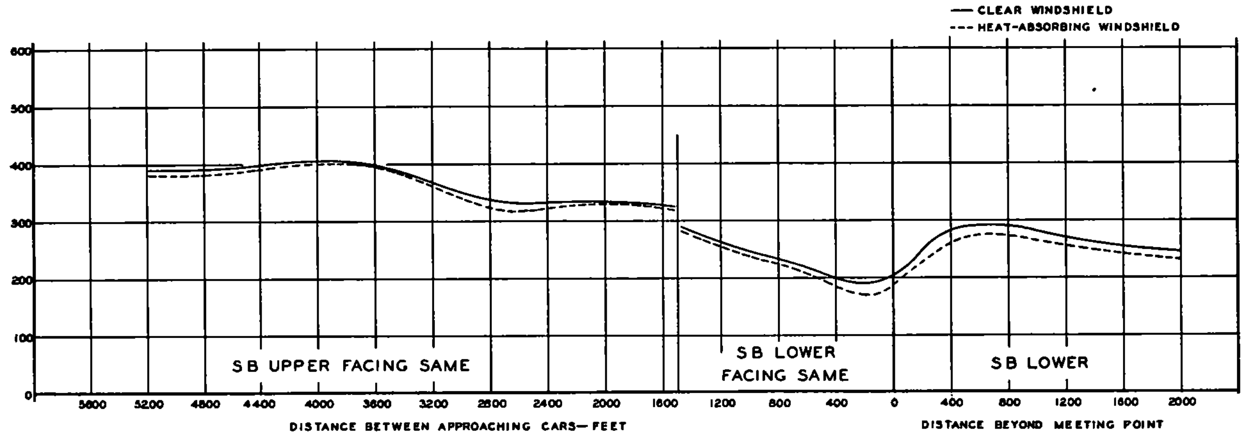

Figure 11. Driver-observer.

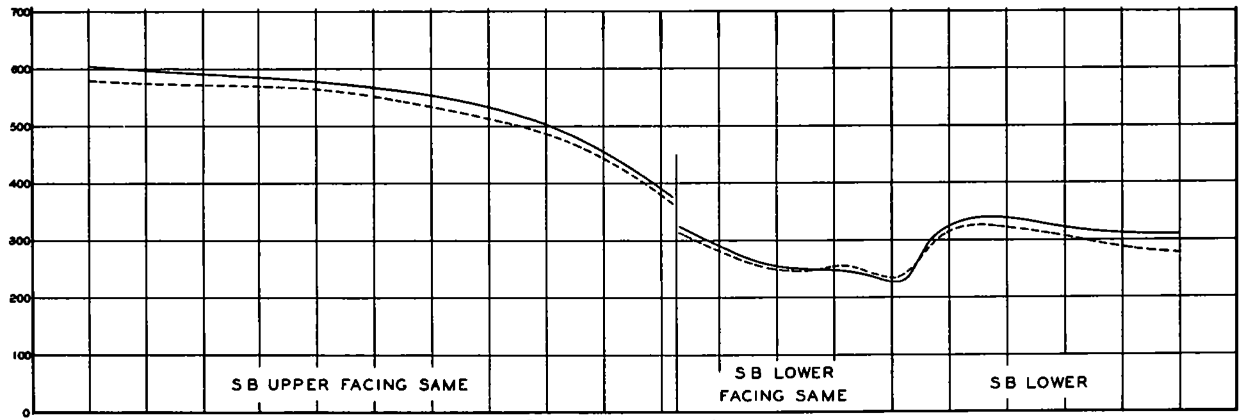

Figure 12. Driver-observer.

TABLE 2

SEEING DISTANCES PERCENT HEAT ABSORBING OF CLEAR WINDSHIELD

			Averages		
*	Devine	Boylan	Besch	Wagar	Average
20A	97.7	95.5	100.8	92.2	96.55
15A	99.5	97.9	100.0	97.1	98.62
10A	95.8	96.0	96.7	97.2	96.43
6A	98.8	97.0	97.9	91.1	96.20
3A	98.0	97.2	100.7	95.9	97.95
1A	94.1	98.4	100.0	97.7	97.55
1B	89.9	104.5	100.0	106.7	100.28
3B	95.9	104.0	99.2	102.8	100.47
6B	92.0	97.4	96.0	94.6	95.00
10B	93.8	95.5	90.7	93.9	93.48
15B	93.7	95.6	95.7	98.1	95.78
20B	94.0	90.3	93.7	94.0	93.00
Avg.	95.27	97.44	97.62	96.78	96.78

*Hundreds of feet ahead and behind meeting point.

The average loss in seeing distance with the heat-absorbing windshield is somewhat less for that portion of the curve involving an opposing vehicle, especially within the last 1,500 ft. before meeting. This may be explained by the 18-percent reduction in brightness of the opposing headlamps viewed through the heat-absorbing windwhield as compared to the regular windshield. This reduction in glare, although too slight to be noticeable, does counteract to some extent the reduction in obstacle brightness. For what might be termed the most-critical portion of this seeing-distance curve, that portion providing the least seeing distance, there is little reduction effected by the heat-absorbing windshield. The average reduction for all obstacle positions involving opposing headlamps was 2 percent. The average reduction for those obstacle positions involving clear road driving was 5.7 percent. The over-all average of all the readings through the clear windshield was 325 ft., of those through the heat-absorbing shield, 315 ft. A single composite graph of the average of all observers is given in Figure 15.

These data prove that the difference in nighttime-seeing values through the heat-absorbing windshields currently available and standard glass windshields is, indeed, much less than the additional light absorption of the heat-absorbing glass.

You will observe a break in each average seeing-distance curve at the point where the two cars are 1,500 ft. apart. This is the point at which both cars shifted from the sealed-beam upper beam to the sealed-beam lower beam. It was somewhat in advance of the optimum point for depressing the beams, which according to previous data (4) is on the order of 1200 ft. with sealed-beam headlamps. This explains the immediate drop in seeing-distance values.

In actual practice, the seeing distances would be considerably less than those obtained in this test. These observer-drivers knew the test

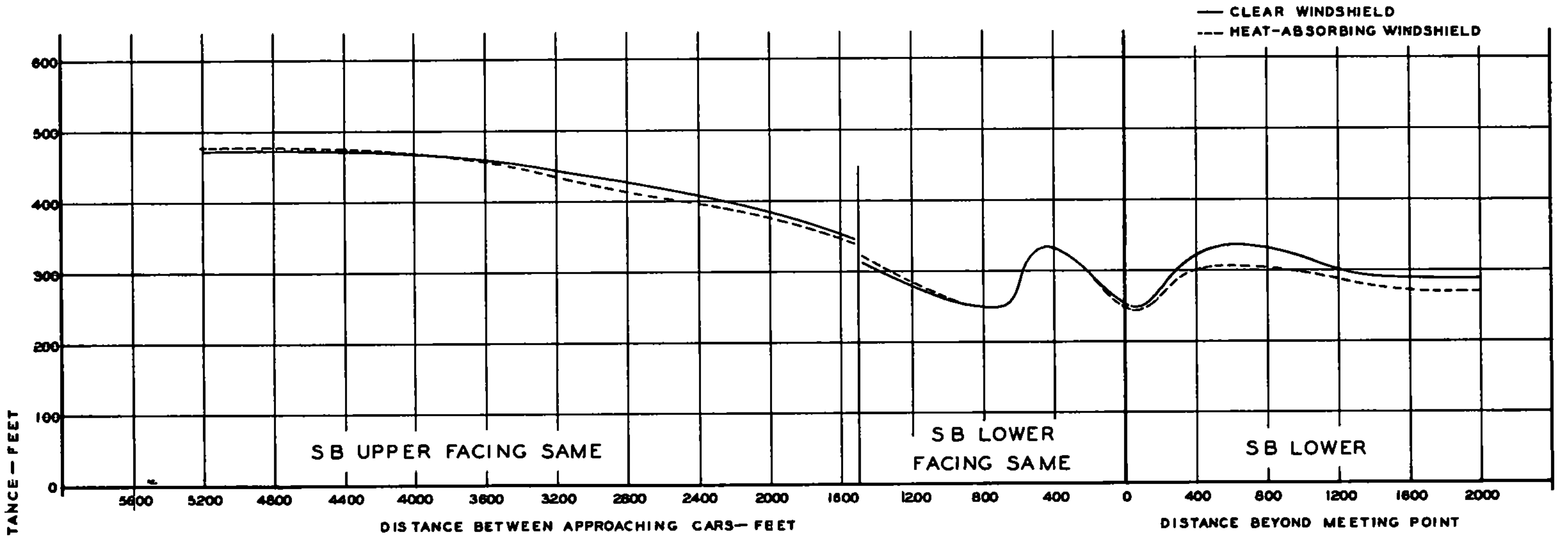

Figure 13. Passenger observer.

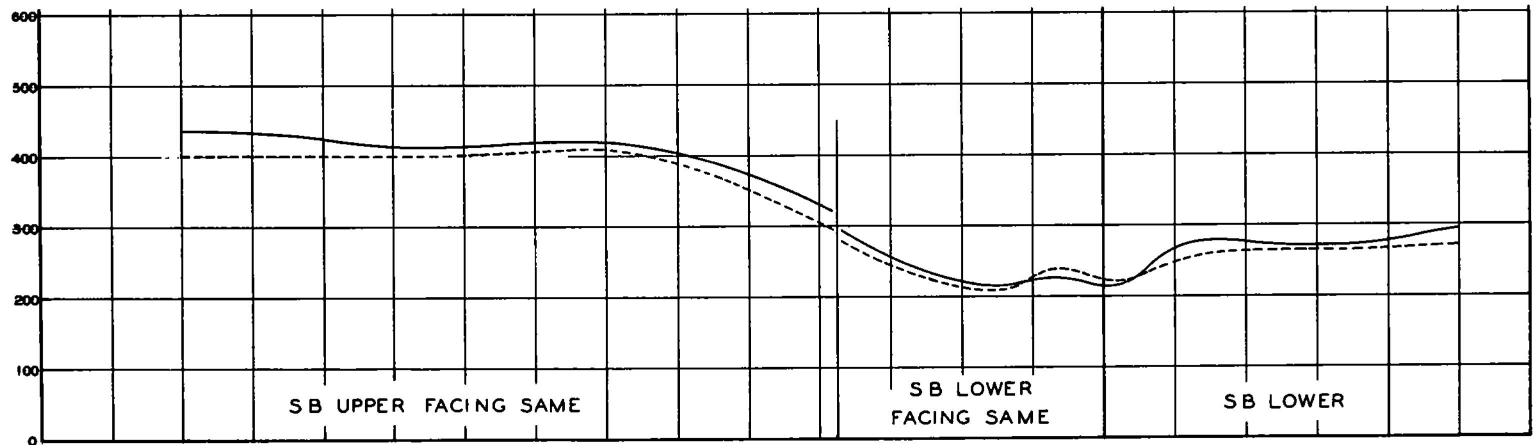

Figure 14. Passenger-observer.

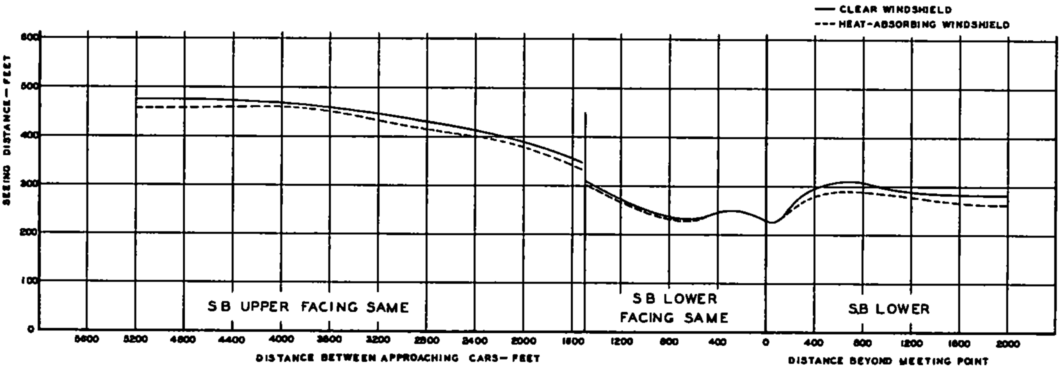

Figure 15. Average of four observers.

obstacles were there and where to look for them. Therefore, they were displaying more than normal attention, and obtained seeing-distance values higher than those which would be normal in ordinary driving (1, 2). It follows that state administrators were properly concerned about any change which reduced nighttime-seeing distances. For at best, these are none too good. The car manufacturers were, of course, equally concerned about the situation and, from the information available at the time of introduction of heat-absorbing glass windshields, were of the opinion that the reduction in light transmission was not sufficient to offset their daytime advantages. The results of the Orlando test can be interpreted to justify this position.

VISIBILITY ON LIGHTED STREETS*

Direct measurements of relative visibility, comparing windshields of regular, clear glass and heat-absorbing glass, were made on lighted streets. There were 3 observers, S. K. Guth, A. A. Eastman, and R. C. Rodgers, all of the Lighting Research Laboratory at Nela Park. These observers took readings simultaneously from the front seat of a test car, using Luckiesh-Moss Visibility Meters. The test object, of which relative visibility measurements were made, was a 12-in. disk, of 8 percent reflectance, in a vertical position at street level, 200 ft. in front of the test car. This technique of measurement had been employed by Reid and Chanon (5, 6) in earlier studies of factors affecting visibility on lighted streets.

Measurements were made under three street-lighting systems. These lighting systems conformed to standards of the American Standard Practice for Street and Highway Lighting (7) for street classifications of local traffic, light traffic, and medium traffic, respectively. On each street were four test stations, uniformly spaced between street lamps. At each station measurements were made first with one type of windshield then with the other. The sequence was reversed at successive test stations. The test car, with readily replaceable windshields, was provided by H. C. Doane of Buick.

*Contributed by Kirk M. Reid, Illuminating Engineer, Lamp Division, General Electric Company, Cleveland.

The average of all measurements showed a relative visibility with the heat-absorbing windshield approximately 2 percent below that with the clear windshield. Measurements under each of the lighting systems conformed to this average, within reasonable variations.

The heat-absorbing windshield with a darkened strip near the top gave best results when the darkened strip reduced the veiling glare from one or more of the nearby street lamps. This took place at some stations, depending on the height and posture of the observer. At such stations the visibility with the heat-absorbing windshields was fully equal to that with the clear windshield. Under other conditions the differential in favor of the clear windshield was somewhat greater than the overall average of 2 percent.

ACKNOWLEDGMENTS

The test cars used were furnished by the Buick Motor Division of General Motors. The observer-drivers were A. W. Devine, assistant registrar of the state of Massachusetts, and Henry W. Boylan, Experimental Engineering Department, Buick Motor Division. The observer-passengers were Emil Besch, assistant supervisor, Chemical Laboratories, Chrysler Corporation, and T. E. Wagar, chief electrical engineer, Studebaker Corporation. The test monitors were Val Roper and Glen Pracejus of the General Electric Co., Nela Park, Cleveland. H. C. Doane, assistant chief engineer, Buick Motor Division, served as chairman of a committee of the Automobile Manufacturers Association charged with organization for the test. Also present as consultants and observers were George E. Keneipp, director of vehicles and traffic for the District of Columbia and chairman of the Committee on Engineering and Vehicle Inspection of the American Association of Motor Vehicle Administrators; Rudolph F. King, registrar of the state of Massachusetts; W. F. Sherman, manager, Engineering and Technical Department of the Automobile Manufacturers Association; T. F. Creedan, field representative, Automobile Manufacturers Association; Bruce G. Booth, of the legal staff of General Motors; and Don Munroe, of Chemical Laboratories, Chrysler Corporation.

The authors are also indebted to W. H. Abbott, expert statistician at G. E.'s Nela Park, for his statistical analyses of the 2,880 observations; to Byron F. King, Orlando Buick dealer, for the arrangements with the Airport; and to Col. James E. Roberts, Pine Castle Base Commander, who provided the facilities at the Pine Castle Airport, Orlando, Florida.

REFERENCES

1. Seeing with Motor Car Headlamps, "Transactions I.E.S.", Vol. XXXIII, No. 5 (May 1938).
2. Seeing Against Headlamp Glare, "Illuminating Engineering" Vol. XLVII, No. 3 (March 1952).
3. An Illumination Recorder - "Illuminating Engineering", Vol. 46, P. 310, 1951.
4. Silhouette Seeing With Motor Car Headlamps, "Transactions I.E.S.", Vol. XXXIV, No. 9, (November 1939).

5. Studies in Fundamentals of Highway Lighting, "Transactions I.E.S", Vol. XXXI, No. 2 (February 1936).
6. Determination of Visibility on Lighted Highways, "Transactions I.E.S.", Vol. XXXII, No. 2 (February 1937).
7. American Standard Practice for Street and Highway Lighting, "Illuminating Engineering", Vol. XLVII, No. 8 (August 1952).

APPENDIX

Heat-Absorbing Windshield
Orlando (Fla.) Tests

Procedure, February 26, 1952

<u>SIGNALS</u> - Control Car A signals by turning upper beam on and off twice.
Then turn lights off and wait for reply signal.
Car B uses same signal in reply.
Car A turns lights on and starts.
Car B does likewise.

<u>SPEED</u> - 40 mph.

<u>LIGHTS</u> - Cars start on upper beam, 6,000 ft. apart. Depress beams at red lantern when cars are 1,500 ft. apart. Continue to end of run on lower beam. Raise to upper beam and turn around for next run. Turn lights out at starting point.

<u>TEST RUNS</u> - Each run to be numbered consecutively. Bad runs to be noted on log sheet (no signal to other car). Run numbers to be put both on the test tape and on the log sheet. Also note car number on each. When run is rejected, note and explain on log sheet. Each car to report at north end whether runs are good or bad, and reason. Controller at north end will note and advise time for windshield change.

<u>MATERIAL</u> - Start with clear glass and make enough runs to get six good ones. Change to heat-absorbing glass (no tint in upper part) and get six good runs. Repeat.

<u>RECALL SIGNAL</u> - Spotlight flashed in air.