NATIONAL BUREAU OF STANDARDS REPORT

10 105

FIELD TESTS OF AN EXPERIMENTAL MODEL VISIBILITY METER

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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FIELD TESTS OF AN EXPERIMENTAL MODEL VISIBILITY METER

By
J. W. Simeroth
J. C. Wilkerson
J. E. Davis

For
Naval Air Systems Command

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This report describes the field testing of and results obtained from an experimental model visibility meter developed by AGA. The device operated from the backscatter of infrared radiation by particles in the atmosphere. The output followed the visibility trends and the average output varied approximately linearly with the logarithm of the visibility for ranges greater than one kilometer. The instrument output for a given transmittance had a wide range of values. Some of the malfunctions encountered and the limitations of performance and suggestions for improvement of the equipment are discussed.

1. INTRODUCTION

Accurate and timely visibility information is very important for operations at airfields. This information is usually obtained from visual observations or from the runway visual range (RVR) or runway visibility (RVV) determined from the transmissometer measurements. The increase in amount of traffic at most major airfields and the emphasis on operations in lower visibility conditions require continuous visibility measurements from several locations on the field. Other applications in addition to those of aviation, such as controlling traffic on highways and waterways and measuring fog density at remote sites and at special locations, are developing. In many locations a single-ended installation, one with all the field components placed at one site, is needed because terrain or obstructions prevent installing a transmissometer. The recent development of several types of fog detector devices using either the backward scatter or forward scatter of emitted radiation has possibilities of making measurements suitable for determining visibility.

AGA Aktiebolag, Signals Division, Lidingo, Sweden, developed and tested an experimental model of a visibility meter. This visibility meter has the potential of measurements along a path at angles above, as well as in, a horizontal direction. AGA agreed to lend this visibility meter to the National Bureau of Standards (NBS) for tests at the Arcata (Airport), California, for a period of six months starting in January 1968. Since this period was not in the main fog season at Arcata, the loan period was extended to October.

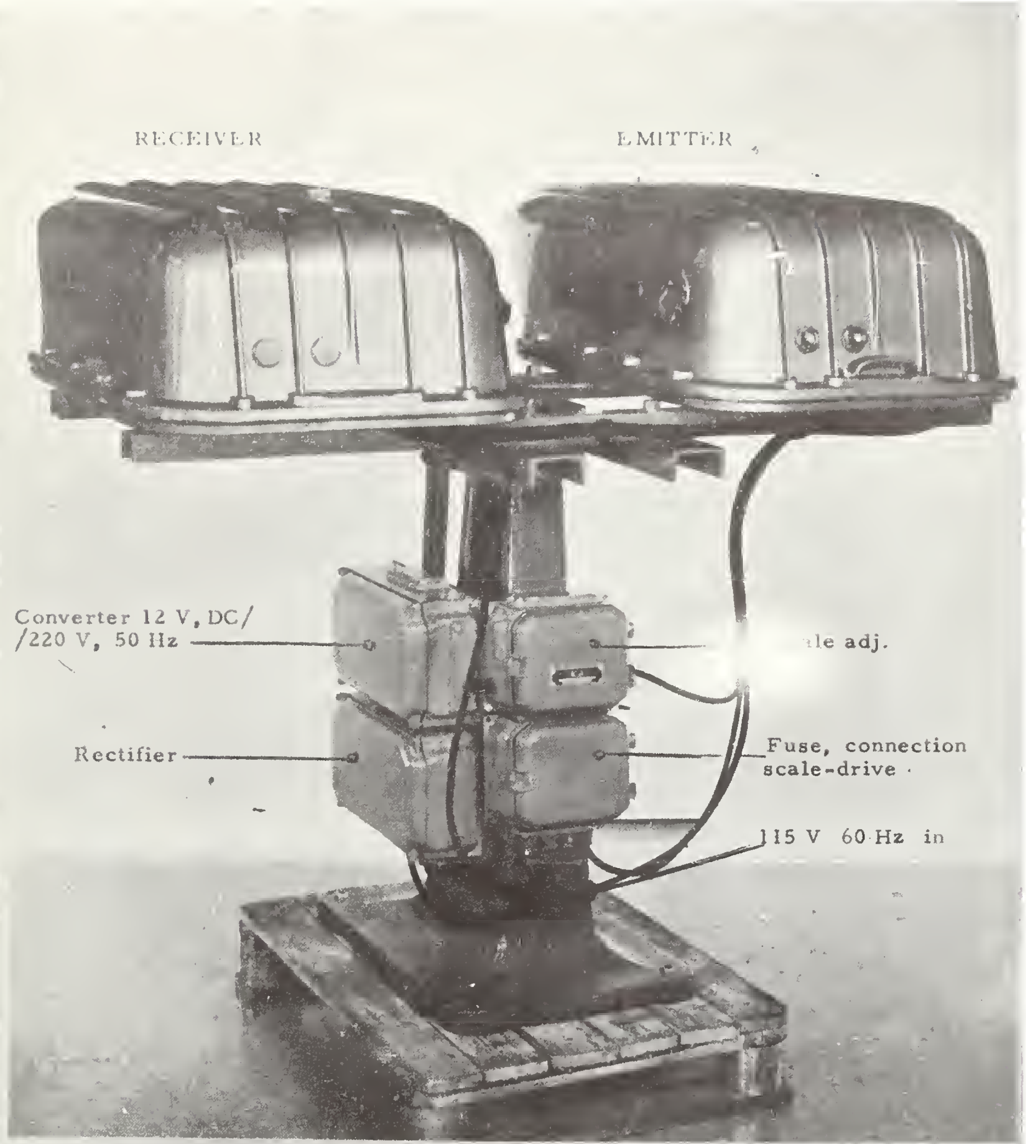
2. DESCRIPTION OF EQUIPMENT

2.1 System Description. The AGA visibility meter was an experimental model developed from the RTM-1A fog detector which is based on the backscatter of infrared radiation. The test instrument consisted of an emitter, a receiver, a 60-hertz to 50-hertz power frequency converter, and a scale adjuster (see figure 1). The emitter and receiver were housed in separate units which bolted to a common frame. This assembly was mounted atop a pedestal, which permitted the optical axes to be adjusted simultaneously to any angle from horizontal to nearly vertical. The power frequency converter and scale adjuster were housed in four small boxes which were fastened to the sides of the pedestal. The power required for this unit was approximately 200 watts from a 120-volt, 60-hertz source. The recorder was a 1.0 milliampere d-c instrument which could be located at any site as long as the resistance of the meter lines did not exceed 200 ohms.

The instrument worked on the backscatter principle (see figure 2). An infrared light beam was projected from the unit and partly scattered by particles in the atmosphere. The backscattered light was focused on a photo-diode in the receiver, and the signal generated by the photo-diode was amplified by an electronic amplifier. A sample of light (pilot beam) from the emitter was fed into the receiver photo-diode by a fiber-optics bundle. The intensity of the pilot beam was automatically adjusted to balance with the atmospheric return signal. A signal corresponding to the attenuation of the pilot beam fed the indicating element of the recorder.

The optical axes at the emitter and receiver were separated by 1.0 meter and were alined so the axes crossed at 200 meters from the visibility meter. The visibility meter was sensitive to the backscattered light in the region from 6 to 200 meters from the instrument. The instrument was intended to operate in visibilities between 0.8 and 20 kilometers. The apparatus had a built-in protection against sunlight which screened the photocell when the sun was within three sun diameters of the optical axis.

2.2 Emitter. The emitter utilized a 150-watt, 12-volt, photographic projection lamp, which was operated at 6 volts for extended life. The light was projected through a perforated-shutter disk operated by a 50-hertz synchronous motor, which modulated the beam of light at 750 flashes per second. The light beam was filtered by a dark red filter so that the projected radiation was near infrared. This light then passed through a 200-millimeter diameter lens-window combination and into the atmosphere. This beam of light was shaped by an auxiliary lens to spread part of the light towards the axis of the receiver. The intensity distribution of this spread light was designed to produce an approximately uniform response independent of distance from the receiver of each section of the fog volume sampled. The instrument is sometimes referred to as a "tailored-beam" visibility meter. The pilot beam was obtained through



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Visibility Meter (experimental model)
seen from the rear

Figure 1. AGA Visibility Meter seen from rear.

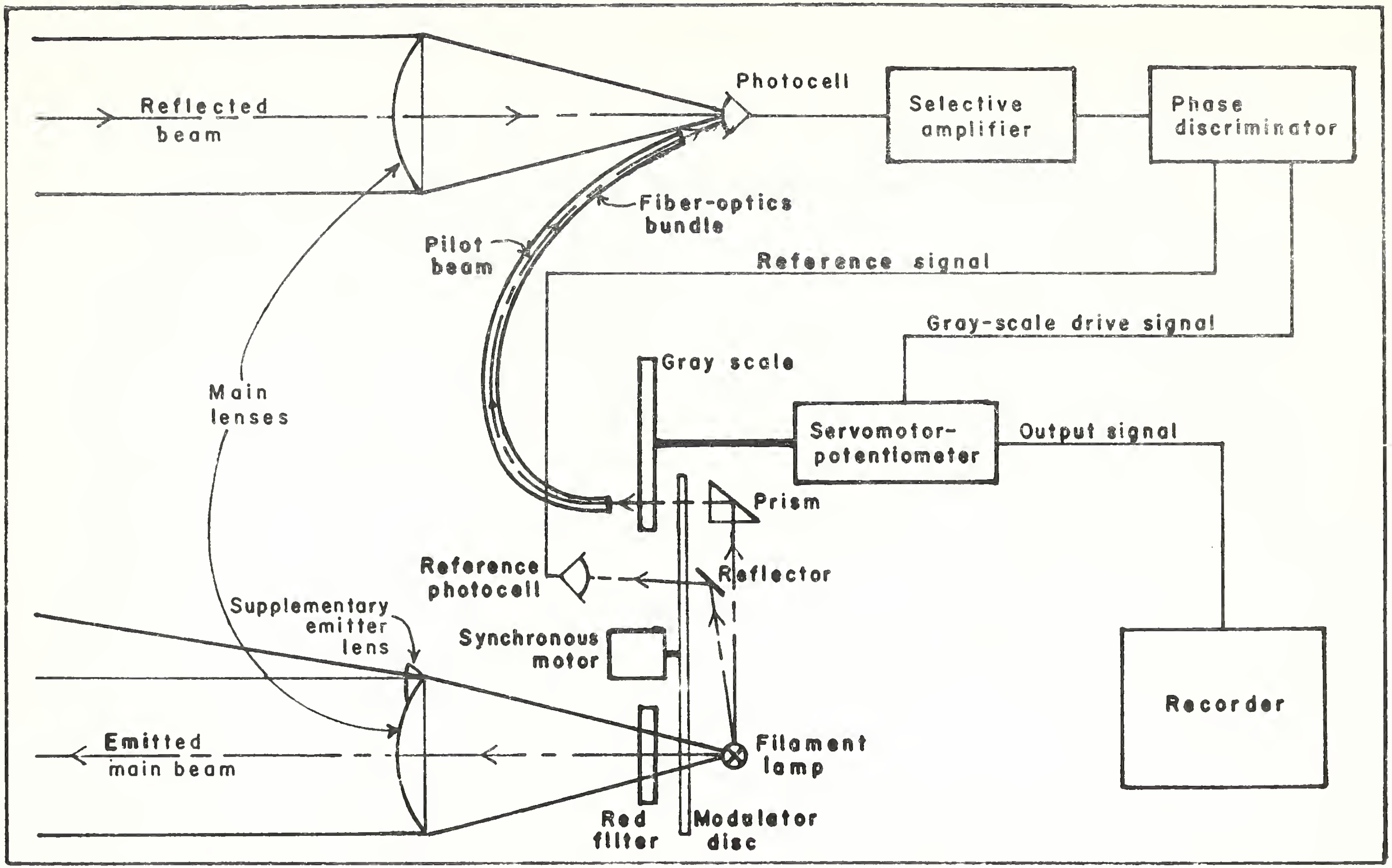

Figure 2. Diagram of the AGA visibility meter.

a hole in the reflectorized coating at the side of the lamp. After modulation at 750 flashes per second in a different phase from that of the main beam, the pilot-beam signal passed through a neutral-density filter and fiber-optics bundle to the receiver photo-diode. This neutral-density filter was a circular-type variable filter with a density range of 1 to 1000 which was calibrated along the edge with a linear scale from 0.0 to 3.0 and was called the "gray-scale". The gray-scale, servomotor, and the potentiometer for driving the recorder were mounted in the emitter housing and are discussed with the receiver.

2.3 Receiver. The receiver portion of the instrument viewed the atmospheric backscattered light through a lens-window combination similar to that of the emitter. The receiver photo-diode sensing element (photocell) was mounted near the focal point of the lens and viewed both the atmospheric return and the pilot-beam signal from the emitter. Because of the synchronous shutter arrangement, the receiver viewed the atmospheric return signal and the pilot signal alternately. The sensing element was followed by several tuned amplifier stages and a synchronous detector. The action of the synchronous detector and associated circuitry was to compare the amplitude of the atmospheric return signal with that of the pilot-beam signal. When the signals were not equal or balanced, the circularly-mounted gray-scale was rotated by a servo-motor towards balance every five seconds. When the signals were balanced or when the reflected signal was greater, an indicating lamp visible from outside the instrument was energized. The instrument output for the recorder was taken from a one-turn potentiometer connected to the gray-scale shaft. The output current varied directly with the gray-scale setting. The output circuit allowed wide adjustment of the gray-scale positions to be represented by the zero and full scale positions of the recorder.

2.4 Recorder. The recorder furnished with the equipment was a Siemens dotted-line recorder type M734. This recorder had a range of 0 to 1.0 milliamperes d-c and was of the falling-bar type. The paper speed was 60 millimeters per hour, and each roll lasted approximately one month. There were two hand-produced scales on the recorder, one for fog and rain, and one for snow. These scales were intended to apply when the range of the recorder was adjusted for gray-scale settings of 0.5 and 3.0 to agree with recorder readings of 0.0 and 1.0, respectively. The recorder was powered from a 120-volt, 60-hertz source.

2.5 Power Frequency Converter. The instrument utilized a 60-hertz to 50-hertz power frequency converter. The 50-hertz power was required to operate the synchronous shutter-drive motor. The remaining portion of the instrument operated from 60 hertz. The input to the converter unit was 120 volts, 60 hertz at 1 ampere. The 60-hertz power was rectified to 12-volts d-c and the 12-volts d-c was converted to 50 hertz at 220 volts. Sixty-hertz 220-volt power was also provided.

3. INSTALLATION

The site selected for testing of the visibility meter was the east test site at the Arcata Airport. This site is relatively flat and free of obstructions which interfere with the fog, as is shown in the aerial view, figure 3. The instrument was mounted on a concrete pad and covered by an instrument shelter which had two apertures cut in the wall for the emitter and receiver. This allowed the optical axes to be alined from 0 to 6 degrees above horizontal. The instrument shelter also had a movable roof to provide the opening when the instrument was aimed more than 6 degrees above the horizontal. The instrument and instrument shelter are shown in figure 4.

The installation of this instrument was near the projector stand of transmissometer TL-2. The atmosphere sampled by the visibility meter was close to and nearly parallel with the 250-foot baseline of the transmissometer TL-2.

The readout-meter leads were extended 2600 feet to the recorder in the laboratory. A milliammeter was also installed in the instrument shelter for maintenance and calibration purposes.

4. TEST PROCEDURE

The procedure for the field tests of this visibility meter was to operate the equipment continuously and to record the output. Except for some special occasions, the unit was aimed with the optical axes of the emitter and receiver at six degrees above the horizontal. In several fog conditions, series of measurements were made with the optical axes aimed at 6, 30, and 60 degrees above the horizontal. For these measurements, the elevation angles were changed manually by raising and lowering one edge of the frame on which the emitter and receiver were mounted. At each of these angles, the position was maintained for approximately four minutes or longer while two sets of readings were recorded. Throughout the field tests, the records of transmittance from a 250-foot-baseline transmissometer located approximately 20 feet from the visibility meter were obtained for comparison with the visibility meter records.

The calibration of the visibility meter was checked at the initial installation by the manufacturer's representatives and was checked periodically during the field tests. These calibrations were made by placing a diffuse white target approximately ten meters in front of the unit. Then the gray-scale reading for a balance was determined for different aperture openings of the receiver. Diaphragms to fit over the receiver lens were provided with apertures of 4, 14, and 50 millimeters diameter which were intended to provide gray-scale readings of 2.7, 1.5, and 0.3.

Figure 3. Aerial View of the East test site.

Figure 4. AGA Visibility Meter as installed in its shelter.

Two potentiometers were provided, one for adjusting the recorder zero to correspond to any desired minimum gray-scale setting, and the second to adjust the recorder range to agree with the desired range of gray-scale values. For the original adjustments, the recorder indication corresponded to a gray-scale range of 0.5 to 3.0. This range, according to the manufacturer's calibration for fog and rain, was designed to cover visibilities of one kilometer and above. To obtain data at lower visibility conditions, the limits were adjusted so the recorder would cover gray-scale ranges of 0.2 to 3.0, 0.0 to 3.0, and 0.0 to 1.0 at various times during the field testing. The balance position was determined by the density of the gray-scale filter and was not related to the range of gray-scale covered by the recorder. The recorder indication was linear with the gray-scale setting for the range covered. The recorded data were converted from recorder indications to gray-scale settings for presentation.

5. RESULTS

5.1 Results from Continuous Operation. The gray-scale settings (as indicated by the recorder) as a function of transmissometer reading over a 250-foot baseline are shown in figure 5. The unit was aimed with the optical axes six degrees above the horizontal for these data. These data were obtained during the first six weeks of the field testing before the records indicated changes in the sensitivity of the unit. The average value and range of gray-scale settings for each transmissometer reading interval are shown with the number of observations in each average. Usually these observations were made when the recorder indication was nearly stable for five minutes or longer; however, some measurements of shorter duration were used to obtain data in transmittance ranges which seldom have stable periods or at times when the recorder indication reached temporary peak or minimum values.

5.2 Effect of Changing Elevation Angles. A series of measurements were made, for several different fog conditions, in which the elevation angles were at 30 and 60 degrees, as well as at the normal six degrees above the horizontal. The results from those tests made before the equipment malfunctions affected performance are given in table 1. Most of these tests were in atmospheric conditions with fairly good visibility below denser layers of fog. The data obtained before the equipment malfunctions were too limited to evaluate the effect of changing elevation angles in all conditions. This limitation is discussed further in section 6.4. The differences of the gray-scale settings at balance for 30 and 60 degrees to the gray-scale settings at six degrees show some effects of angle on the gray-scale setting for associated transmissometer readings. Federal Aviation Administration (FAA) Flight Service Station official observations of ceiling and visibility were used to provide ceiling information. The sets of data are arranged in order of reported ceiling heights and visibilities and not in chronological order.

TABLE 1

The Effect of Elevation Angle on AGA Visibility Meter Response

FAA Observations		Transmissometer	Gray-Scale Settings						
Ceiling (feet)	Visibility (miles)	Readings (250-foot baseline)	6° Setting	30° Setting	Difference 30° - 6°	V_{30}/V_6	60° Setting	Difference 60° - 6°	V_{60}/V_6
100	3/16	0.56	0.65	0.44	-0.21	0.75	0.45	-0.20	0.76
100	1/4	0.35	0.38	0.41	+0.03	1.04	0.37	-0.01	0.99
100	1/4	0.43	0.35	0.35	-0.00	1.00	0.36	+0.01	1.01
100	1/4	0.76	0.54	0.21	-0.33	0.63	0.23	-0.31	0.65
200	1	0.96	1.59	0.45	-1.14	0.21	0.17	-1.42	0.14
300	1	0.93	1.70	0.89	-0.81	0.33	0.56	-1.14	0.21
300	1	0.95	1.99	1.33	-0.66	0.40	0.79	-1.20	0.19
300	1 1/2	0.94	1.66	1.24	-0.42	0.56	0.68	-0.98	0.26
400	1	0.93	1.82	1.43	-0.39	0.58	0.84	-0.98	0.26
400	1 1/4	0.93	1.80	1.39	-0.41	0.57	0.89	-0.91	0.28
400	1 1/2	0.92	1.68	1.35	-0.33	0.63	0.98	-0.70	0.38
400	1 1/2	0.90	1.59	1.38	-0.21	0.75	0.96	-0.63	0.42
500	2 1/2	0.955	1.73	1.46	-0.27	0.69	1.21	-0.52	0.49
500	3	0.96	2.15	1.33	-0.82	0.32	0.94	-1.21	0.19
500	3	0.965	2.22	1.40	-0.82	0.32	0.90	-1.32	0.16
600	5	0.965	2.08	1.38	-0.70	0.38	0.86	-1.22	0.19
600	5	0.965	2.06	1.32	-0.74	0.36	1.08	-0.98	0.26
600	5	0.965	2.08	1.43	-0.65	0.41	1.12	-0.96	0.27
800	2	0.96	2.13	1.82	-0.31	0.65	1.52	-0.61	0.43
800	2	0.97	2.26	1.80	-0.46	0.52	1.46	-0.80	0.33
1100	5	0.97	2.08	1.99	-0.09	0.88	1.96	-0.12	0.85
1200	5	0.97	2.21	2.08	-0.13	0.83	1.96	-0.25	0.71

(The significance of the columns headed V_{30}/V_6 and V_{60}/V_6 is discussed in Section 6.4.)

5.3 Calibration Results. The initial calibration, made immediately after installation, showed the gray-scale setting at balance to be within 0.05 of the prescribed values for each aperture. A calibration check after one month of operation gave results which differed greatly from the initial settings, indicating a malfunction. The emitter lamp was replaced and the hole in the reflector coating from which the pilot beam was obtained was enlarged. The gray-scale settings at calibration were then within 0.1 of the initial settings. After another month of operation, the results during a calibration check indicated more malfunctioning. Investigation showed that the emitter lamp socket was damaged either from excessive heat or arcing at the contacts. A replacement socket was not available so the contacts were cleaned and adjusted. The calibration check then gave gray-scale settings 0.1 to 0.3 units higher than the recommended values. Calibration checks before the equipment was dismantled were intermittant but none were considered satisfactory. (The manufacturer reported that calibration checks made after the instruments were returned and after replacement of the emitter lamp and socket indicated normal performance.)

5.4 Response During Unsatisfactory Operation. The records of operation appeared nearly normal during the period when the calibration check gave gray-scale settings 0.1 and 0.3 units higher than recommended. To determine the change in performance indicated by this change in calibration, the gray scale settings and corresponding transmissometer readings were tabulated for a two-week period. The results are shown in figure 6. Note that the average results are approximately 0.3 units higher than the averages in figure 5.

5.5 Response in Rain. The spread of the gray-scale settings of the AGA visibility meter for a given transmittance, as shown in figure 5, is very wide. One possible cause of this wide variation is believed to be the relation between particle size and the backscatter of light. Since there was no equipment at Arcata for measuring atmospheric particle size, the gray-scale settings during a 48-hour period of rain were tabulated as a function of transmissometer reading and are presented in figure 7. Heavy rain which reduces transmittance to low values seldom occurs at Arcata. For most of the data used in figure 7, the reduction in transmittance was caused primarily by the fog accompanying the rain but the larger rain drops would be a contributing factor.

5.6 Daylight Effects. The response of this visibility meter was affected by daylight. At the beginning of the field testing, the gray-scale setting was as much as 0.1 gray-scale units lower in daylight than at night for similar transmittance. The decrease in gray-scale setting in daylight increased with time and in some cases appeared to exceed 0.2 gray-scale units. During the period of the lamp malfunction, when the filament was out of focal alinement, the daylight effect exceeded 0.5 gray-scale units.

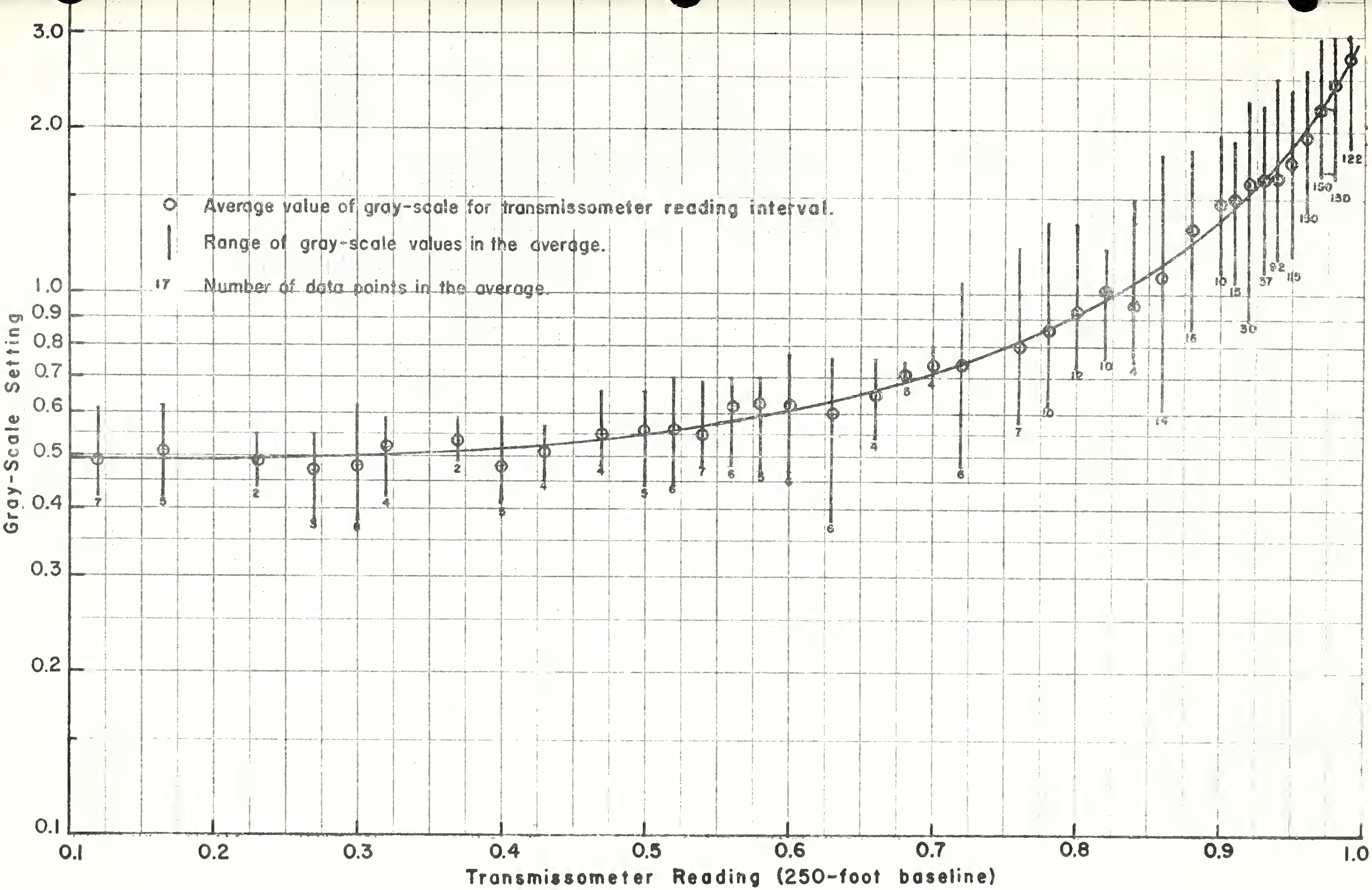

Figure 5. Gray-scale setting as a function of transmissometer reading for period before malfunction.

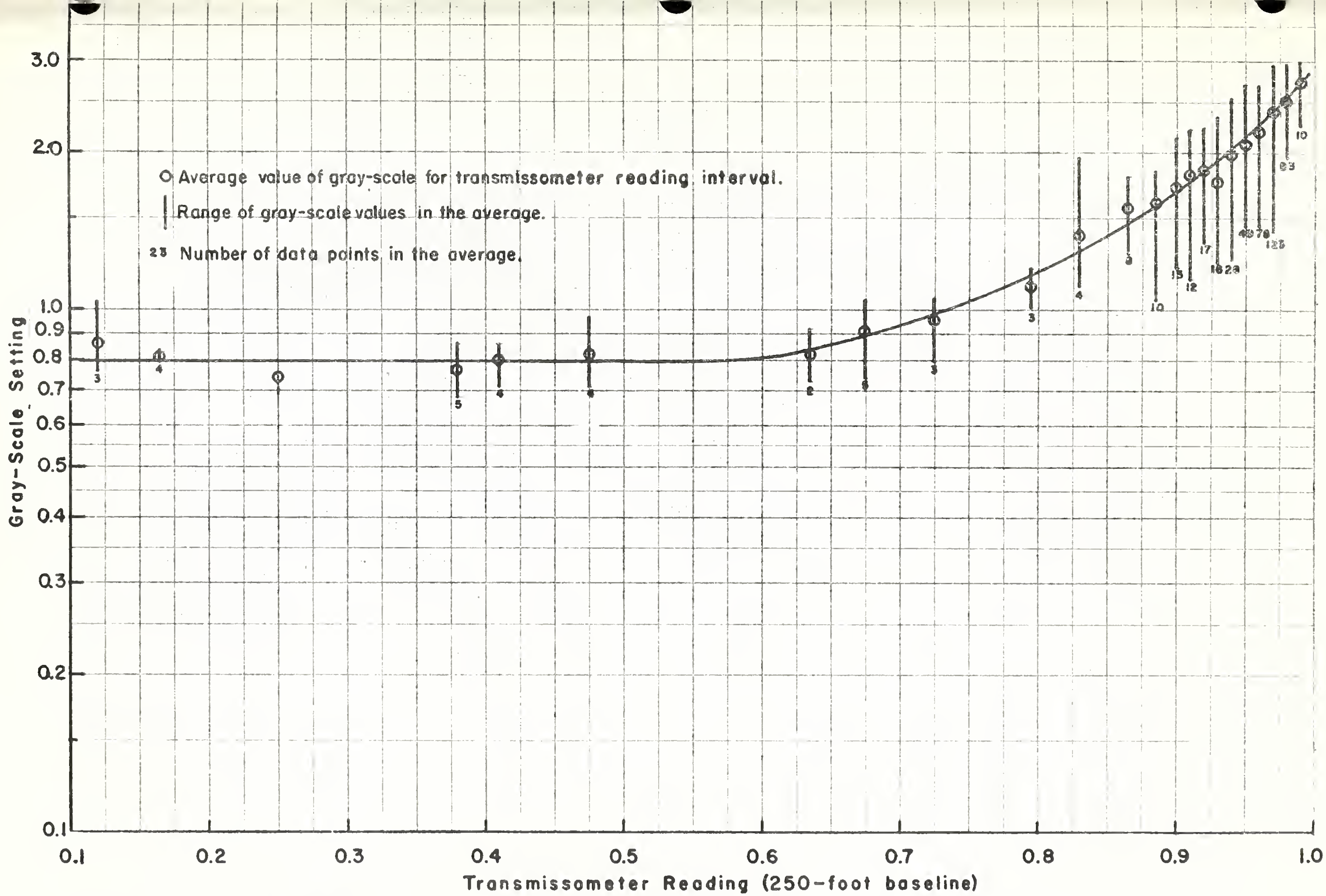

Figure 6. Gray-scale setting as a function of transmissometer reading after malfunction.

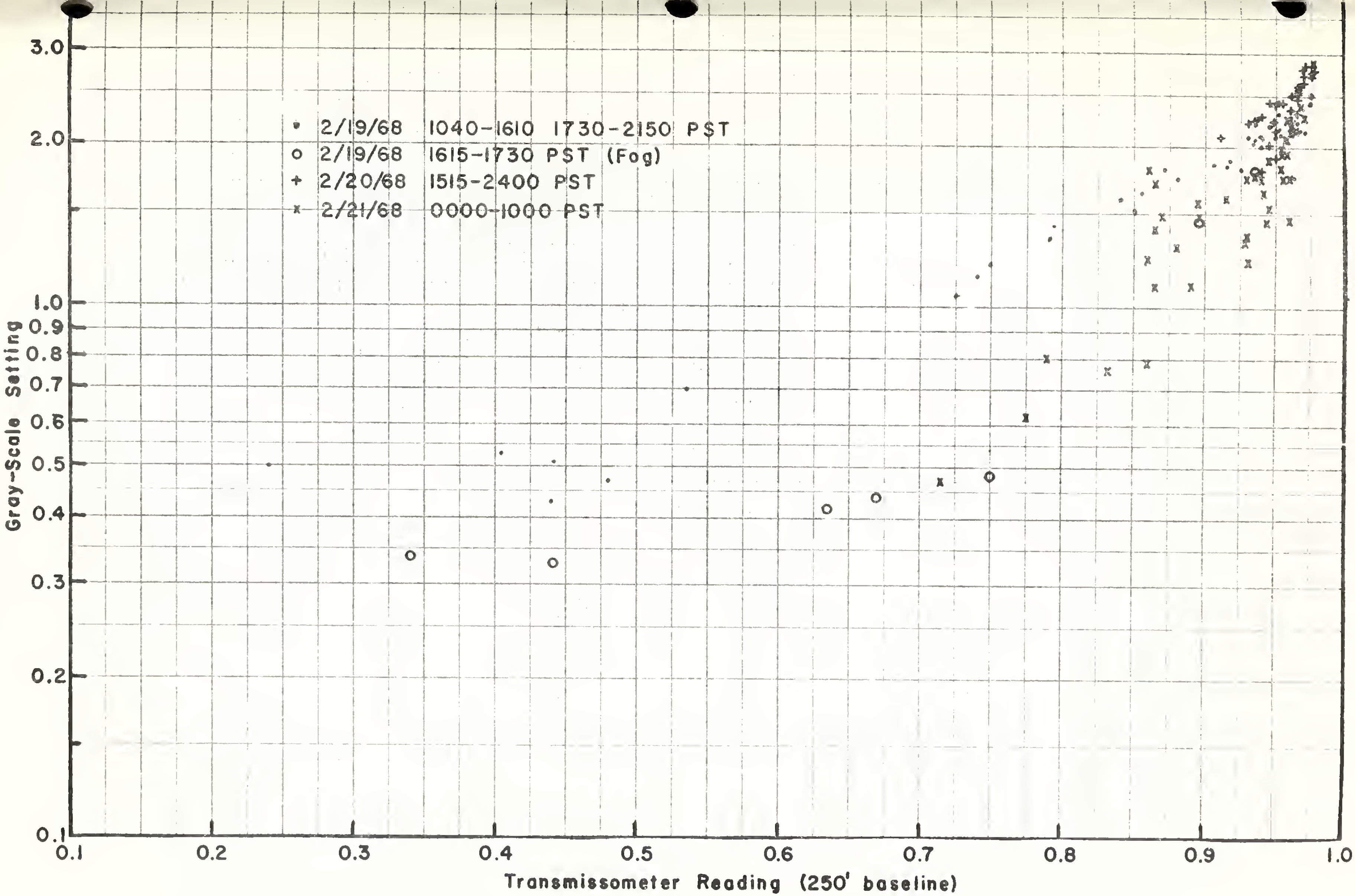

Figure 7. AGA visibility meter response in rain as a function of transmissometer reading.

5.7 Recorder Operation. The dotted-line record usually had a spread of 4 to 10 percent of full scale and the chronological order of the dots was not always easy to determine. The instrument output was also recorded with a continuous-line recorder for many of these tests. This type record was better for reading values. Frequently, the atmospheric conditions changed rapidly at Arcata and the continuous records were more useful for following these trends than were the dotted-line records.

5.8 Maintenance. Routine maintenance consisted of caring for the recorder and keeping the lenses clean. A calibration check was made at approximately one month intervals to determine equipment performance. As indicated in paragraph 5.3, these calibration checks were more sensitive to unsatisfactory performance than routine observation of the records. A number of malfunctions of the components occurred, as was anticipated for an experimental instrument. These malfunctions are discussed in Section 6.7.

6. DISCUSSION OF RESULTS

6.1 Gray-Scale Setting as a Function of Transmittance. The average gray-scale setting at balance, as shown in figure 5, is a smooth function of transmittance. However, the spread in individual readings within a given increment of transmittance was greater than would be expected from normal nonuniformity of the atmosphere. Experience at Arcata indicates that two transmissometers separated by distances similar to the distance between the AGA visibility meter and the transmissometer would seldom have such a marked spread in readings. Several factors inherent in the system or equipment may have contributed to the spread. The servomotor drive at balance appeared to vary by as much as 0.1 units of the gray-scale. The daylight effects described in paragraph 5.6 may have changed the setting by 0.1 or more units between daylight and night. Perhaps the major factor in response variation is the effect of the particle size on the backscatter.

6.2 The Effect of Particle Size. The backscatter of light from a particle in the atmosphere is dependent on the size of the particle and the wavelength of the light. The total scattering of white light from fog particles is considered to be independent of the particle-size distribution, but scattering in a specified direction, such as backscatter, is dependent on the particle size. In previous tests by AGA, two curves for visual range as a function recorder indication were obtained--one for water in liquid state and one for water in a crystalline state. The liquid-water curve was intended to include rain, mist, and fog and perhaps haze.

The data on the response in rain at Arcata are presented in figure 7. The rain data were limited to a 48-hour period from two separate storms. The rain varied from moderate to very light and most of the time was accompanied by fog. On February 19, except for a short period when dense fog occurred, the gray-scale setting, as depicted by the closed dots, showed higher than average gray-scale settings, near the upper limit of the ranges shown in figure 5. This indicates a low backscatter for a given transmittance. For the one-hour period of dense fog identified by the open circles, the gray-scale settings indicate a very high backscatter. Although light rain continued to fall, the transmissometer records indicated that the surface air mass had characteristics which differed from those of the surface air mass earlier and later. The data for February 20, identified by the +'s, were obtained primarily in rain and indicate low backscatter. The data for February 21, for rain accompanied by fog, indicate the backscatter was moderate to high. Further investigation, with measurements of particle size and distribution, is needed to determine the effect of particle size on the response of this equipment. Although the data in rain do not definitely show the effect of particle size on backscatter, they do show that the gray-scale setting for a given transmittance changes with a change of air mass.

6.3 Correlation of Gray-Scale Setting with Visibility. The visibility curve for liquid particles furnished with the recorder indicated that the gray-scale setting varies linearly with the logarithm of the visibility. Figure 8 shows this recorder-scale calibration provided by AGA and the visibility for day and night as determined from the transmissometer readings as a function of gray-scale settings.

Visibilities derived from the transmissometer readings for day are computed from the relation

$$T_{250}^{V_o/250} = \varepsilon$$

where

T_{250} is the transmittance over a 250-foot baseline,

V_o is the visibility (of a large dark object) in feet, and

ε is the contrast threshold. A value of 0.55 is used for ε.

Visibilities at night are determined from the relation

$$IT_{250}^{V_n/250} = S_v V_n$$

where

I is the intensity of the light source observed, assumed to be 25 candelas

T_{250} is defined as above

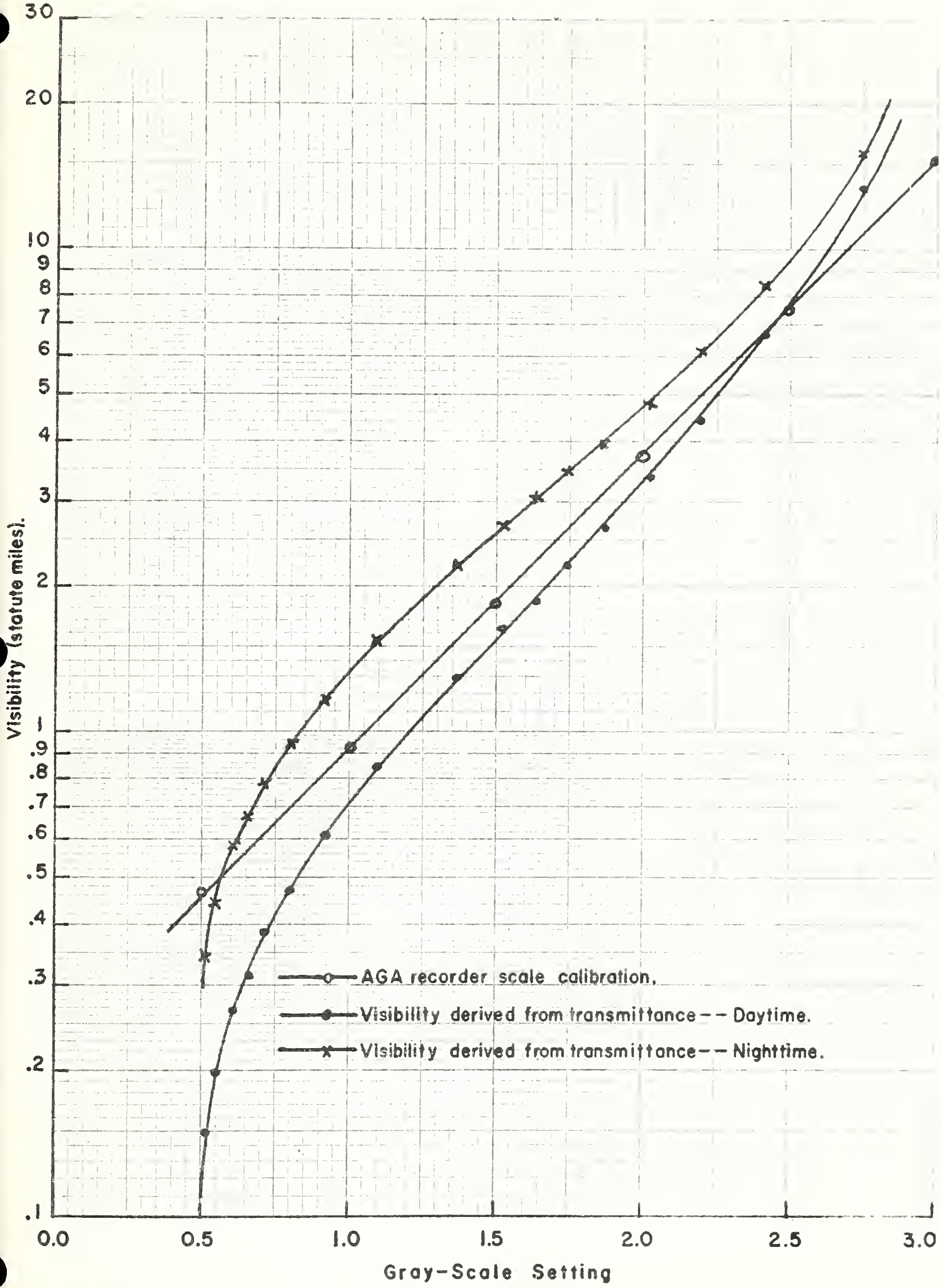

Figure 8. Relation between visibility and gray-scale setting.

V_n is the visibility (of the light) in feet, and

S_v is the illuminance threshold of the observer, assumed to be 1.58×10^{-5} lumens per square foot.

The gray-scale settings corresponding to transmissometer readings were obtained from the curve in figure 5. Note that the curve for daytime visibilities obtained from transmittances is nearly a straight line down to about one-half mile (one kilometer) or 0.8 transmittance. For lower visibilities, the gray-scale settings decreased very slowly. At the high visibilities, the departure from linearity may be caused partly by small errors in the 100 percent setting of the transmissometer or the error in averaging the AGA visibility meter recorder readings near the top limit. Because of the set upper limit on the recorder and servometer drive, departures from the average reading near full scale can be greater downward than upward, and the mean reading will tend to be low. The representatives from AGA stated that satisfactory operation was expected down to gray-scale settings of 0.2. If satisfactory operation to this level were obtained, this would extend useful range in daytime visibility to approximately one-fourth mile.

6.4 Effects of Elevation Angle. The data obtained with the axes of the emitter and receiver more than six degrees above horizontal were inadequate to evaluate accurately the instrument's suitability for determining slant visibility. Additional tests of changing elevation angles were not made because the data were not reliable after the equipment malfunctions. The tests which were performed were in advection type fogs or low stratus cloud conditions only. Under these conditions the visibility is greater near the ground than at higher elevations in the fog or inside the stratus clouds. Thus the gray-scale settings were expected to be lower as the elevation angle was increased. Note that the differences in table 1 are nearly all negative at both 30 and 60 degrees for reported ceilings up to 800 feet. At these elevation angles, the backscatter into the receiver from particles more than 200 or 300 feet above the ground should be negligible. The differences obtained indicate that transmittance was lower for several hundred feet below the bases of clouds or fog layers than at ground level. No data were obtained in radiation type fog, which occurs infrequently at Arcata. In shallow radiation type fogs, differences of the type reported in table 1 might be positive. Further investigation will be required to accurately determine slant visual ranges from these measurements.

As is evident from figure 8, the calibration curve of the visibility meter is of the form

$$\log V = aS + b$$

where V is the visibility, S is the gray-scale setting and a and b are constants. Therefore, the difference between two gray-scale settings is proportional to the logarithm of the ratio of the corresponding visibilities; that is

$$\log(V_1/V_2) = a(S_1 - S_2)$$

From figure 8 it is seen that a is approximately 0.6. Thus

$$\log(V_1/V_2) = 0.6(S_1 - S_2)$$

The ratios of the visibilities indicated by the 30° and the 60° elevations to the visibility indicated by the 6° elevation have been computed using this relation and are included in table 1. Note that the instrument is designed to use a fog sample approximately 300 feet long. Thus, if the fog density is uniform horizontally but varies with height, measurements made at elevations of 30° and 60° should be indicative of the slant visibility from heights of 150 and 300 feet respectively.

6.5 The Effectiveness of the Calibration Checks. Despite the capability of the calibration checks producing useful check information, there was a lack of confidence in the results of these checks. This lack of confidence was caused primarily by inconsistency of results when the checks were repeated. Repeated checks sometimes differed by 0.5 units of the gray-scale setting. However, the inconsistency in results seemed greater when the equipment was malfunctioning; thus the variations may have been real rather than inconsistencies in check procedure. The inability of the operators to see the emitted infrared radiation for checking target alinement reduced confidence in the alinement. An infrared sensitive sighting device for the emitter would aid in target location. A more definite indication of an erroneous calibration than the 0.1 to 0.3 gray-scale units would be desirable because of lack of confidence in the reading, although the change in operating response as shown in figure 6 was of the same order as the change in calibration.

6.6 Error from Daylight Effects. The daylight effect produced a serious error in response which should be eliminated. Since the daylight effect seemed to be increased by malfunctioning components, it is possible that the effect may be eliminated or reduced to an acceptable level. Further investigation is needed.

6.7 Discussion of Equipment Malfunctions. The several malfunctions which developed in this equipment were not catastrophic but seriously affected the performance of the instrument. The more important of these malfunctions will be discussed individually.

6.7.1 Emitter Lamp Failures. The photographic lamp used as the emitter source failed after operating less than two months. This trouble was caused by the failure of the cement, allowing the bulb to come loose from the lamp base. The bulb was hanging by the lead-in wires and the lamp still functioned. (The manufacturer reported that the replacement lamp had failed similarly when he inspected the unit after the unit was returned to him.) Rearranging the mounting to provide a base-down installation for the lamp would reduce the heat on the cement. Since the emitted radiation is not in the visible range, the effects of this lamp failure were not visible and were not detected until an attempted calibration showed the instrument performance unsatisfactory.

After lamp replacement, performance continued unsatisfactory. The manufacturer suggested enlarging the opening through the reflecting surface at the side of the lamp from which the pilot-beam signal was obtained. This helped but a fully satisfactory calibration was not obtained.

6.7.2 Lamp Socket Failure. The lamp socket was damaged either by the heat from the lamp or from arcing at the contacts. A replacement socket of a suitable type was not available. Adjustments were attempted which appeared to correct the troubles, but these may not have been fully satisfactory *. The calibration checks after the trouble was originally discovered never gave gray-scale settings as close to the specified values as desired.

6.7.3 Output-Voltage Potentiometer Failure. Shortly after the equipment was put in operation, intermittent output was noted and traced to poor contact in the potentiometer supplying the output voltage corresponding to the gray-scale position. A replacement potentiometer was installed, which corrected this problem.

6.7.4 Backlash in the Servodrive. After replacement of the output-voltage potentiometer, excessive backlash was noted in the coupling to the servomotor drive. The couplings and connections were tightened. This eliminated some of the backlash effect, but at times the drive seemed to hesitate or overdrive by 0.1 or sometimes 0.2 units of the gray-scale. (This intermittent functioning may have resulted from failure to respond correctly to signal and not to mechanical backlash.)

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*The manufacturer reported this socket was defective when he inspected the equipment after its return.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions.

7.1.1 Instrument Performance. For visibilities greater than one kilometer (day scale), the average gray-scale setting varied approximately linearly with the logarithm of the visibility. For lower visibilities, the gray-scale setting approached a minimum value with very little change below 0.5 kilometer. The spread of gray-scale settings for a given transmittance was so great that individual measurements would be of limited usefulness. The spread of data is wider than would be expected from comparison of the measurements from two parallel transmissometer installations.

7.1.2 Slant Visibility Measurements. More investigation will be needed to determine the capability of the instrument as a slant visibility meter. These tests could not be conducted during the time at Arcata because of instrument malfunctions.

7.2 Recommendations.

7.2.1 Minimum Response. Improve the sensitivity of the device so that the gray-scale setting will continue to decrease with transmittance down to or below a gray-scale setting of 0.2.

7.2.2 Daylight Effect. Eliminate the effect of daylight on the response or reduce the change in response to less than 0.02 gray-scale units.

7.2.3 Lamp and Lamp Socket. Correct the lamp and lamp socket troubles.

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