A COMPARISON OF THE LEGIBILITY AND VISIBILITY OF ENAMEL AND REFLECTORIZED 1971 VIRGINIA LICENSE PLATES

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ABSTRACT

The Safety Section of the Virginia Highway Research Council carried out observation tests of the legibility and visibility of reflectorized and enamel license plates.

The primary objectives were to determine the comparative legibility and visibility distances of these plates under low beam headlights and from several angles of approach.

Fifteen subjects were selected from the civilian driving population and law enforcement agencies. Each was required to have a valid motor vehicle operators license and to pass a visual screening examination.

License plates were mounted on the rear of a 1968 Chevrolet four door sedan. A 1970 Ford station wagon was used as the test vehicle. The same vehicles were used for each subject. Tests were carried out during favorable weather conditions, in a rural locale at night.

For legibility tests the test vehicle started 200 feet from the stationary vehicle and proceeded until the subject could read all the digits without error.

Visibility tests started 2,000 feet from the stationary vehicle and proceeded at a speed not in excess of 5 mph until either the license plate or car could be seen.

Tests were performed at various angles of approach and at various lighting arrays.

In each set of legibility tests, the reflectorized plate could be read at a greater distance than could a similar enamel plate. In each set of recognition visibility tests an individual was able to determine that a danger to his vehicle operation existed at a greater distance when the stationary vehicle he was approaching was equipped with a reflectorized license plate.

In each set of point source visibility tests, the distance at which a subject could detect light coming from a stationary vehicle was significantly greater for an automobile equipped with reflectorized license plates.

SUMMARY OF FINDINGS

(1) Reflectorized license plates can be read at an average distance 43% greater than can enamel plates.

(2) Enamel plates can be read at a 23% greater average distance on the rear of a darkened vehicle than on the front of the same vehicle with its low beam headlights on.

(3) A vehicle equipped with a reflectorized license plate can be "recognized" at a distance from 1.70 to 2.78 times greater than can the same vehicle equipped with an enamel license plate.

(4) An automobile equipped with a reflectorized license plate can be "detected" at a distance between 2.25 to 3.75 times greater than can the same vehicle equipped with enamel plates.

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BACKGROUND AND PURPOSE

The state of Virginia is contemplating a change in its motor vehicle license plates from enamel to reflectorized. To supervise an evaluation of the alternative, a committee composed of Vern L. Hill, Commissioner of the Division of Motor Vehicles; Col. H. W. Burgess, Superintendent of State Police; and John T. Hanna, Director of the Highway Safety Division, was established by an act of the 1970 Virginia General Assembly. Each of the three state agencies headed by the committee members was assigned a specific function to carry out. A consolidated report of the findings and recommendations from the study will be made to the Governor and the General Assembly prior to January 1, 1972.

For purposes of the study, the 1970 Virginia General Assembly authorized the issuance of experimental reflectorized license plates. [Virginia Code Annotated §§46.1-103.1 (1970).] The DMV issued 100,000 sets of reflectorized steel tags, 100,000 sets of specially designated plates to serve as a control group, as well as, 150,000 sets of aluminum plates, and the traditional steel tags coated with enamel paint. All the plates were manufactured by the Division of Corrections and were in a black-on-white color scheme.

On behalf of the Highway Safety Division, the Safety Section of the Virginia Highway Research Council conducted observation tests of the legibility and visibility distances of sample reflectorized and enamel types of license plates issued specifically for the comparative study.

The primary objectives of the observations were to determine: (1) Comparative legibility distances of reflectorized and enamel license plates under low beam headlight, (2) comparative visibility distances of the first point source of light, (3) comparative visibility distances at which distinct objects could be recognized under low beam light, and (4) the legibility and visibility of above three conditions from several angles of approach, under low beam headlight conditions.

PROJECT SIMULATION

In order to test the experimental design proposed in the working plan, several members of the Highway Research Council's Safety Section journeyed to the test site on July 7, 1971 to carry out a simulation of the test procedures. As a result of this first night's experimentation, the coordinators of the field studies made alterations in the proposed testing procedure in order to adhere to time restrictions placed upon the use of the test site.

The data tabulation form was redesigned to permit a more rapid recording of the information. In addition, the number of subjects to be used was reduced from twenty to fifteen. Other changes included a reduction in the number of angular positions in which the stationary vehicle would be observed from eleven to three. It was also decided that the headlights on the test vehicle carrying the observers would be on low beam rather than high beam for all test passes in order to provide minimum rather than optimum lighting conditions.

The enamel and reflectorized plates were alternated on the rear of the stationary vehicle for four passes of the test vehicle at each angle. An identical route of approach was used for both the moving and static tests, and the moving test was conducted only at 30 mph. The lights of the parked vehicle remained off during all tests to simulate a disabled vehicle parked along the roadway.

On July 12, 1971 four members of the Safety Section staff again performed a simulation of the testing procedures. As a result, additional changes were made in the experimental procedures.

It was decided to take two readings instead of one on each run of the visibility tests. One would be termed "point source" and the other "recognition". The first reading required the subject to state at what point he was first able to detect light from the parked vehicle. The second required the subject to make a subjective judgement as to the point at which he realized a clear and present danger existed and that he must take some form of evasive action to avoid colliding with the parked vehicle.

The number of positions of the stationary vehicle during the legibility tests was expanded to include the angles of 30^{o} and 00^{o} with lights off and 180^{o} and 150^{o} with the lights on; and the angles of 30^{o}, 00^{o}, and 180^{o} with lights off for the visibility tests (see Figure 1). Two passes rather than four, were made at each of these angles, one for enamel plates and one for reflectorized.

All legibility tests began 200 feet from the stationary vehicle, a distance at which the test subject would not be able to read the digits on the plates, and were conducted first. The visibility phase of testing commenced immediately at the conclusion of the legibility tests and began at a point 2,000 feet from the stationary vehicle. At this distance an observer cannot see an automobile when viewed under low beam headlights. The 30 mph moving test was deleted from the study because of the similarity to the newly designed static visibility tests.

In addition, all road signs and reflectorized road markers were covered to prevent these objects from being mistaken for a reflectorized license plate by the test subjects. The final modification resulting from the second night's simulation was that all observations would be conducted with the test vehicle traveling in the right-hand lane of the highway to simulate normal driving conditions.

METHODOLOGY

Fifteen experimental subjects ranging in age from 22 to 50 were used for the study. Eight came from the ranks of law enforcement agencies (state troopers, city policemen, and county deputies) and seven were licensed male adult drivers.

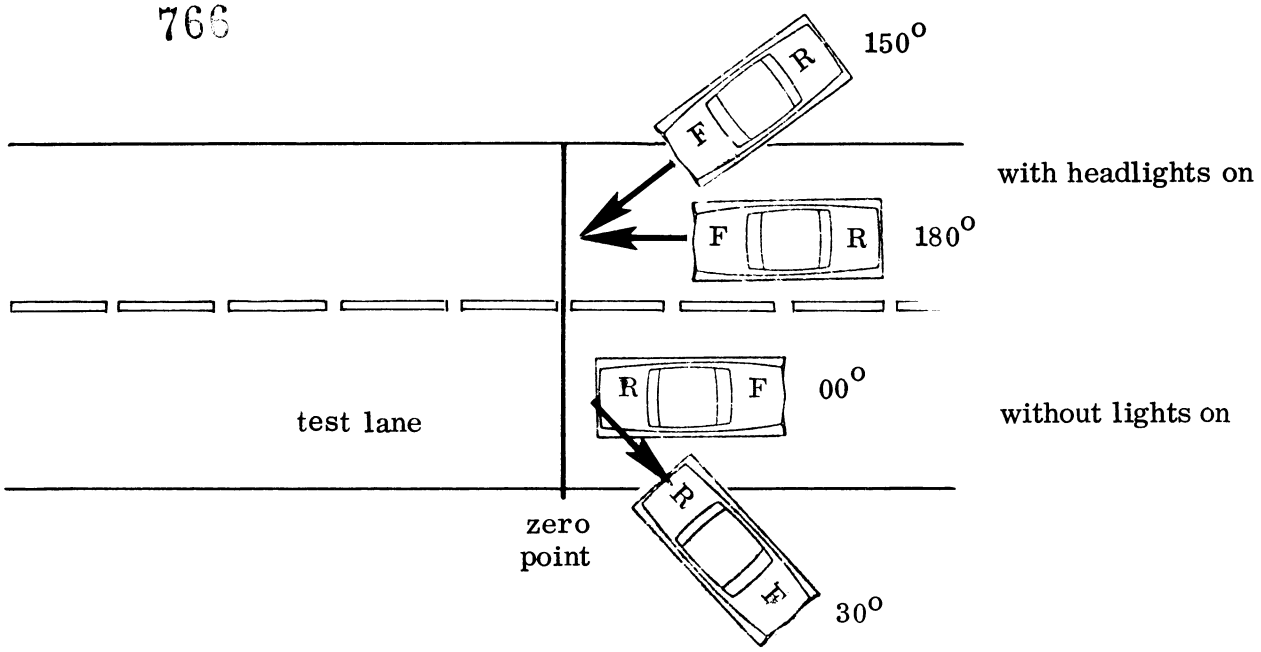
Observations were made during nighttime under favorable weather conditions. To prevent the test subjects from memorizing the plate numbers, twenty sets with different digital combinations were used. In each set one plate was of the reflectorized type and one was enamel. To aid the statistical analysis of the test data, a random selection technique was used to assign the plates an order of use for each night's session.

The testing course (see Figure 1) was located in the eastbound lanes of an unopened section of Interstate 64 west of Waynesboro, Virginia in a rural locale. This area was selected because it contained a minimum of distractions to the subjects, public, and researchers.

A parked vehicle was equipped with one type of plate for the first set of observations and the other plate type was used on the second run. The selection of the initial plate in each test was based on a random drawing procedure. One limiting criterion was that there must be an equal number of each type of plate for every test situation.

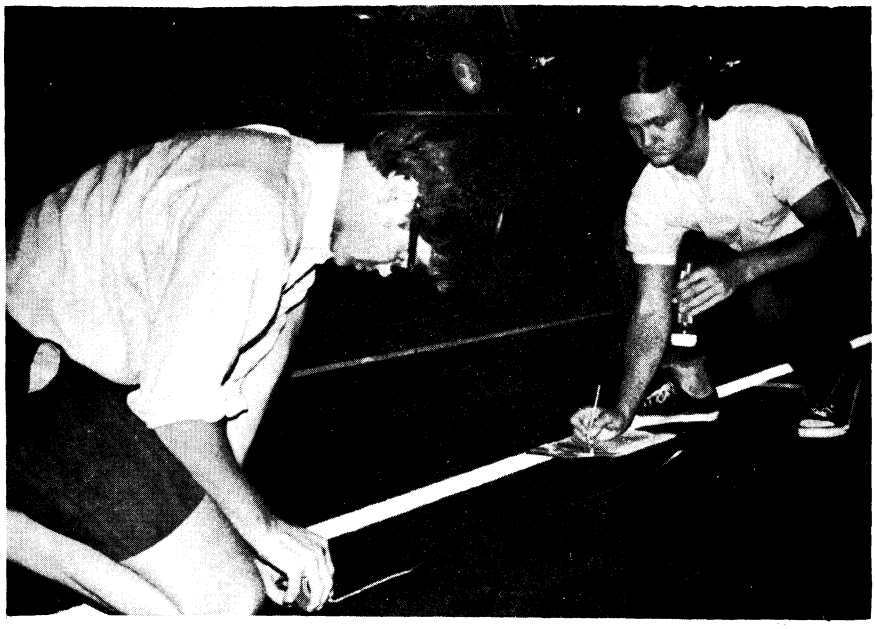
A second vehicle, with the subject sitting in the passenger seat, started 200 feet from the stationary vehicle and proceeded down the test course at a speed less than 5 mph until the plate being tested became legible. The car was stopped and the distance to the studied plate was measured (see Photograph 1) and recorded on a data tabulation form (see Figure 2). The position of the stationary vehicle was changed for each test and this, in effect, altered the test course.

An attempt was made to have the test conditions closely resemble actual roadside situations. Rear end measurements were obtained when the target vehicle's lights were off; thus it resembled a car blocking a traffic lane or parked on the road shoulder. Front end measurements were taken with the stationary vehicle's headlights on and the car appeared as an approaching vehicle.



TESTS Low Beam — Visibility Reflectorized and Enamel		TESTS Low Beam — Legibility Reflectorized and Enamel
Rear without lights at 00°	Point source	Rear without lights at 00°
Rear without lights at 00°	Recognition	
		Rear without lights at 30°
Rear without lights at 30°	Point Source	
Rear without lights at 30°	Recognition	Front with low beam at 180°
Front without lights at 180°	Point Source	Front with low beam at 150°
Front without lights at 180°	Recognition	

Figure 1. Test course diagram.



Photograph 1. Measuring test distances.

In the second phase of the study, the visibility of both types of plates was measured on the same test site and course used in the legibility tests.

The test vehicle started toward the stationary vehicle from a distance of 2,000 feet and traveled at a speed of 5 mph or less. When the subject was able to detect the first clear light reflected from the parked car, the test vehicle was stopped and the distance measured and recorded. The test vehicle then proceeded along the course until the subject was able to recognize that an emergency existed and that he would be required to take some evasive action. This point was also measured and recorded.

Each subject was given a visual screening examination with the TITMUS vision tester. A corrected or uncorrected vision of 20/40 was required of each participant. Also, each subject was to possess a valid Virginia drivers license.

Each night the test site was closed to all traffic. A barricade consisting of two signs, one "road closed" and the other "do not enter", as well as two blinking amber lights, five octopus reflectorized markers, and five lane marking standards with reflectorized flags were used at the west end of the site (see Photograph 2). These precautions were taken to protect the subjects, researchers, and visitors from construction and illegal traffic approaching from the rear.

DATA TABULATION FORM

NAME _____ AGE _____ OCCUPATION _____

DATE _____ WEATHER CONDITION _____

Run Number	License Plate Number	Plate Type (R-E)	Test Vehicle Headlight	Parked Vehicle Lights on = N off = F	Parked Vehicle Angle	Visibility Distance in Feet		Legibility Distance in Feet
1								
2								
3								
4								
5								
6								
7								
8								
						Point Source	Recog-nition	
9								
10								
11								
12								
13								
14								

Figure 2. Data tabulation form.

Photograph 2. West barricade as viewed from west.

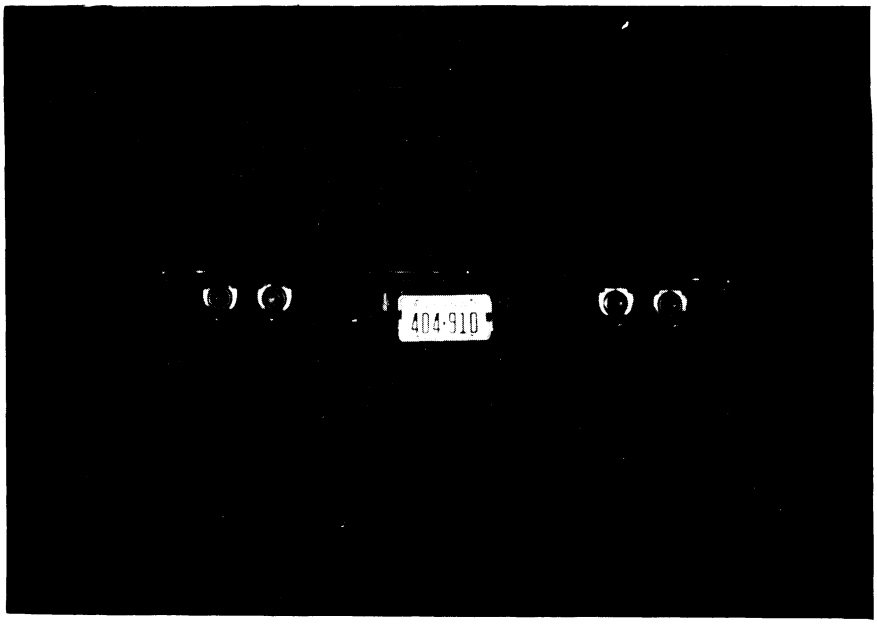
The east end of the site was not as conspicuously marked so that the subject would not be distracted by the barricade. Five standards with flags, five octopus markers, and one "do not enter" sign were used. These barriers were placed well beyond the normal vision of the test subjects under night conditions.

Even with these elaborate precautions, there were numerous vehicles traveling through the test site and causing a disruption in the experiment.

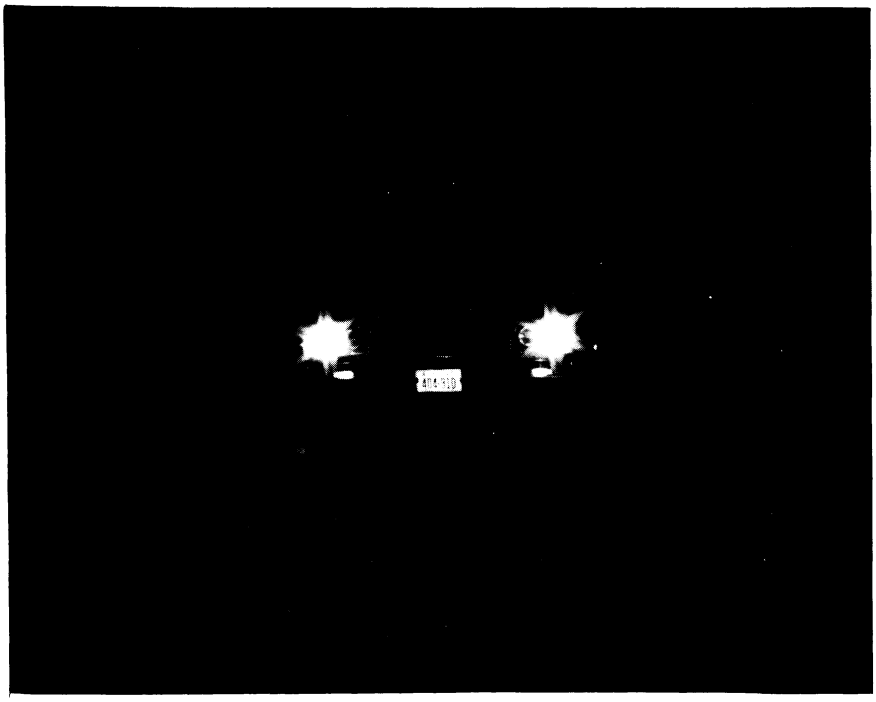
LEGIBILITY RESULTS

Fifteen pairs of license plates were observed at each angle of the experiment. Photograph 3 represents a plate as viewed by a test subject when the stationary vehicle was at 00^{o}, and photograph 4 depicts a plate as viewed when the stationary vehicle was at 180^{o}. Table 1 shows the means, standard deviations, and t values of the results.

The student's t test was used to determine the significance of the difference between the means. Since all values exceed $p \leq .01$, it may be assumed that the difference in the legibility distances between reflectorized and enamel plates is significant.



Photograph 3. Plate at 00^{o}.



Photograph 4. Plate at 180^{o}.

In layman's terms, this means that in 99 cases out of 100 the fact that a reflectorized plate can be read at a greater distance is due to the properties of the plate itself and not to a chance happening, to the design of the test procedures, or to the normal variability of the test subjects.

In each pair of measurements the mean distance at which a reflectorized plate could be read was greater than the mean distance at which an enamel plate could be read. By referring to Table 1, one also is able to determine that an enamel plate can be read at a greater distance when the lights are off and the rear of the parked car is pointed toward the observer than when a stationary vehicle with its lights on low beam is approached by the test vehicle from the front.

TABLE 1
LEGIBILITY TEST RESULTS

	Type of Plate	Angle (Degrees)	Mean Distance (Feet)	Standard Deviation (Feet)	t Score	Significant at	
						.05	.01
Rear of Vehicle	Enamel	30°	60.87	9.59	6.85	Yes	Yes
	Reflectorized	30°	72.65	8.24			
	Enamel	00°	60.87	9.48	7.91	Yes	Yes
	Reflectorized	00°	80.33	11.82			
Front of Vehicle	Enamel	180°	48.39	4.30	10.22	Yes	Yes
	Reflectorized	180°	77.20	15.18			
	Enamel	150°	45.03	6.11	11.82	Yes	Yes
	Reflectorized	150°	73.80	13.36			

772

Even though the legibility distance is statistically greater for reflectorized plates than for enamel plates, the practical value must be considered. For example, with a closing speed of 88 ft./sec., and two cars approaching each other at 30 mph each, or one car traveling at 60 mph closing on a stopped vehicle, is an increased legibility distance of 28.81 feet (maximum) and 11.78 feet (minimum) of great importance? At increased speeds the time available for reading plates is reduced. The researchers will not attempt to make a judgement as to the value of this increased distance to individuals attempting to correctly read a license plate.

Appendix A graphically presents the individual measurements for every subject and for each type plate and vehicle angle. It can be seen that the subjects were able to read the reflectorized plates at a greater distance than the enamel plates. The curves also depict the internal variations by plate type and vehicle angle.

VISIBILITY RESULTS

Recognition

The distance from which an individual recognizes an object in the road as representing a danger to his operation of a vehicle is necessarily a subjective judgement. It involves the person's frame of reference, his visual acuity, and his definition of the terms "danger" and "recognition".

While recognizing several possible sources of error, the researchers attempted to measure, with a high degree of accuracy, the distance from the parked car to the observer-subject. The results are given in Table 2. Appendix B graphically presents a comparison of the visibility recognition results of enamel and reflectorized plates for each test subject and for each test condition.

It might be recognized that only fourteen points are plotted for the visibility data where there were fifteen points for legibility. Data obtained from one test subject did not reflect points which could be considered as falling within the normal distribution from which the other data were obtained. At the time of data collection it was noticed that the cooperation of this subject had not been received and he was not honestly participating in the experiment. These discordant values were not used in the computation of the means and standard deviations. A test for rejection as proposed by W. J. Dixon was used.[1/] These doubtful values were also rejected by this method.

1/ Dixon, W. J., "Analysis of Extreme Values," Annals of Math. Sta., December 1950.

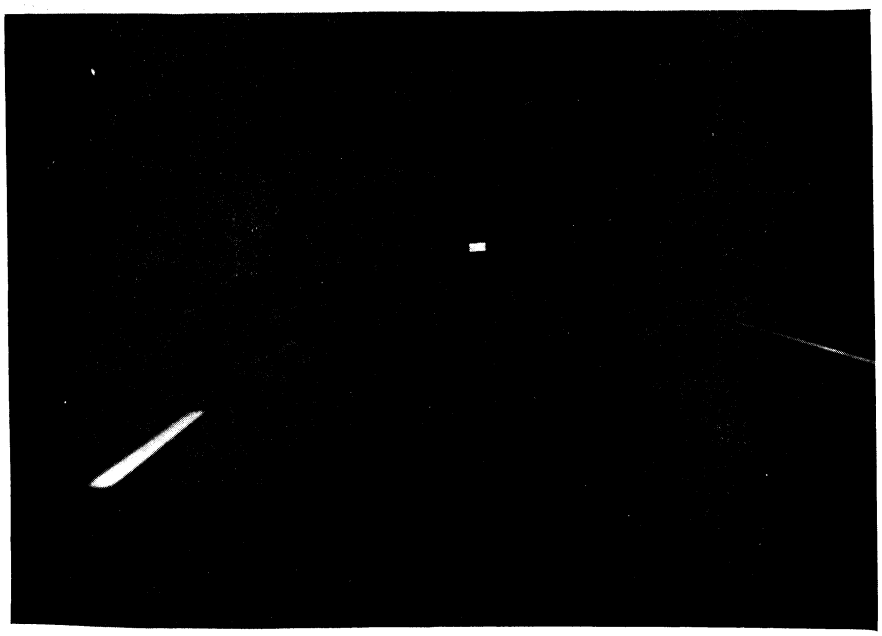
The results of the t test, $p \leq .01$, indicates that one can be certain in 99 out of 100 cases that a vehicle equipped with a reflectorized license plate will be recognized at a greater mean distance than the same vehicle equipped with an enamel plate. Comments from the test observers indicated that when a reflectorized plate was used the object recognized was the plate itself (see Photograph 5). When an enamel plate was used the subject first recognized the tail light (see Photograph 6) or headlight reflex reflectors rather than the license tag.

The very large standard deviations for reflectorized plates on this series of tests is the result of the wide variability of individual judgements of what constitutes a danger to vehicle operation. The distance any driver visualizes danger is dependent upon his assessments of the problem presented and his ability to react in sufficient time.

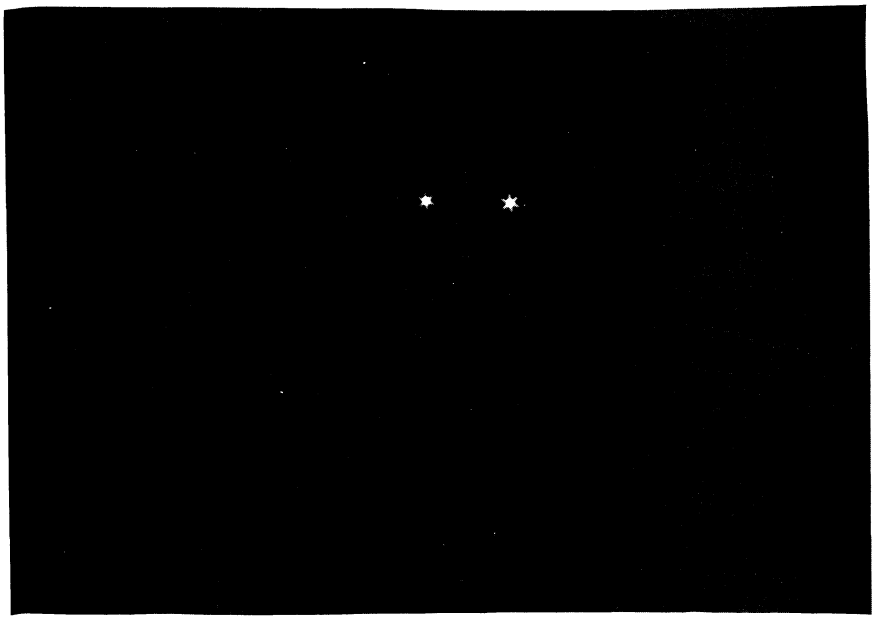
This variability could account for some accidents, because even though a driver receives the proper visual clues to indicate that a vehicle is in his path, he does not properly react to prevent a collision.

TABLE 2
VISIBILITY TEST RESULTS — Recognition

	Type of Plate	Angle (Degrees)	Mean Distance (Feet)	Standard Deviation (Feet)	t Score	Significant at	
						.05	.01
Rear of Vehicle	Enamel	30°	276.93	40.51	6.07	Yes	Yes
	Reflectorized	30°	772.32	330.49			
	Enamel	00°	439.14	52.15	4.69	Yes	Yes
	Reflectorized	00°	866.86	344.40			
Front of Vehicle	Enamel	180°	504.18	127.52	5.07	Yes	Yes
	Reflectorized	180°	860.93	315.10			



Photograph 5. Reflectorized plate recognition.



Photograph 6. Enameled plate recognition.

Reflectorized license plates are promoted as a safety feature primarily because of the increased visibility distances of a vehicle whose lights are not in operation. An automobile traveling at 60 mph requires a minimum of 434 feet stopping distance on dry pavement and 620 feet total stopping distance on wet pavement.[2/] Both figures are for a level grade. More extreme conditions exist but these two are within the realm of everyday driving conditions. It can be seen that only the reflectorized license plate provides more than a bare minimal safety margin in conditions similar to those tested.

Point Source

The results of the second phase of the visibility experiment are given in Table 3. This set of tests was termed "point source", which is defined as the point at which the subject-observer was able to detect the first light from the parked vehicle.

Fifteen subjects participated in the experiment, but only fourteen points were plotted on the graphs (see Appendix C) and used to calculate the means and standard deviations. The one deviant value was discarded for the same reasons, and by the same statistical techniques, as mentioned for the recognition visibility results.

In every case the vehicle equipped with a reflectorized plate could be seen at a significantly greater distance than could the same vehicle equipped with an enamel plate. The results of the t test, $p \leq .01$, indicates that in 99 cases out of 100 the difference between the means is real and did not occur by chance. One, therefore, can be confident in saying that reflectorized license plates provide an automobile driver with an opportunity to see another vehicle at a greater distance than he is able to at present. This gives him visual clues for a more safe operation of a motor vehicle.

The mean visibility test distances were in excess of 1,400 feet for reflectorized plates under low beam headlight conditions. Sufficient time and distance for an individual to become aware that there is an automobile in his path and to begin operating his vehicle in a defensive manner is thus provided by reflectorized license plates. The maximum mean distance of 671 feet for an enamel plate provides only a 51 foot margin of safety at a speed of 60 mph if the road is wet. If the speed is greater or there is a down grade, the minimum stopping distance is increased and there is not sufficient distance to bring a vehicle to a halt.

2/ AASHO calculations of minimum stopping distances for wet and dry pavement conditions of new highways.

Throughout the experiment, the mean scores and standard deviations of the reflectorized plates had more consistency on the part of the test subject-observers than did mean scores and standard deviations for enamel plates. This consistency might be the result of a more definitive object, and therefore, less susceptibility to an error of individual judgement.

TABLE 3
VISIBILITY TEST RESULTS -- Point Source

	Type of Plate	Angle (Degrees)	Mean Distance (Feet)	Standard Deviation (Feet)	t Score	Significant at	
						.05	.01
Rear of Vehicle	Enamel	30°	372.57	56.31	20.75	Yes	Yes
	Reflectorized	30°	1,412.57	173.63			
	Enamel	00°	561.18	98.53	16.30	Yes	Yes
	Reflectorized	00°	1,493.89	197.63			
Front of Vehicle	Enamel	180°	670.96	194.03	19.76	Yes	Yes
	Reflectorized	180°	1,511.89	174.73			

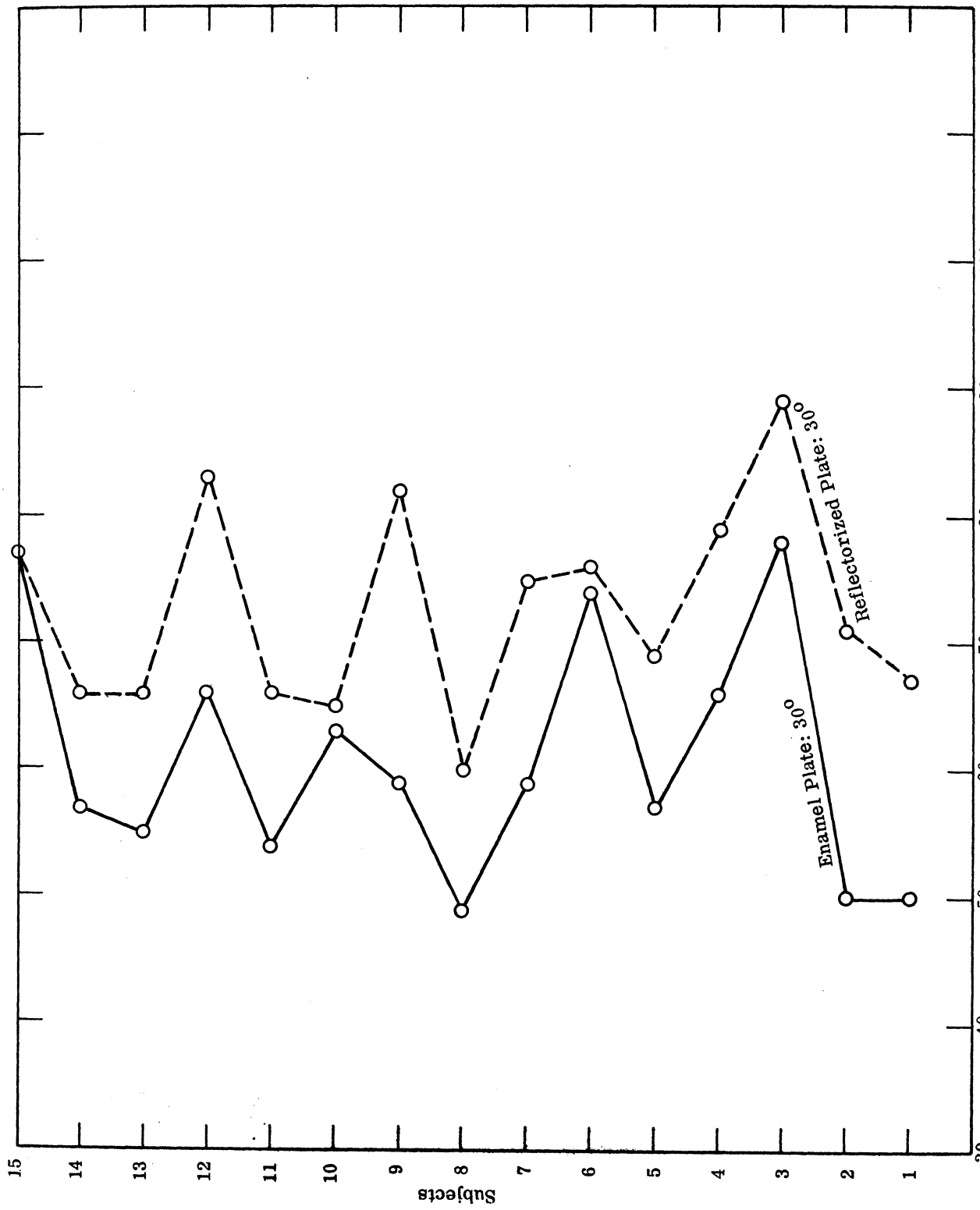
The researchers also noticed that a variation in the horizontal and vertical planes in which an enamel plate was attached to the stationary vehicle caused a difference in the amount of glare reflected toward the observer, and thus affected the distance at which the plate could be read. Reflectorized plates were also affected but did not appear to have as proportionally as great a fluctuation. For this reason, clamps were used on each side of the plate on every test run to assure that it would remain flat and thus reduce variations in the plane of view.

Appendix D graphically presents a comparison of the visibility test results for each angle of approach. The first point source of light was visible to the subjects before they were able to recognize the object as an automobile. Additionally, a motor vehicle equipped with a reflectorized license plate was both recognized as a vehicle and seen as a light source at a significantly greater distance.

The significance attached to these results is that a reflectorized automobile license plate attached to a passenger vehicle makes that vehicle more readily seen and recognized than an automobile with conventional enamel license plates.

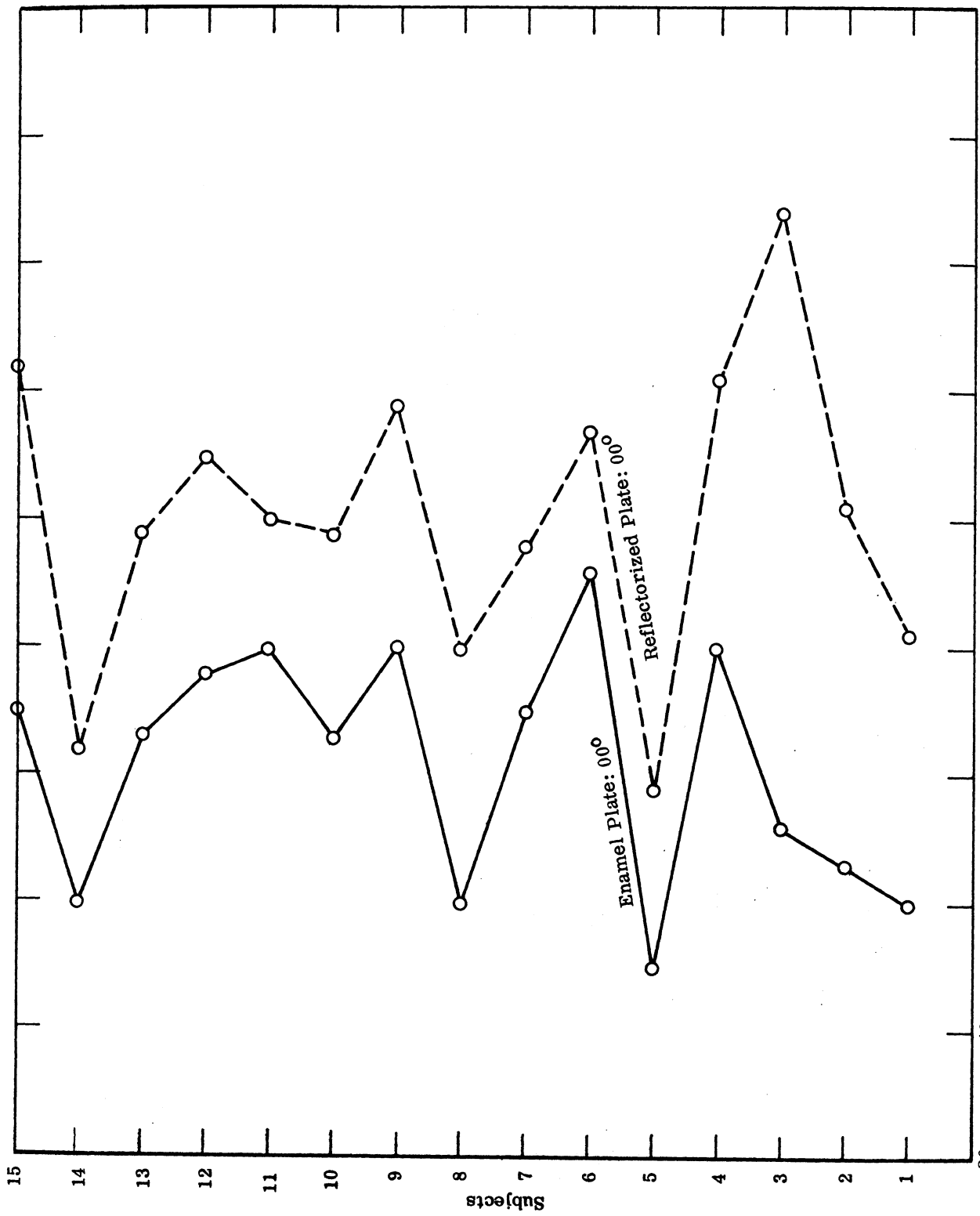
APPENDIX

APPENDIX A
GRAPHIC LEGIBILITY RESULTS



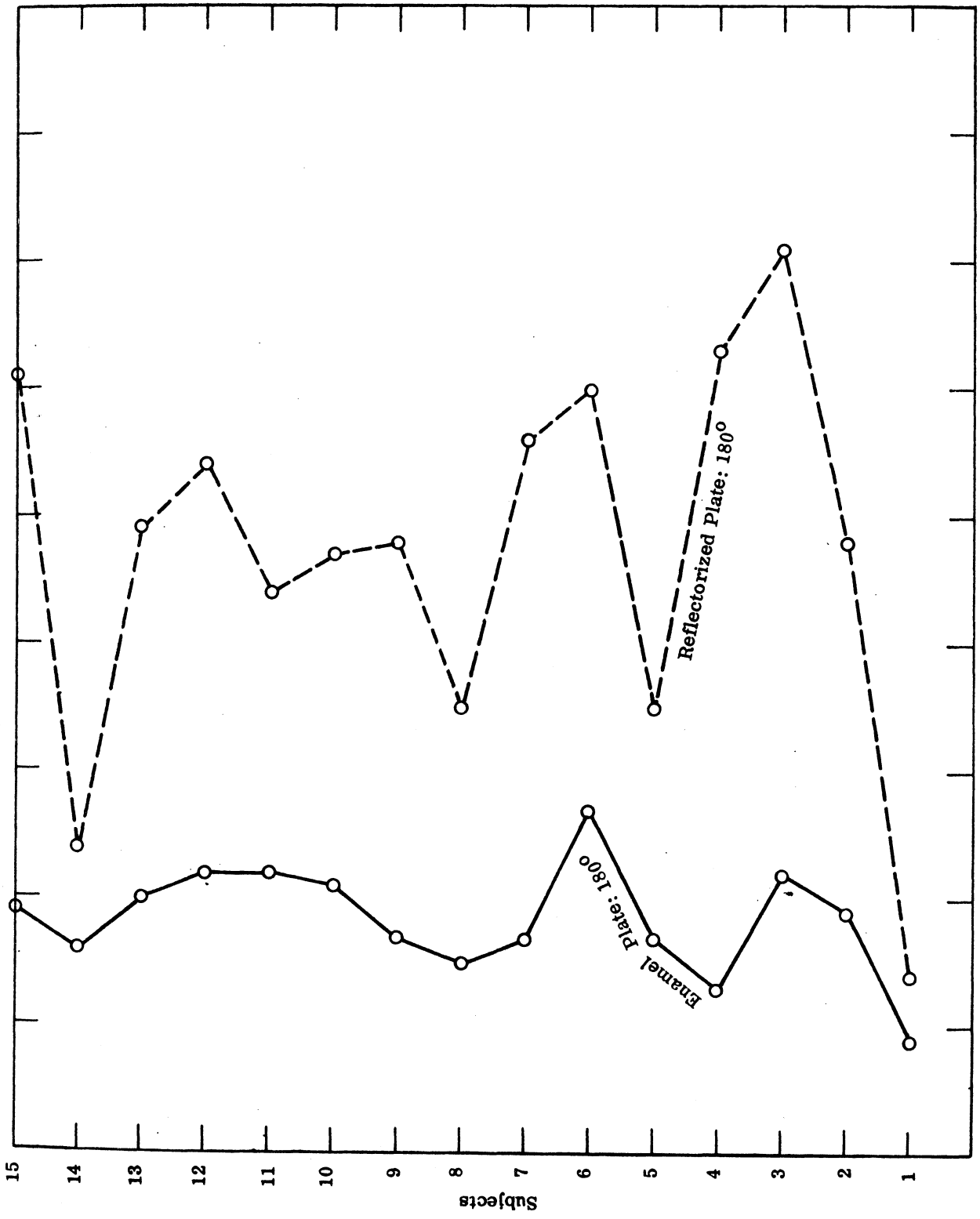
LEGIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 30°

APPENDIX A (continued)



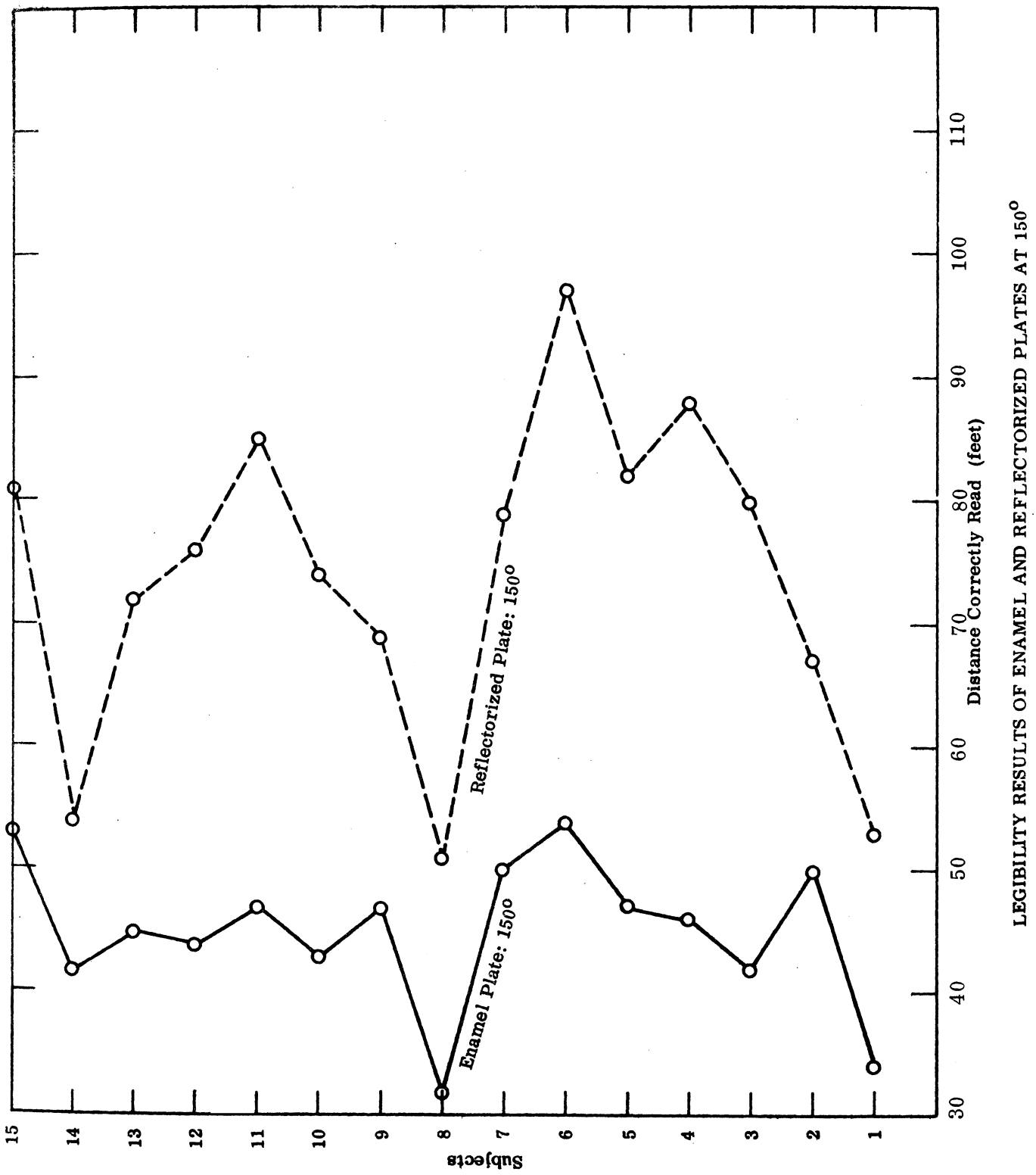
LEGIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 00°

APPENDIX A (continued)

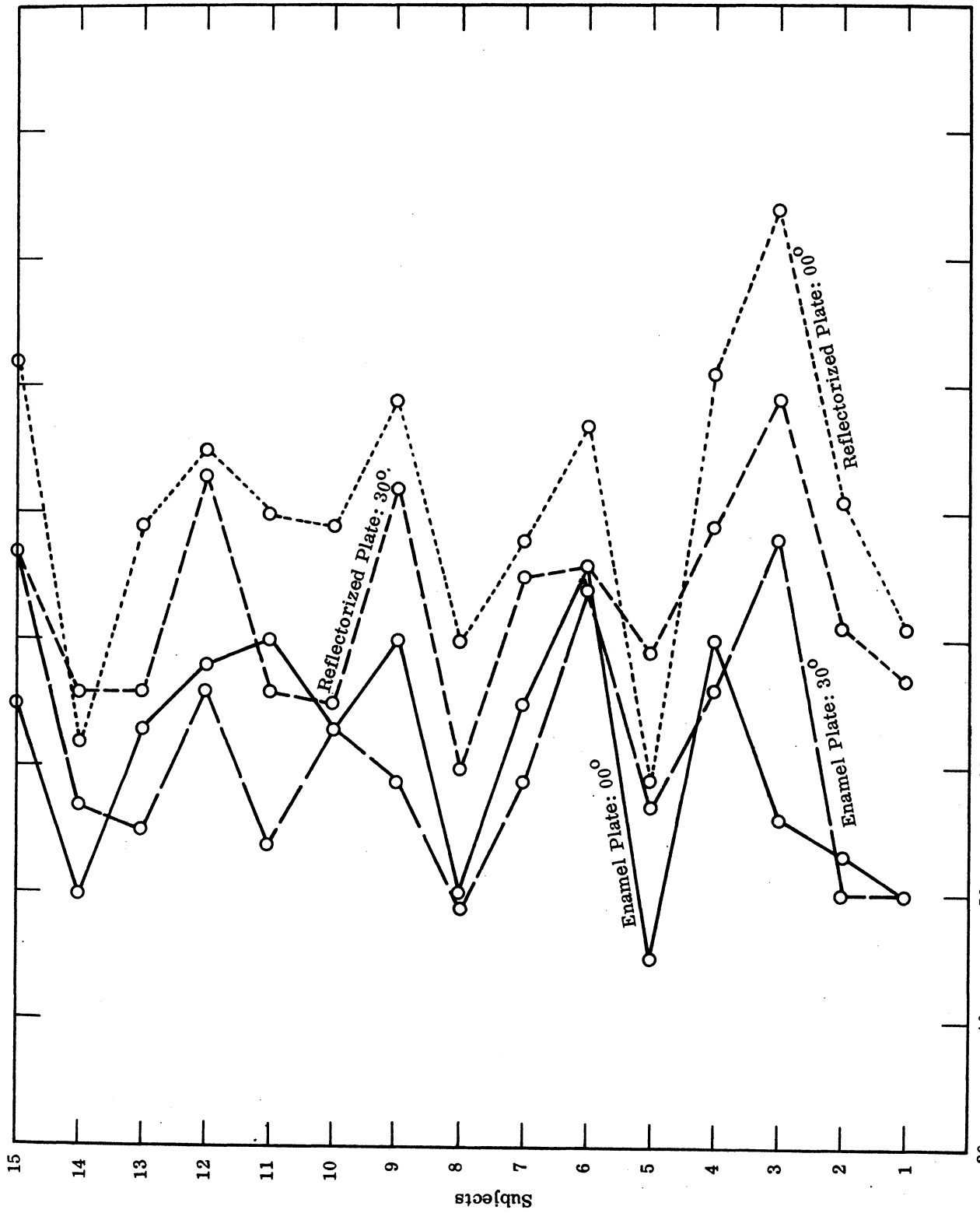


LEGIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 180°

APPENDIX A (continued)

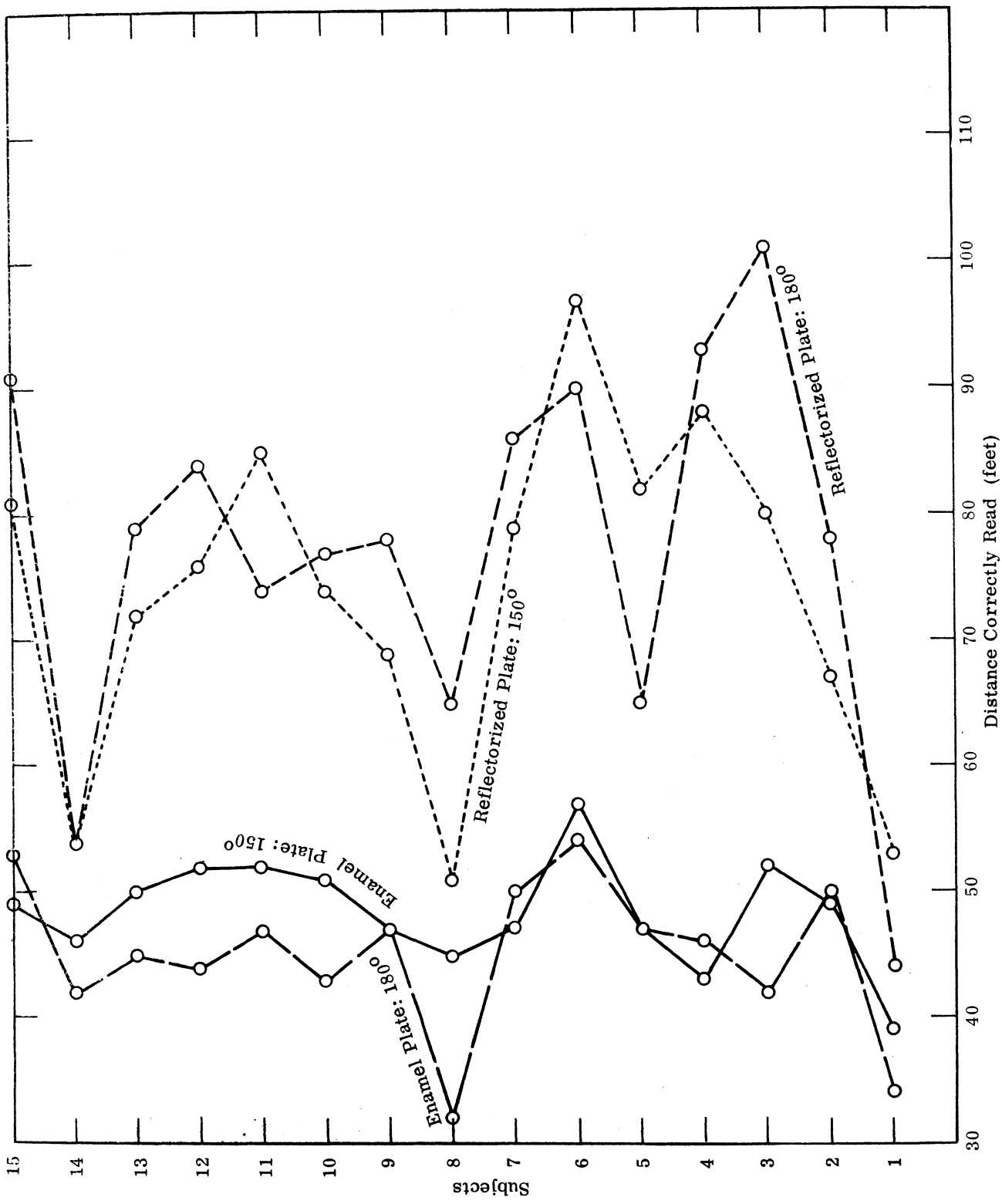


LEGIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 150°



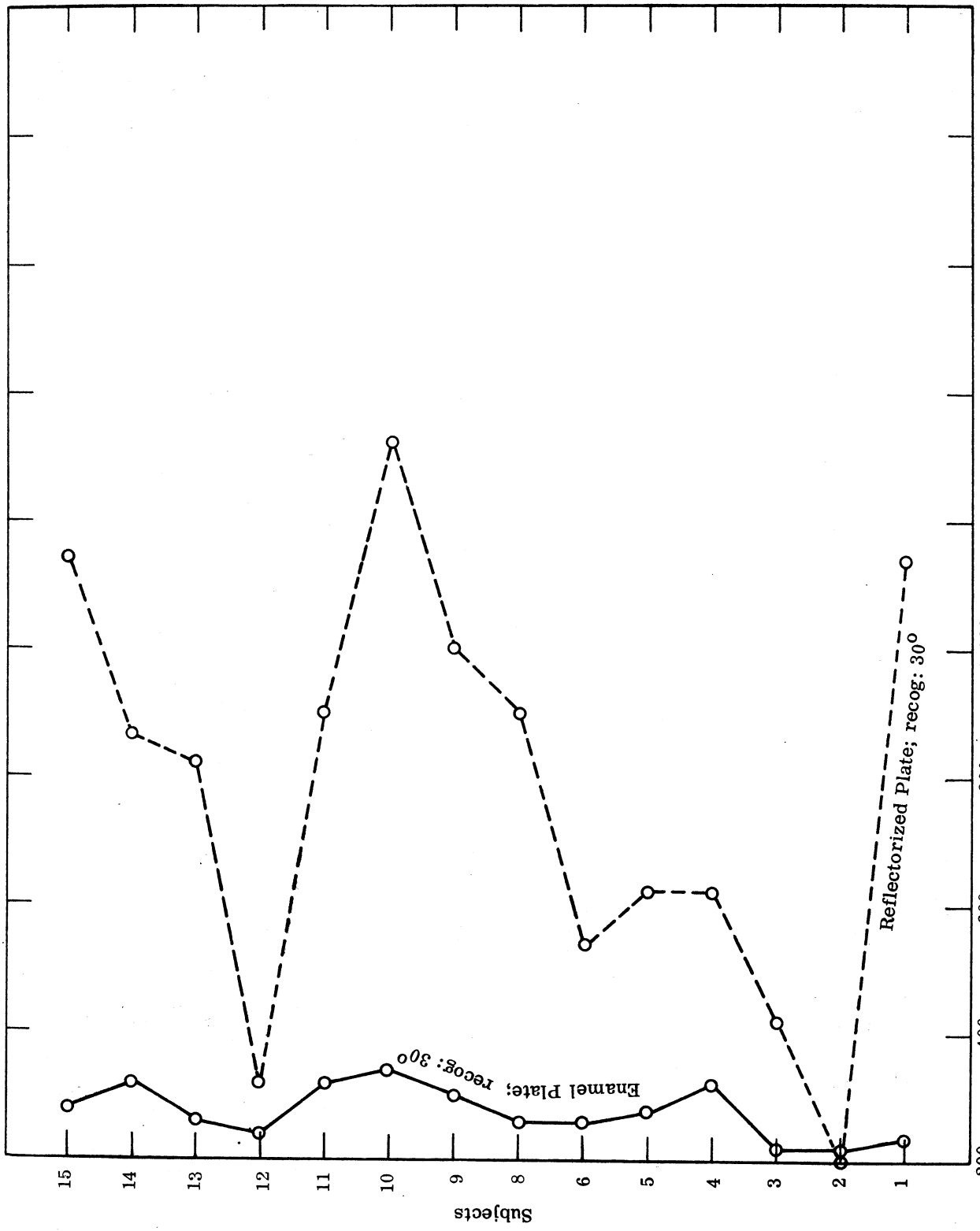
LEGIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 30° and 00°

APPENDIX A (continued)



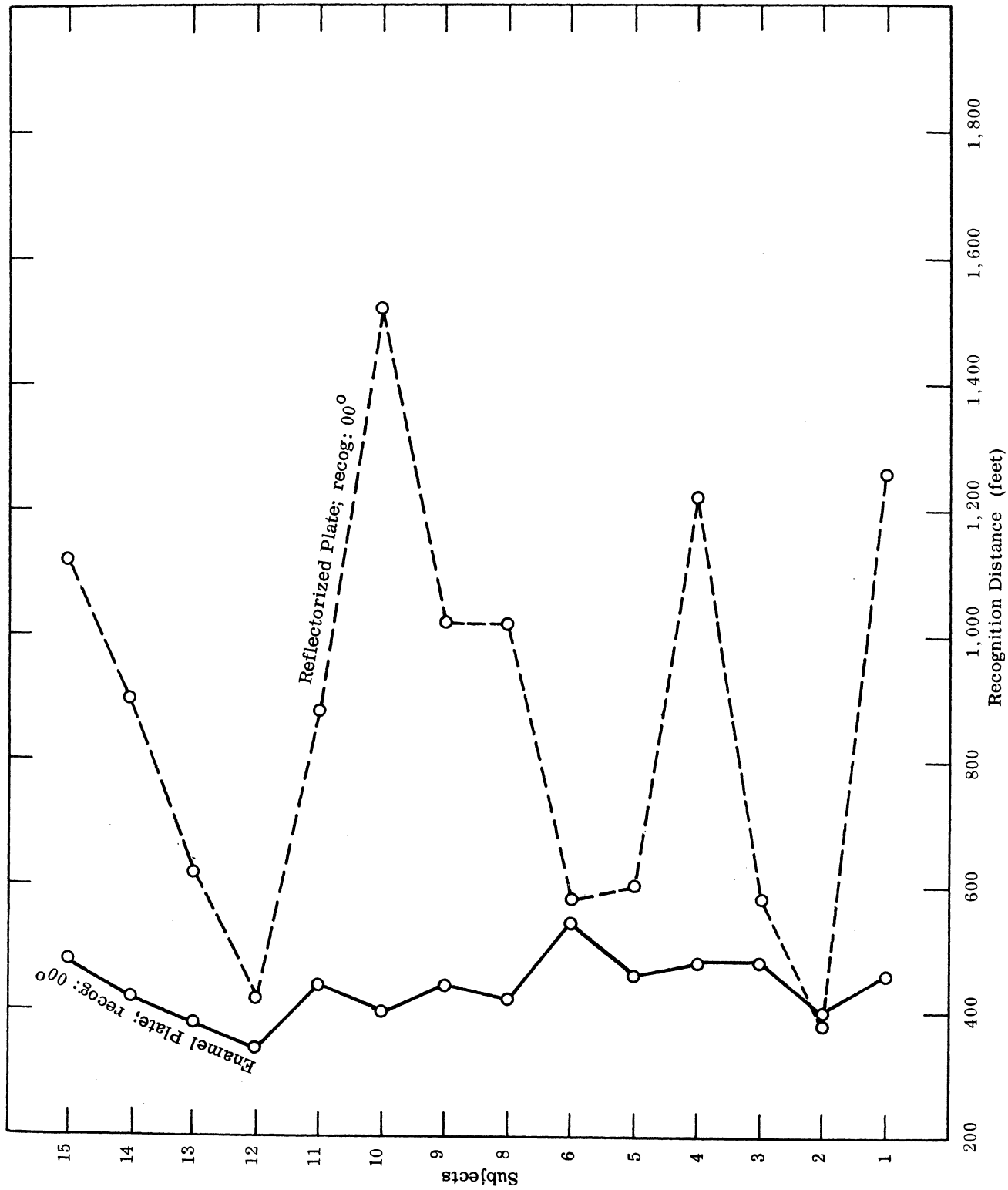
LEGIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 180° AND 150°

APPENDIX B
GRAPHIC VISIBILITY RESULTS -- Recognition

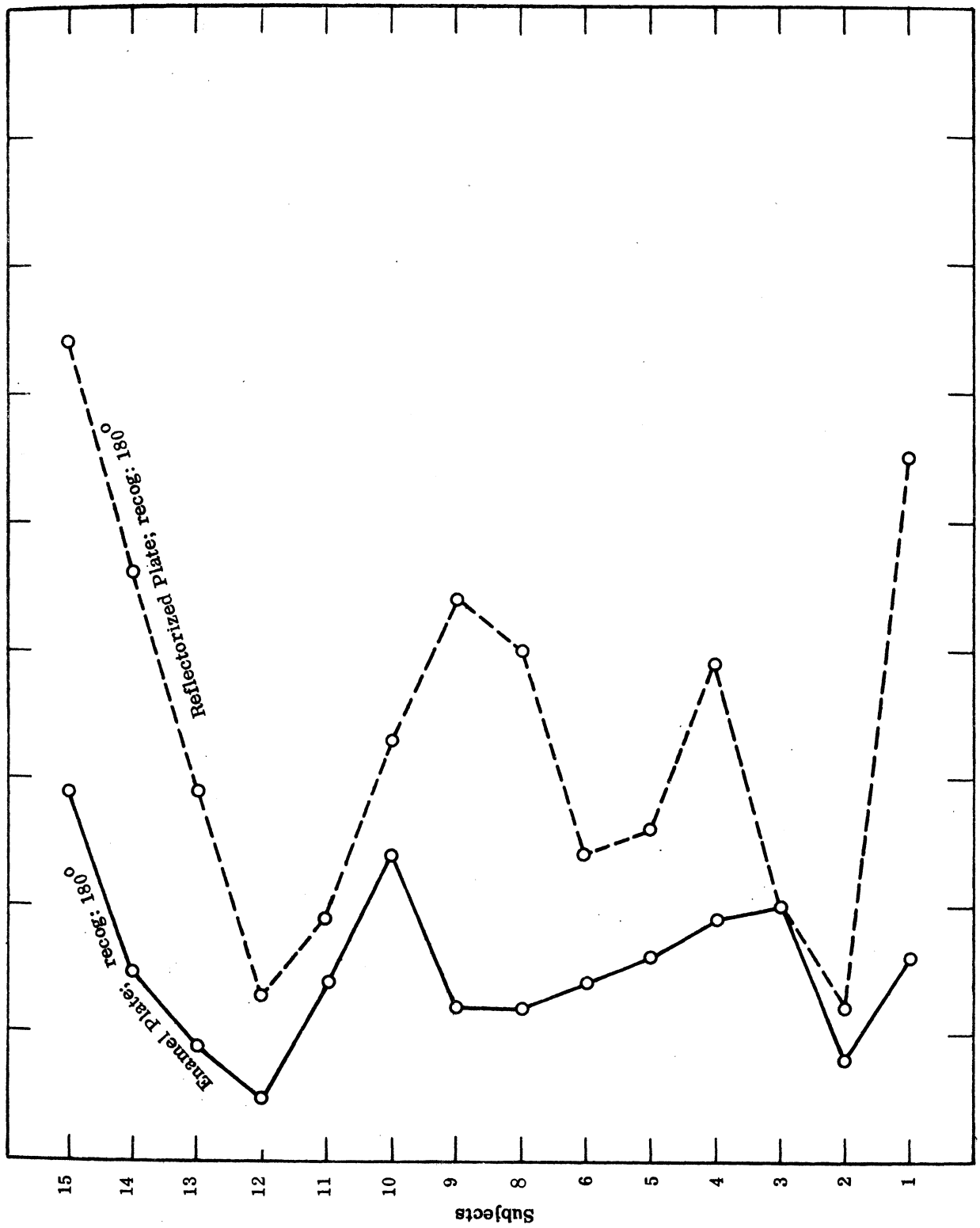


VISIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 30°

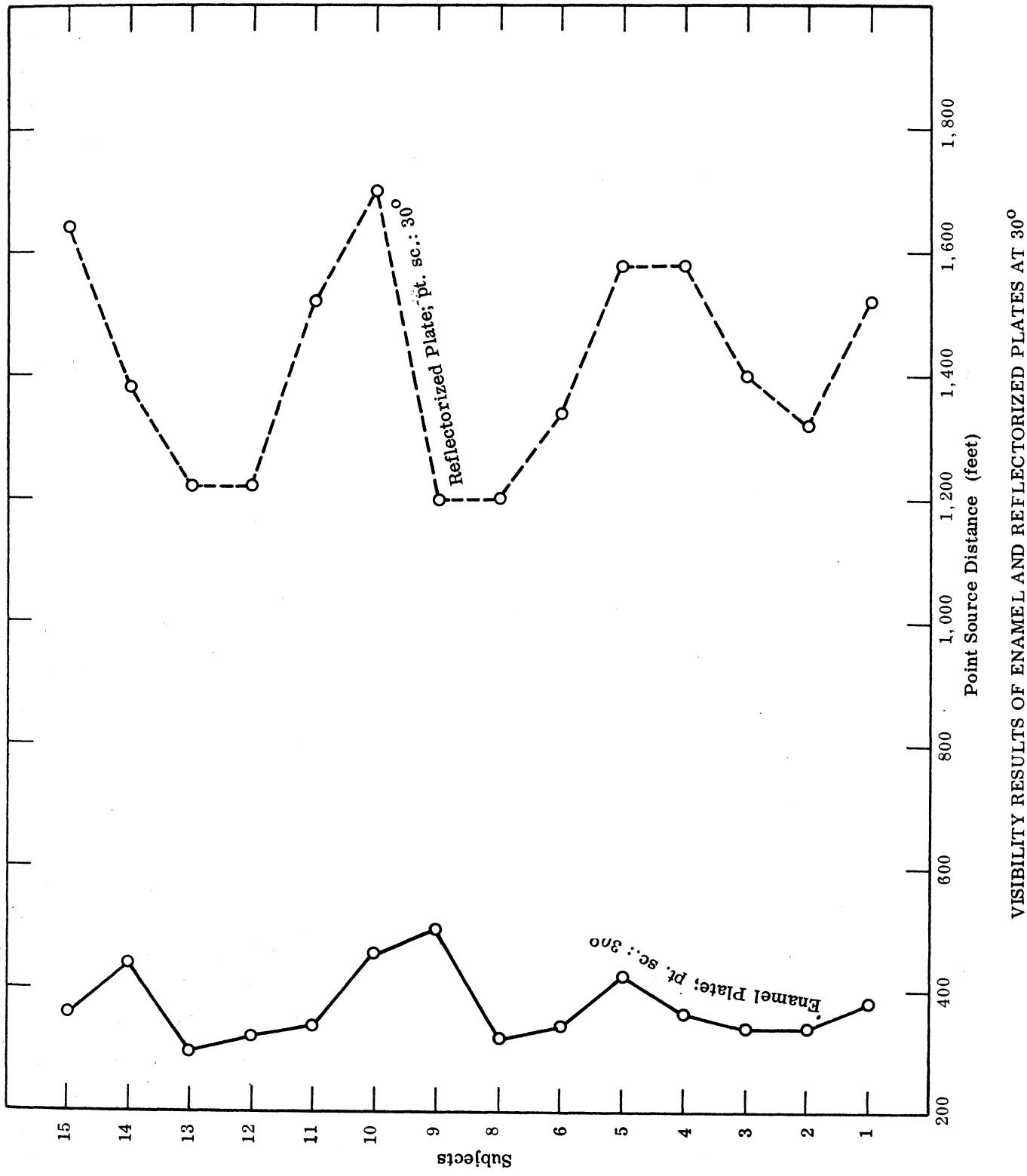
APPENDIX B (continued)



VISIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 00°

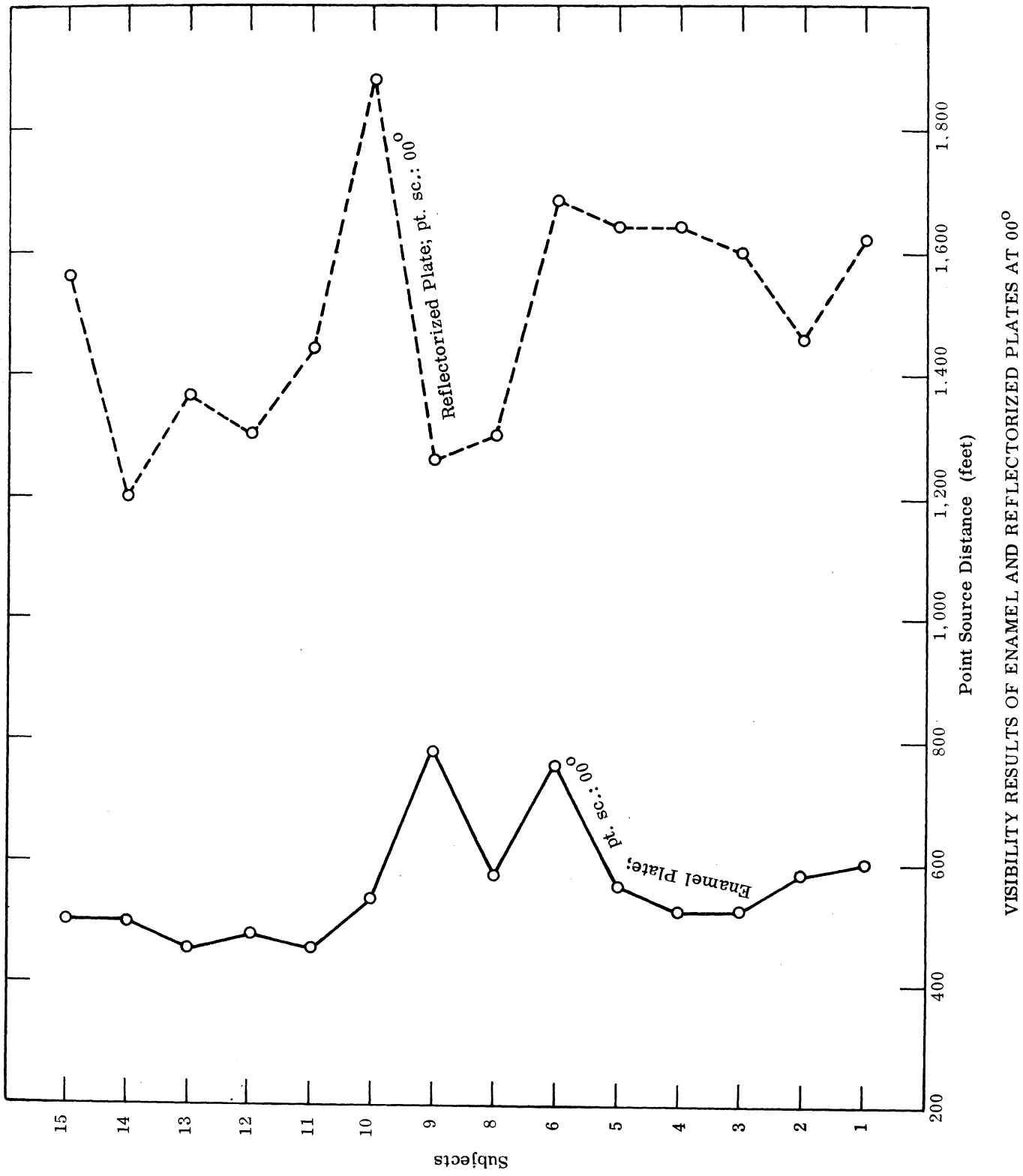


VISIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 180°

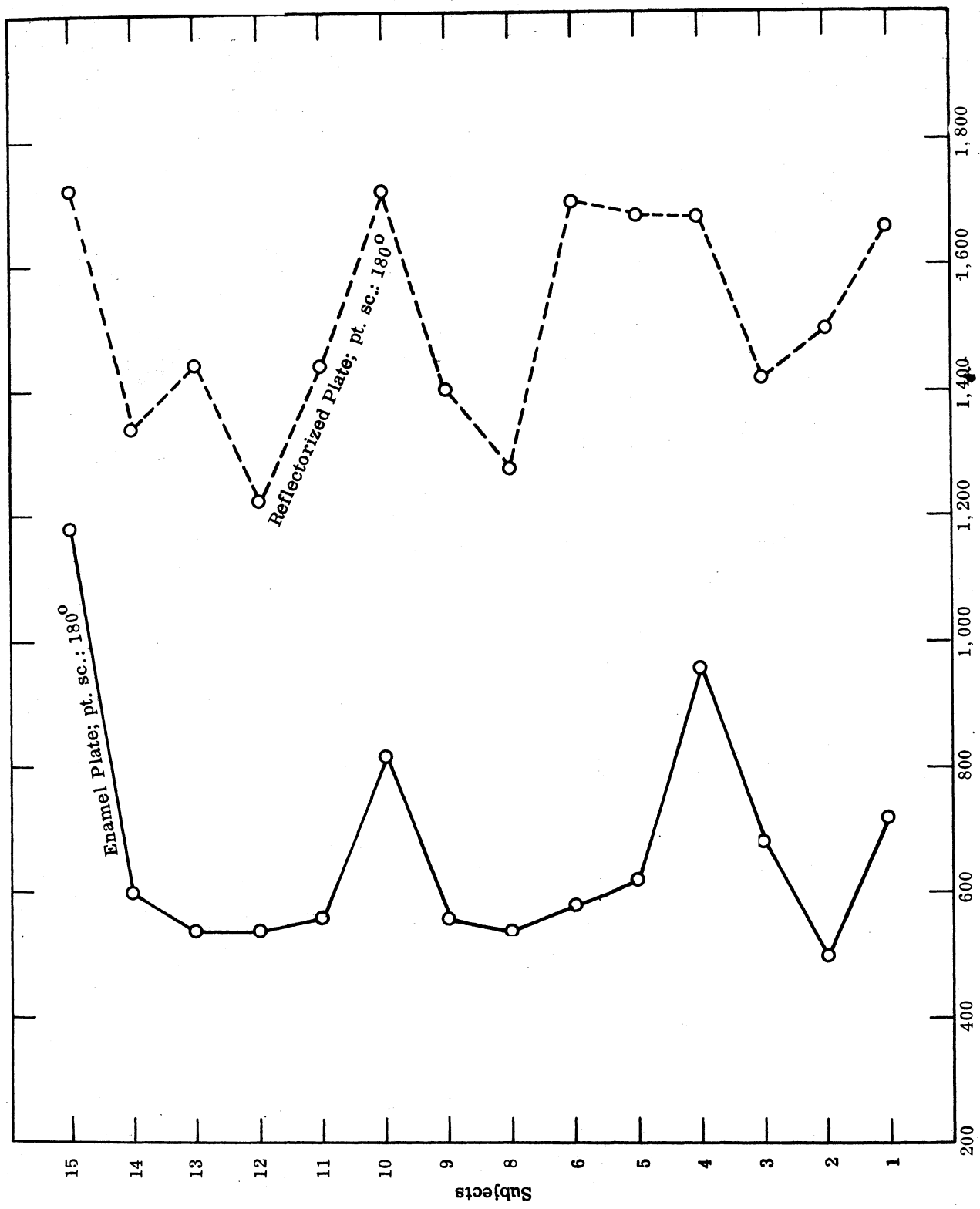


VISIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 30°

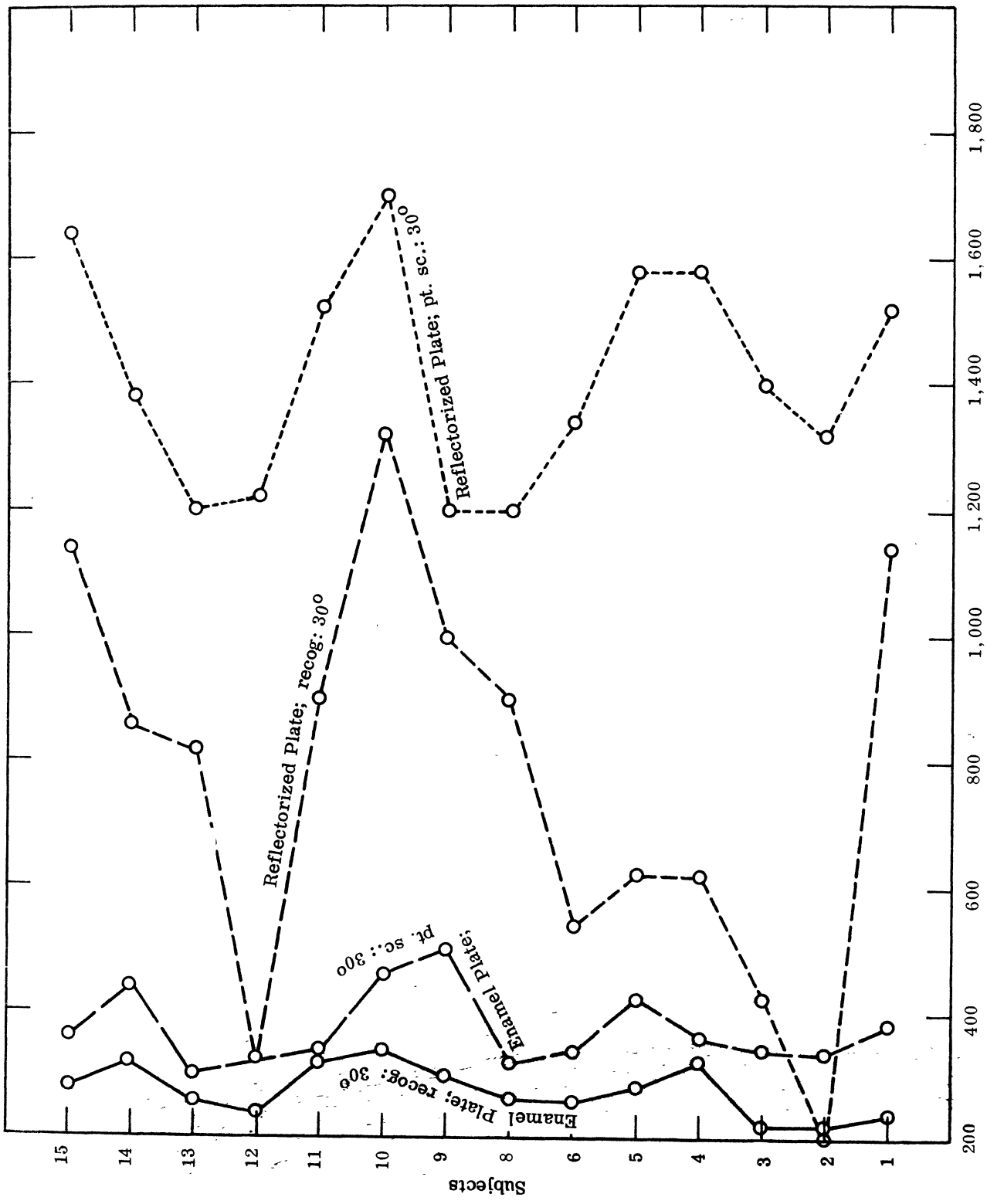
APPENDIX C (continued)



VISIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 00°

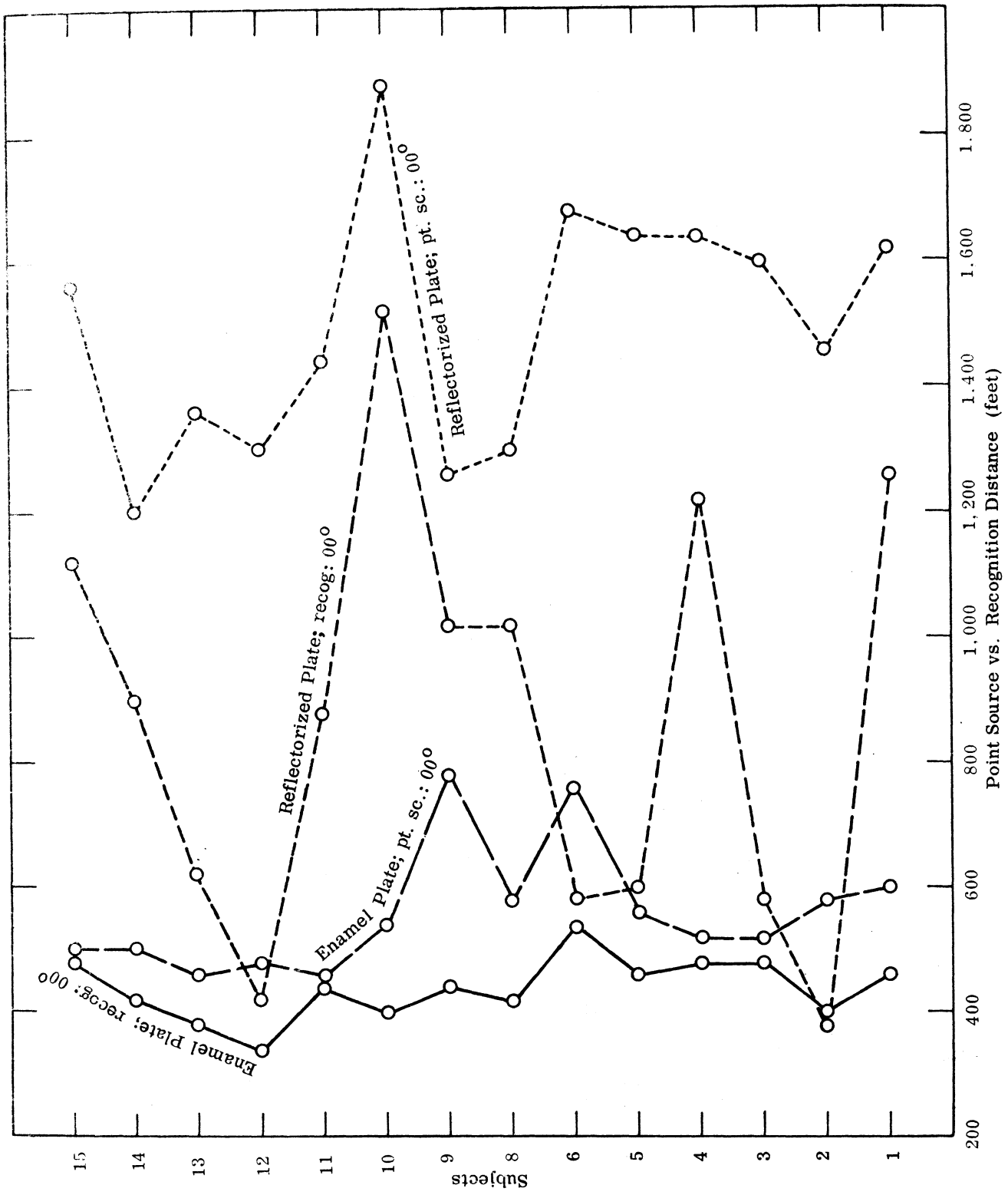


VISIBILITY RESULTS OF ENAMEL AND REFLECTORIZED PLATES AT 180°

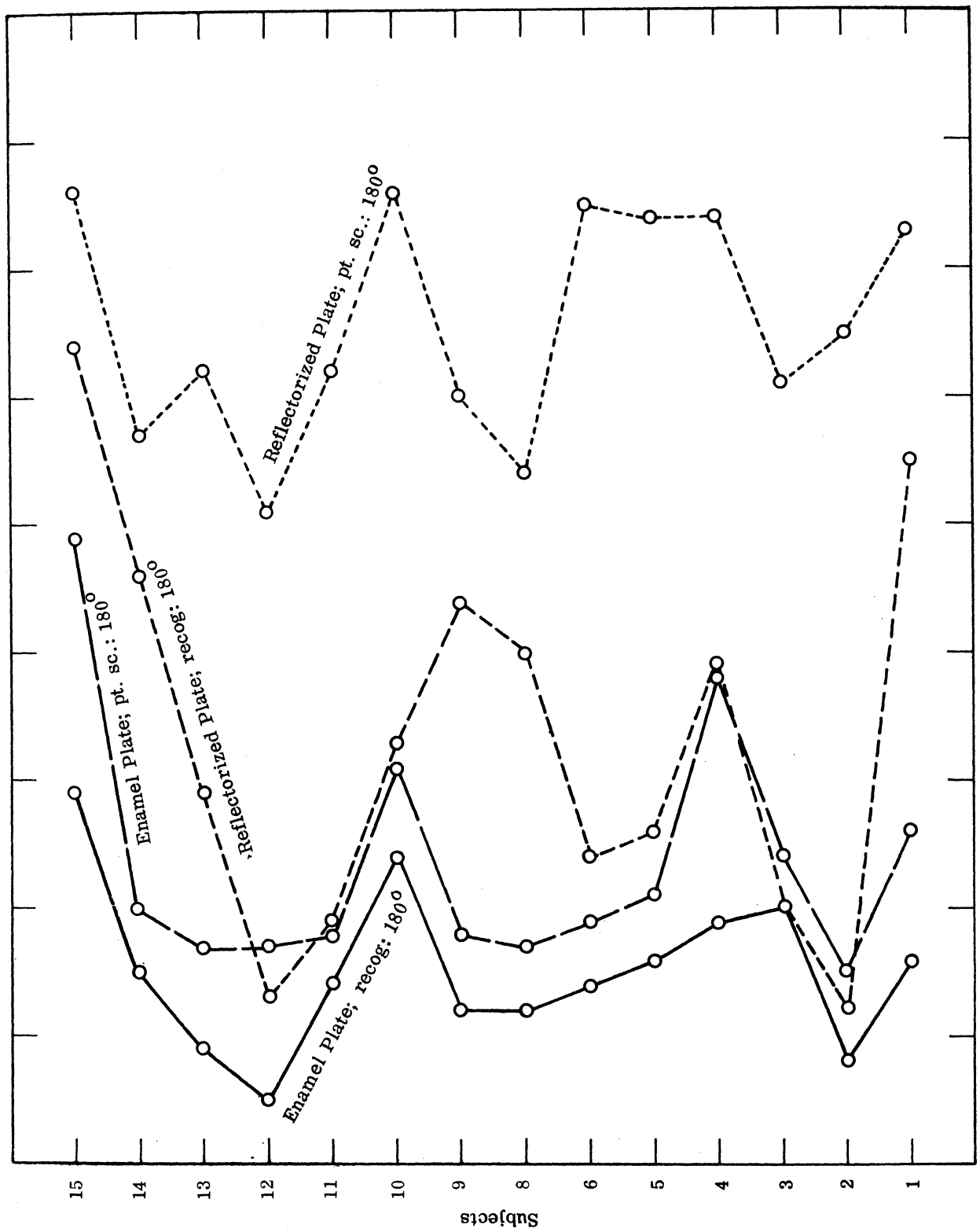


VISIBILITY RESULTS FOR ENAMEL AND REFLECTORIZED PLATES AT 30°

APPENDIX D (continued)



VISIBILITY RESULTS FOR ENAMEL AND REFLECTORIZED PLATES AT 00°



VISIBILITY RESULTS FOR ENAMEL AND REFLECTORIZED PLATES AT 180°