DEMONSTRATION OF VISIBILITY MEASURING DEVICE TO DETECT HIGHWAY FOG CONDITIONS

FRANCIS D. LANE
LINDA HANNAMON
DWAYNE HOFSTETTER

OREGON DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY DIVISION
SALEM, OREGON 97310

AUGUST 1972

INTERIM REPORT SEPTEMBER 1968-AUGUST 1972

PREPARED FOR THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WASHINGTON D. C., 20590

CONTRACT NUMBER FH-11-7152

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
Demonstration of Visibility Measuring Device to Detect Highway Fog Conditions

5. Report Date
September 1972

6. Performing Organization Code

7. Author(s)
Francis D. Lane, Linda Hannaman and Dwayne Hofstetter

8. Performing Organization Report No.

9. Performing Organization Name and Address
Oregon Department of Transportation
State Highway Division
Salem, Oregon 97310

10. Work Unit No.

11. Contract or Grant No.
FH-11-7152

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Federal Highway Administration
Washington, D.C. 20590

13. Type of Report and Period Covered
Interim Report,
Sep. 1969 - Aug. 1972

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
This project is being conducted to evaluate a commercially available visibility measuring device (Impulsphysik, GmbH Videograph) as to its possible application in the field of traffic control under reduced visibility driving conditions. The evaluation consists of a comparison of the Videograph ranges with human visual range and the operating experiences with the equipment. The Videograph is a back-scatter type of transmissiometer.

Due to inadequate time periods of fog since the equipment was installed, valid conclusions are difficult to achieve; however, the data which has been collected indicates a fairly strong correlation between the indicated Videograph ranges and human visual range and the equipment has been relatively trouble free. The major obstacle to its use as a control device appears to be rapid changes in fog density which were encountered. These changes caused the Videograph's output to fluctuate rapidly, which in turn would have caused the speed advisory information to fluctuate in an unsatisfactory manner. Based upon these results, the tentative conclusions reached are that the Videograph would not be practical for controlling the signs without the addition of visibility averaging equipment to dampen the fluctuation. A Videograph with such equipment appears to have potential as an automatic control device and should be evaluated. The Videograph may also have application as an advisory device and/or as an on-off sign system control.

17. Key Words	18. Distribution Statement
Highway Fog Detection Visibility Measuring Devices	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	20	

Form DOT F 1700.7 (8-69)

List of Illustrations

List of Tables

Summary:

The objective of this study was to investigate the feasibility of adapting existing commercially available transmissiometers to the control of highway traffic signs during periods of reduced visibility. Specifically it was intended to: (1) evaluate a visibility measuring device in terms of its reliability and operability as a control unit, and (2) to conduct a comparison of the device's output with human visual capability. Based on a preliminary analysis of available equipment on the market, it was determined that a single-ended back scatter device would be most practical for highway use. As a result, an Impulsphysik, GmbH Videograph was obtained and installed for evaluation.

Although an inadequate amount of fog has occurred in the area to conduct a complete analysis, the data which has been collected indicates that a fairly strong correlation exists between the Videograph and human visual ranges (r = .82). However, the data was highly variable and the Videograph ranges averaged about 50 feet longer than the visual. No data was obtained for the critical short ranges of 200 feet or less and a minimal amount under night conditions.

With respect to the second objective, the Videograph was found to be relatively trouble-free, although restart due to power failure was a problem. However, a number of minor problems were encountered with its recording equipment. The major obstacles to the Videograph appeared to be the sudden temporary changes in fog density which were encountered. As presently designed, the Videograph

uses preset alarm levels (visibility ranges) to control external equipment. The changes in density encountered in this study caused the Videograph output to fluctuate around and between alarm settings, which in turn would have caused the advisory information on the signs to fluctuate in an unsatisfactory manner.

Based on these results, the tentative conclusions reached are that the Videograph would not be practical for controlling the signs without the addition of visibility averaging equipment to dampen the fluctuations. A Videograph with such equipment appears to have potential for automatic control and an evaluation of such a system is recommended. Without averaging equipment, alternative uses of the Videograph as a device to provide a warning of the development of adverse conditions and/or as a possible on-off control for portions of the signs are suggested.

Introduction:

As a part of a continuous effort to enhance safety for the traveling public, the State of Oregon has implemented a Warning Sign System[1/] to advise motorists of adverse road conditions. Since November, 1968, the system has been in operation on the Albany Section of Interstate 5 where there was a history of dense fog. In the six-year period preceding the sign installation, a total of 13 fog-related accidents occurred involving 127 vehicles, 7 fatalities and 73 injuries. A review of the accident records indicated that during periods of reduced visibility due to fog, the ten-mile section of the freeway experienced almost as many accidents as the remaining 300 miles of Interstate 5 located in Oregon.

To alleviate this condition the Warning Sign System was constructed in 1968 as an experimental Federal-aid Program. The system consists of a series of three north and three southbound variable message signs with a control panel located at the Albany State Police Office. Each sign contains two, 12" flashing beacons and the word "SLOW" in three-foot high letters. Also included are the words "WRECK", "FOG" and "SPEED" in letters 1½ feet high and numerical indications of the speed from 10 to 50 MPH in 10 MPH increments (Figs. 1 and 2). The flashing beacons and the "SLOW" message come on whenever a sign is actuated. The legends "FOG", "WRECK" and "SPEED" and the numerical indications can then be chosen for each sign.

1/ *Variable Message Fog Hazard Warning Signs to Control Vehicle Operating Characteristics. (Interim Report). Oregon Department of Transportation, State Highway Division, April, 1972. Prepared in cooperation with U.S. Department of Transportation, Federal Highway Administration.*

Fig. 1 Typical Sign Installation showing Fog-Speed Message

Fig. 2 Typical Sign Installation showing Wreck-Speed Message

At the present time the decision to actuate or deactivate the signs and the advisory conditions to be established are based on information radioed by police officers patrolling the freeway. This information consists of the police officer's estimate of the existing visual range. While the State Police are more than conscientious about exercising good judgement and operating the signs on a strict basis, no single criteria exists. In addition, the requirement to check the area adds an additional burden upon the police officer's already busy schedule.

As a result of the above conditions, it was desirable that some form of visibility measuring device be evolved to automatically control the signs, based upon a continuous measurement of the existing visual conditions. As envisioned, this device would actuate the signs when the visibility conditions warrant their use and maintain a recommended speed appropriate (as determined from engineering studies) for the existing visual conditions. Such a system or its instrumentation was not available commercially. Consequently, it was decided to obtain a system which was commercially available (but not necessarily designed for highway use) and to evaluate it as a sign control device. In order to fulfill this function, such a device would have to display a high degree of reliability and also provide outputs which are consistant with human visual capabilities. The purpose of this study is to conduct such an investigation. Specifically it is intended to: (1) evaluate a visibility measuring device in terms of its reliability and operability as a control unit, and (2) to conduct a comparison of the device's output with human visual capability.

Equipment Description:

Prior to conducting this study an analysis was made of commercially available visibility measuring devices in terms of initial cost, installation and alignment requirements, accuracy at short ranges, maintenance and potential interference drivers on the highway at night. As a result of this analysis it was determined that a single-ended back scatter device would be most practical for highway use. Such a device, an Impulsphysik, GmbH Videograph was obtained through the Ion Physics Corporation, Burlington, Massachusettes. This device is in essence a visibility meter which used the principle of atmospheric back scatter to measure visual range. The Videograph consists of a projector inclined upwards at an angle of 3.5^{0} and a photosensitive receiver mounted directly above it. The axis of the two components intersect at a distance of approximately 15 meters. (Fig. 3) The projector emits short, intense light pulses into the atmosphere and the receiver measures the amount of the light reflected back by the aerosal particles. An aperture located on the receiver is designed to reject all signals except those resulting from the short (1 u sec.) pulses making it effective under all limits of ambient light and weather conditions.

Visibility is determined by the amount of light scattered back to the receiver, which in turn is a function of the transparency of the air volume measured (approximately 3-30 meters in front of the instrument). A large amount of back scatter indicates dense air and low visibility. Minimal back scatter indicates clear air and high visibility. According to the supplier, the Videograph

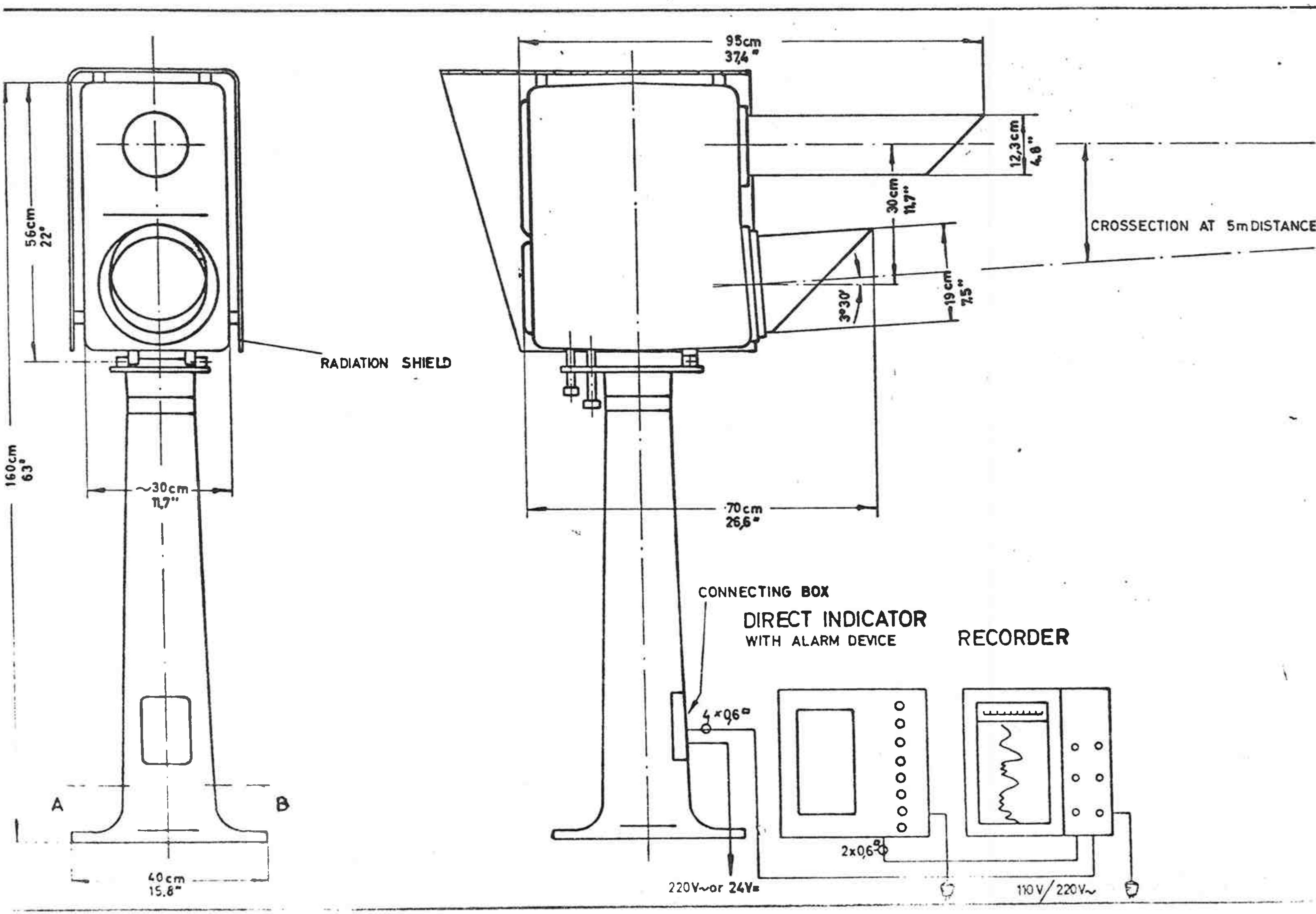

FIG 3. VIDEOGRAPH MOUNTING DIAGRAM

is accurately calibrated to cover visibility ranges from 20 to 1000 meters with a spectral range approximately that of the human eye.

Peripheral equipment used in this study consists of a Strip Chart Recorder, an Alarm Tripping Device and a Recorder Switching Unit. These three pieces of equipment were located in a field cabinet adjacent to the Videograph (Figs. 4 & 5). The Strip Chart Recorder produces a continuous permanent record of the visual conditions by recording (with a pen dot) the visual range every 20 seconds. The Alarm Tripping Device is intended to be used for controlling external equipment. The alarm levels can be set to correspond to specific visual conditions. As soon as the visibility changes above or below a pre-set value, relay contacts open or close to activate or deactivate warning equipment. Although not used to control the signs in this study, five alarm levels were set to correspond to 30, 60, 90, 150 and 200 meters.

The Recorder Switching Unit connects the Chart Recorder and Alarm Tripping Device by deflecting the recorder pen to the left (zero range) whenever an alarm threshhold is reached. This device provides a visual indication on the chart that an alarm level has tripped and, therefore, simulates sign changes that would have occurred if the Alarm Tripping Device was being used to control the advisory information displayed on the signs.

An adjustable delay circuit is included in the Videograph for use on one alarm circuit. This device permits delaying the relay operation for a specified time period (0-5 minutes for switching on and 0-8 minutes for switching off) following a change

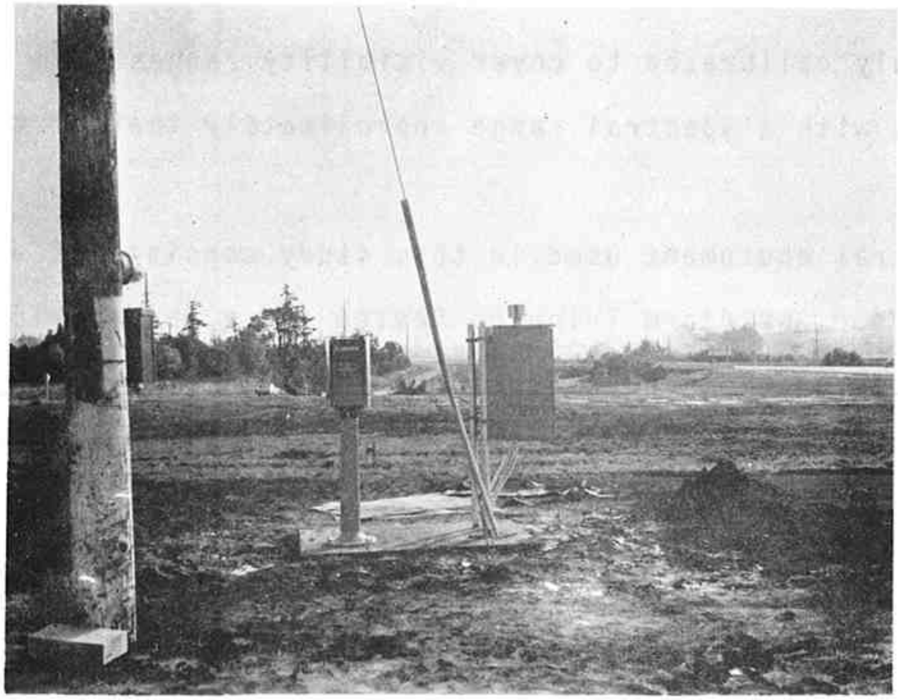

Fig. 4 Videograph Installation

Fig. 5 Field Cabinet with Strip Recorder and Alarm Tripping Device

in visibility levels. However, since the device can be used on only one alarm level at a time it has not been used during this study.

The Videograph was installed in the Millersburg area of Interstate 5. This region, which is one of heavy fog, is approximately located in the center of the highway section under study. The instrument is located 200 feet east of the freeway and faces south overlooking a clear area. The third northbound warning sign is located 1500 feet north of the installation.

The equipment was installed and calibrated in September, 1969, and operated continuously through the three subsequent fog seasons (normally from September to April). The total cost for the equipment and installation was $14,800.

Visual Test Procedures:

To test the consistency of the Videograph readings with human visual capabilities, a visual test range was established parallel to the Videograph's line of view. The range consisted of a row of standard highway delineators which served as sight posts. The posts were located at distances based on stopping sight distance of 30, 60, 90, 150 and 200 meters in front of the Videograph and corresponded to the five alarm tripping levels.

In conducting the visibility test a car containing the observer was positioned such that under normal conditions all five sight posts were in full view. During periods of fog the visual range was established by recording the furthest sight post which could be seen. To correlate these readings with the Videograph a stop watch was synchronized with the time scale on the strip recorder. Visual readings were taken periodically and the range and time recorded. These readings were then paired with the corresponding Videograph reading when the strip chart was removed.

Results & Discussion:

The results of this study consist of both the relationships found between the Videograph and human visual capabilities and the experiences with the equipment.

With respect to the visibility measures, the lack of adequate time periods of fog in the area since the installation of the equipment resulted in an insufficient amount of data to conduct a complete analysis. In addition, based upon the data that was collected, it became apparent that five sight posts were not adequate to obtain accurate estimates. The variable nature of the fog frequently resulted in cases where the visibility was between two sight posts and the specific range could not be determined. This condition was compensated for by installing additional sight posts at 20, 45, 75 and 105 meters, but there was little or no occurrences of fog after their installation.

As a result of these conditions the data presented below should be interpreted as preliminary and representative of the techniques which will be used to analyze future data. It should also be noted that although the visual data is somewhat discontinuous, the assumption of an underlying continuity is made and parametric procedures are used. The Videograph data is based upon the initial calibration.

A total of 157 pairs of observations were made under daylight conditions between September, 1969 and April, 1972. Some readings under night conditions were also obtained, but are not included in the analysis due to the insignificant number.

In conducting a comparison of this data, the basic hypothesis to be tested is that no significant differences exist between the two sets, or alternatively, the two sets were drawn from the same population. The statistical tests considered adequate for such a comparison are: F - test of the homogenity of the variance, t - test of the difference between the means and a correlation analysis.

Figure 6 contains a typical plot of the two sets of data while Table 1 contains the summary statistics for the total sample. In general, the Videograph readings tend to be higher than the visual results. An F-test of the variance was not significant, while the t-test of the differences between the means was significant (p .01). These results indicate that for the overall sample the variations about the means for the two measures are similar, but that the means are offset by approximately 50 feet.

Table 2 contains a bivariate frequency table for the total sample. Figure 7 is a plot of the means of the visual data and the Least Squares Regression Line for predicting the visual range from the Videograph range. An inspection of Table 2 and Figure 7 indicates that a considerable amount of variability exists. However, the means of the visual data tend to be grouped around the regression line, especially in the middle ranges where the higher frequencies occur. The correlation coefficient for the data is .81 substantiating the relationship. It should be noted that no data was collected for the critical short ranges of 200 feet and less, and an insufficient amount in the 200-300 range. Somewhat of a truncation of the visual data occurs at 658 feet.

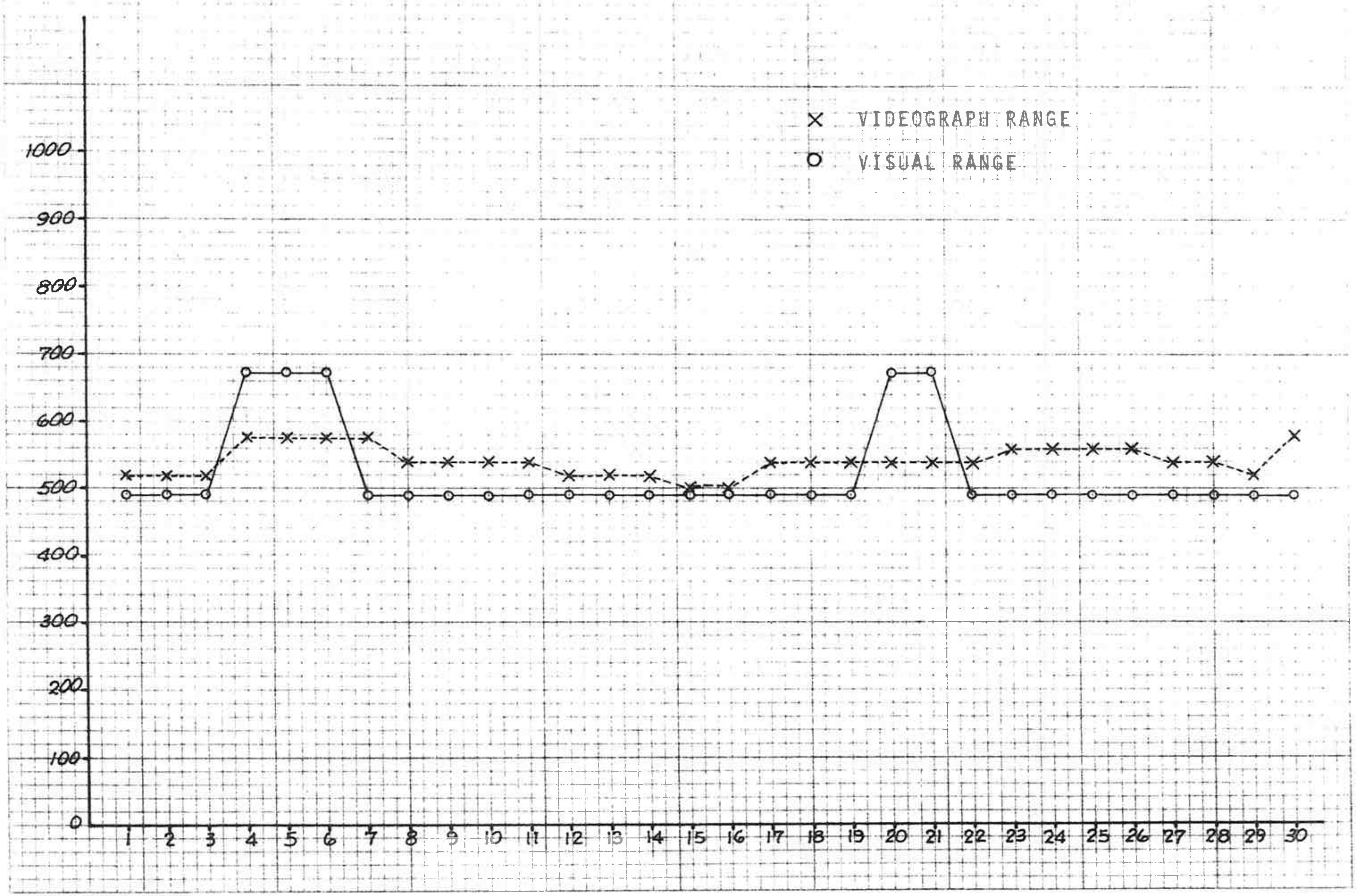

Fig 6. Typical Plot of Corresponding Videograph and Visual Range

	Visual Range (FT)	Videograph Range (FT)
Mean	520	569
Standard Deviations	118.5	140.1
Number	157	157

Table 1 Summary Statistics for Visual and Videograph Ranges

TABLE 2. BIVARIATE FREQUENCY TABLE FOR VISUAL AND VIDEOGRAPH RANGES

VIDEOGRAPH RANGE (FEET)	VISUAL RANGE (FEET)					
	295	392	492	575	658	MEAN
280	9	1				295
296	3	1				319
346	6					308
379			1			492
444		1				392
469			1			492
478	1					292
504	1		4		1	486
520	1		12			476
540			23		2	505
544			2			492
560			11		1	505
576			3			492
578			8		3	537
593			5		5	575
603			1	2	5	630
640			2		4	595
661			3		11	622
680			2			492
708					1	658
756					5	756
758					1	758
780					1	780
810					6	810
839					2	839
854					1	854
855						855
858					1	858
922					2	922
940					1	940
N	21	3	78	2	53	
MEAN	332	362	555	640	693	
STD.DEV.	74	61	45	0	108	

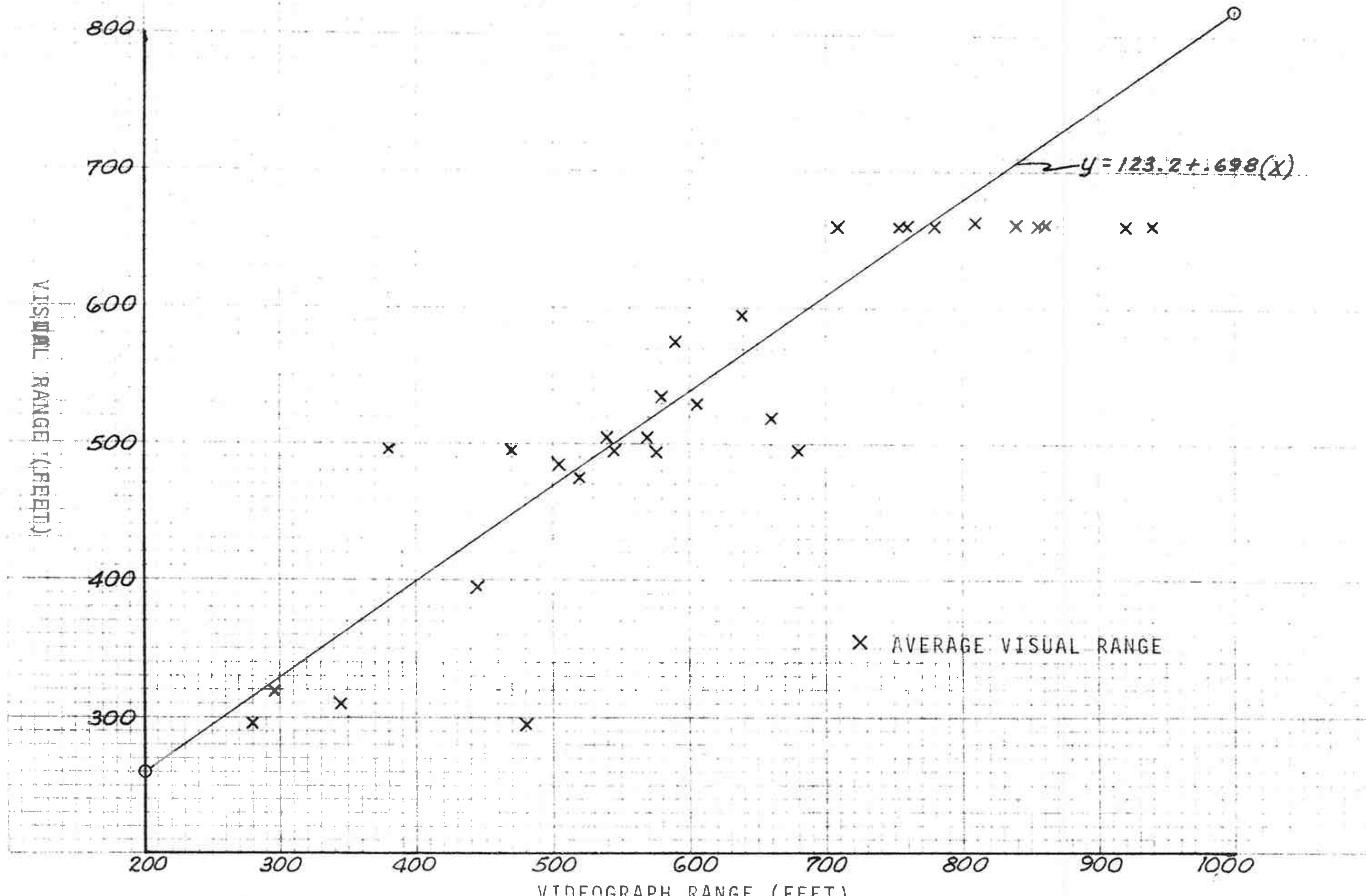

Fig. [illegible] AVERAGE VISUAL RANGE AND LEAST SQUARES REGRESSION LINE

The operating experiences with the Videograph itself have shown it to be relatively trouble free. The only proglem encountered was the requirement to manually restart the equipment following a power fluctuation or power failure. This requirement occurred on the average of three times during each operating season. Other than this, maintenance requirements have been minimal.

Experiences with the recorder showed it to be a greater problem both in terms of maintenance and operation. Idiosyncrasies were found with the paper drive mechanism which required changing the paper and oiling the recorder every seven to ten days. More significant, however, was the operation of the alarm circuitry. As installed, the Recorder Switching Unit caused the scriber on the recorder to drive to the left edge of the recorder tape whenever the visibility went above or below an alarm level set on the Alarm Tripping Device. In practice, when the visibility was near an alarm level, random fluctuations in the density of the fog would cause fluctuations above and below the alarm level as well as between alarm levels, with subsequent movement of the scriber to the left and back again. These frequent movements prohibited accurate determination of the visibility level from the recorder chart and required disconnection of the Recorder Switching Unit.

Since the pen movements correspond to changes in the speed advisory information that would have occurred had the Alarm Tripping Device been used to control the Warning Signs, these results indicate that modifications would be required for satisfactory automatic control of the signs. The most apparent modification would be to include the capability for visibility averaging to dampen the random fluctuations. Using such an approach, the advisory information displayed on the signs would be based upon the average visibility which existed over a specified time period and the display up-dated as required. The time periods would have to be determined experimentally, although consideration should be given to a self-adapting system in which the time period is determined by the rate and magnitude of the density fluctuations which occur. The existing type of delay circuit built into the Videograph does not appear adequate for this purpose since it only delays the switching event for a specified time period.

Conclusions & Recommendations:

Although the results of this study should be considered preliminary, the data collected and personal observations suggest that the Videograph may not be acceptable for complete automatic control of the warning signs without equipment modification. The Videograph measures a sample of the atmosphere 3-30 meters in front of the transmitter and receiver. In the majority of the cases observed in this study, the fog was not homogenous, but varied considerably in density at points even a short distance apart. This condition manifested itself both in the problem experienced with the alarm circuitry and in the visibility data. Although the spacing between the sight posts can account for some of the difference between the means and variability in the data, some can also be attributed to rapidly changing visibility conditions. This situation can be aggravated by wind or air currents, some of which may be generated by the traffic itself.

In light of these findings, it does not appear practical to use the Videograph for automatic control of the warning signs without the addition of equipment for visibility averaging to dampen the random density fluctuations. A Videograph with such equipment appears to have potential for automatic control and an evaluation of such a system should be undertaken.

Without visiblity averaging another possible use of the Videograph is as an indicator of the development of adverse conditions in an area. The location of the device could be selected on the basis of particularly heavy fog (worst case conditions) or on the basis of the area being representative of a larger total area (average conditions). Under this approach the equipment would be used to provide a warning and as a data input into the decision of what speed conditions should be set. It is also possible that the device could be used as an on-off control for the "SLOW - FOG" portion of the sign with the speed limits manually set. Either approach would require additional data, especially in the critical lower visibility ranges of 200 feet and less, and under night conditions.