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ATMOSPHERIC ATTENUATION OF LIGHT RADIATION FROM A POINT SOURCE IN AN ARCTIC ENVIRONMENT

BY

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OCTOBER 1964

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U. S. ARMY ELECTRONICS LABORATORIES
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FORT MONMOUTH, N. J.

ABSTRACT

Twenty-two nighttime measurements were made of the atmospheric effects on light attenuation from a point source during the spring and fall of 1962 at a site on the Greenland icecap (Camp Century) located at 77°10'N and 61°08'W at an elevation of 6800 feet above sea level.

The Arctic environment provided an ideal surface albedo of almost unity, while the additional presence of clouds provided "duct effect," or energy-trapping, situations. Graphs are included to show the total and indirect intensity fluctuations over 12-second intervals under various atmospheric conditions. Some comparison is also made of the ratio of indirect/direct intensity vs optical depth under some Arctic and New Jersey shore atmospheric conditions.

A much greater indirect/direct ratio in an Arctic environment of almost unity albedo, as compared to a local New Jersey environment of about 0.2 and 0.5 for the total albedo, is evident from some of the results noted.

Three "duct effects" were experienced when a maximum 3.5-fold and twofold increase of total intensity resulted; i.e., cases of 29 Oct and 13 Nov, respectively, compared to an atmosphere with a zero albedo and unlimited visibility, while the 15 Nov situation indicated a maximum 16-fold increase. However, each of the above-mentioned cases was complicated by the presence of some scattered fog patches.

Results also indicate that intensities of light pulses from a point light source can vary by more than 100 percent at distances of 4.5 miles over 20-second time intervals.

This is a DASA-sponsored project, under DASA NWER thermal subtask 12.017, "Thermal Atmospheric Scattering Studies."

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FIGURES (contd)

ATMOSPHERIC ATTENUATION OF LIGHT RADIATION FROM A POINT SOURCE IN AN ARCTIC ENVIRONMENT

INTRODUCTION

The analysis of the effects of various atmospheric and terrain conditions on the propagation of light energy is significant in ascertaining the degree of thermal radiation damage that may occur from nuclear detonations in space. Under many atmospheric and terrain conditions, the indirect radiation effects can equal or exceed the direct radiation. A 2 PI detector is therefore necessary to simulate a flat plate receiver so that the full indirect as well as the direct effect can be measured.

Such a receiver, near ground level, was employed with a 6500°K point light source about 400 feet above the surface, under generally hazy atmospheres in the New Jersey shore area from October 1960 to February 1961. These tests indicated sharp increases of radiation under relatively high surface albedos. The maximum surface albedos, however, are readily obtainable in the Arctic or Antarctic regions. This led to the unique situation of studying the attenuation effects of the light energy, with the light source located between two high albedo surfaces, i.e., a homogeneous snow surface and an extensive cloud cover at Camp Century, Greenland.

The problem considered in this report, therefore, concerns itself with the empirical effects of one or two highly diffuse reflective surfaces on the propagation of light from a point light source situated about 100 feet above one such highly diffuse reflective surface. At least one other significant effect arises, however; namely, the large rapid variations of the light signal under certain atmospheric conditions.

DISCUSSION

The site chosen for these studies during March, October, and November, 1962, shown in Fig. 1, is Camp Century, Greenland, located 77°10'N and 61°08'W at an elevation of 6800 ft above sea level and about 900 miles from the North Pole. The terrain (Fig. 2) consists of a vast, flat, homogeneous, almost 100 percent albedo snow surface, extending at least 100 miles in all directions before there is any significant change of terrain. The 200-ft Signal Corps tower, which accommodates the light source, can be seen in the background of Fig. 2.

The equipment employed in obtaining the data in this report was essentially unchanged from that described in USASRDL Technical Report 2270, "Direct and Indirect Thermal Radiation under Various Weather Situations." The light source consisted of a 10-inch-diameter opal-covered G.E. FT 503 Xenon-filled flash tube of about five million peak candle power, with a black body temperature of near 6500°K for the visible region. Frost formation on the opal ball surface was eliminated by the heat of a 25W incandescent bulb within the opal sphere. This source was situated at the end of a 12-ft steel boom projecting from the 100-ft-high platform of a 200-ft tower, as indicated in Fig. 3. The

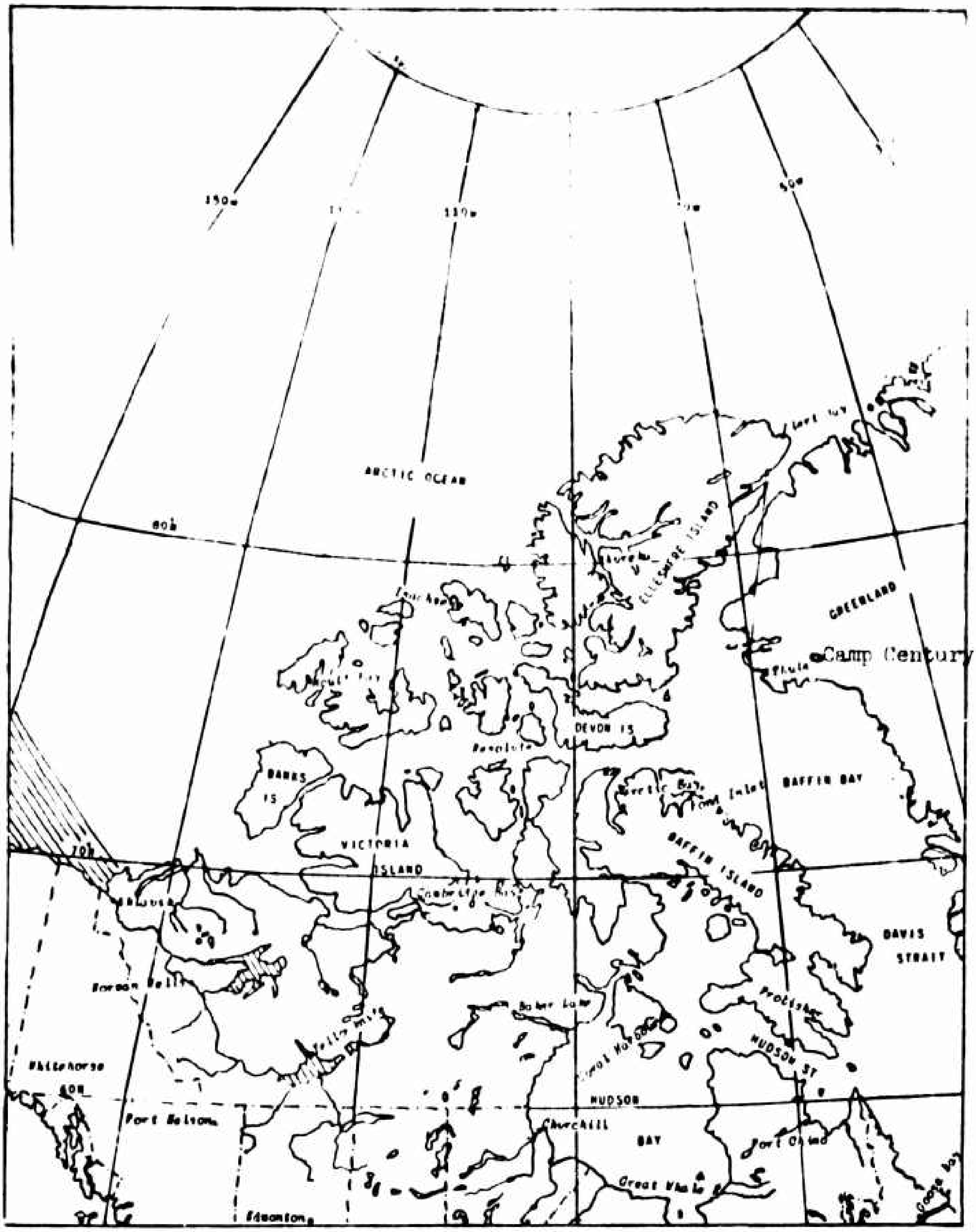


Fig. 1. Camp Century Area

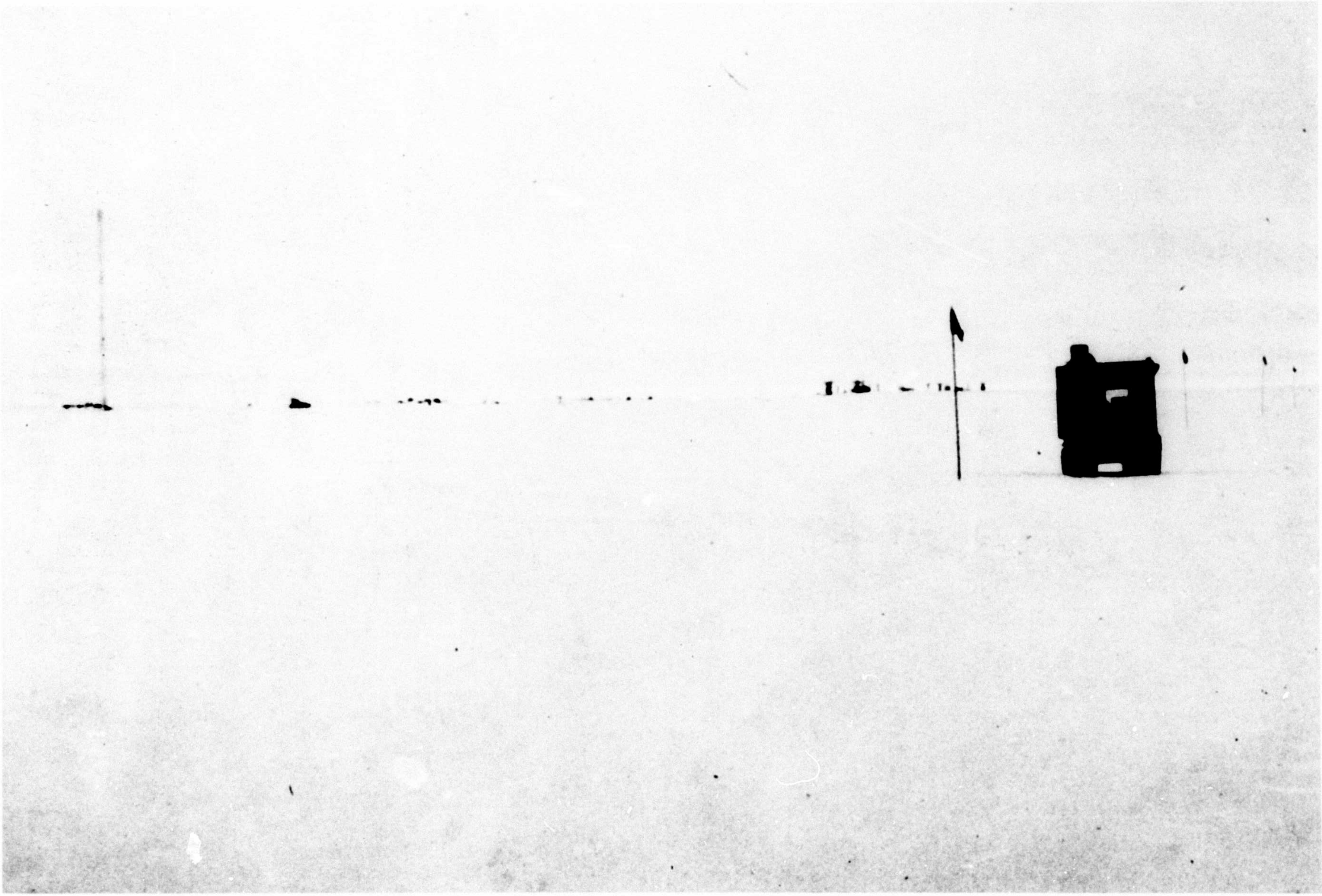


Fig. 2. Camp Century, Greenland, Terrain

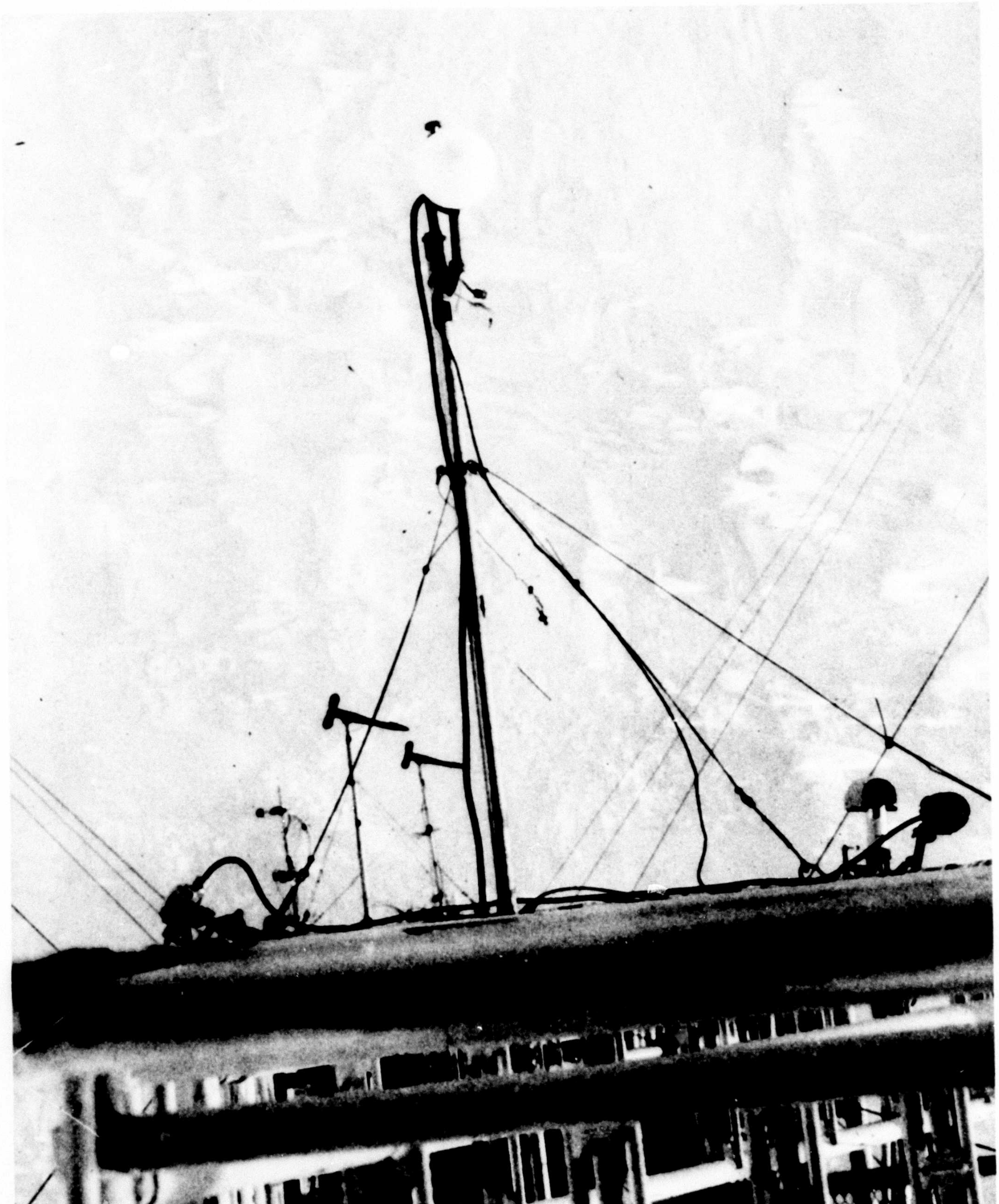


Fig. 3. Light Source at 100-Foot Tower Level

associated regulated 5000V high-voltage, 86-microfarad power supply, also at the 100-ft platform level, was shielded with waxed paper to eliminate the hazards of snow accumulation.

The block diagram of the receiver, described in USASRDL TR-2270, is shown in Fig. 4. The equipment, minus the oscilloscope and neon calibrating unit, is shown in Fig. 5. The Tektronix oscilloscope was employed to ascertain any significant change in waveshape between the total and indirect radiation pulse. Analysis at the 4.5-mile point under 2 to 3 mile visibility conditions indicated negligible change in waveshape, which was of 1.5 milliseconds duration, with the application of a 1.4 millihenry choke in the high-voltage power supply.

The data obtained under Arctic conditions in March 1962 represent a period of five nights, two of which were under clear skies and good visibility conditions. The remaining three nights involved relatively poor visibility conditions in the presence of mist or fog.

A single fixed monitoring wanigan station at 4.5 miles from the light source was regularly employed, with but a single measurement made at a 10.3-mile wanigan station. The fixed stations are called "wanigans," or box cars on sled runners, shown in Fig. 6, with the necessary receiving equipment mounted on shelves and boxes within. The pulse-sensitive, 2 PI detectors were mounted within tracks atop a fixed 6-ft support outside the wanigan and facing the light source. A 7-inch-diameter occulter was placed on top of a pole 20 ft from the receiver and aligned to block out the direct light flash when placed in a raised position. The total light radiation was received by lowering the occulter. These units are shown in Fig. 7.

Seventeen tests were conducted during the October and November 1962 period, under generally prevailing fog conditions or cloudy skies, in the visible and very near infrared regions.

A mobile system and/or a fixed monitoring station were employed at Camp Century during this test period. The mobile unit consisted of a photomultiplier pulse-sensitive receiver, described in USASRDL TR-2270, mounted outside and in a small-size wanigan attached to an L.G.P.* tractor. A 3 kw, 110V AC power generator was mounted on the tongue between the wanigan and tractor. A 7-ft-long flat-black wooden boom, supporting a 4-inch-diameter occulter at the farther end and a 2 PI receiver at the nearer end, with a string attachment for lowering or raising the occulter, was maintained through an opening at the rear of the wanigan. This is shown in Fig. 8. An 8X magnification telescope was mounted alongside and parallel to the boom to facilitate proper alignment between the light source and 2 PI light detector, with the latter being within tracks at the boom end opposite to the occulter so that about a 1½-degree field of view was subtended from the occulter. Measurements were made at the 0.13-, 0.5-, 1-, 4.5-, 7.6-, and 10.3-mile ranges whenever conditions permitted. A fixed-location receiver was mounted outside and alongside a wanigan 4.5 miles away from the light source, with a 7-inch-diameter occulter on a pole 20 ft from the receiver, and so aligned that the direct light flash was blocked from the receiver's detecting unit when the occulter was placed in a raised position.

*Low Ground Pressure

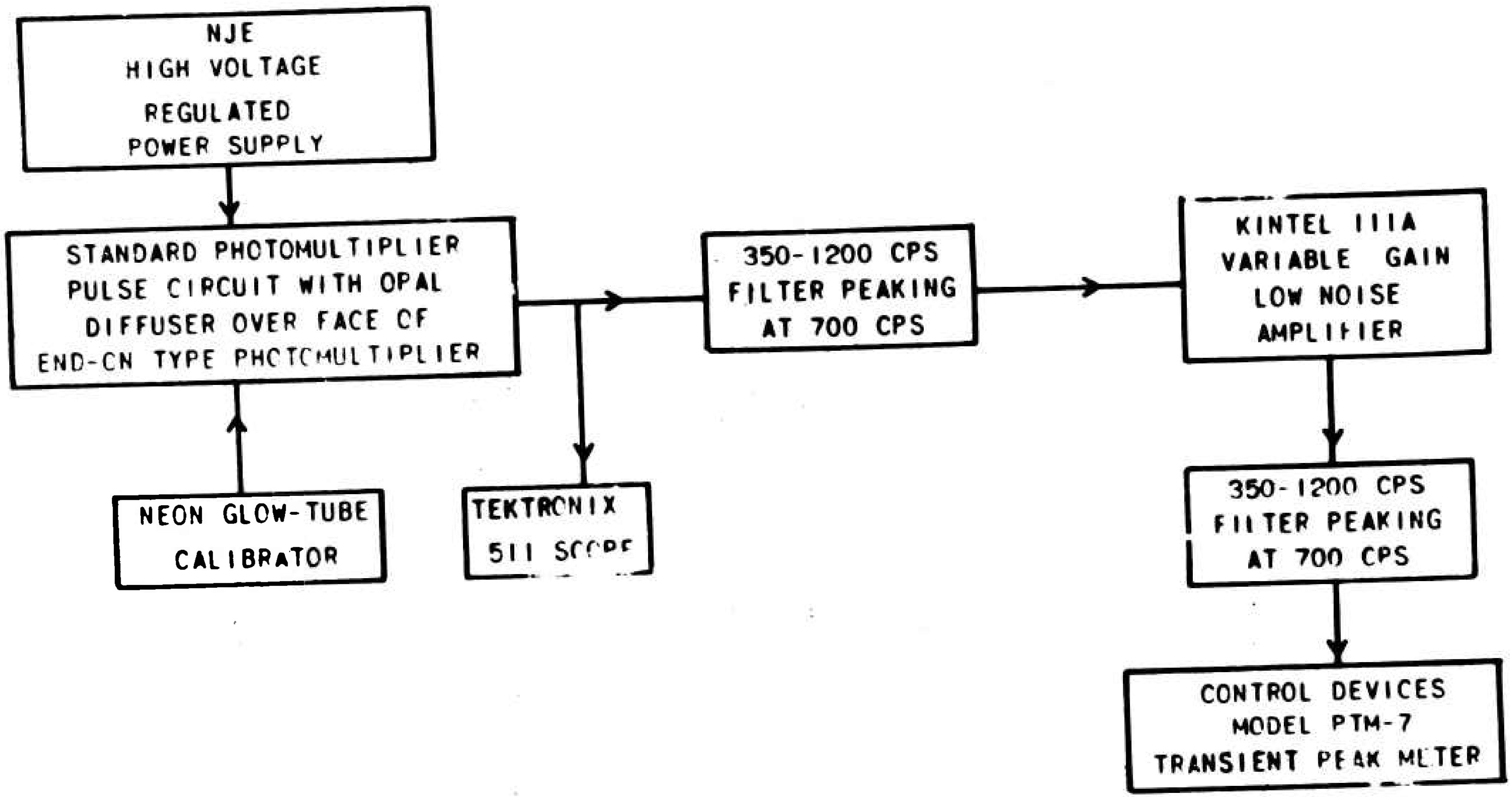


Fig. 3 R... ...er Equipment. Block Diagram

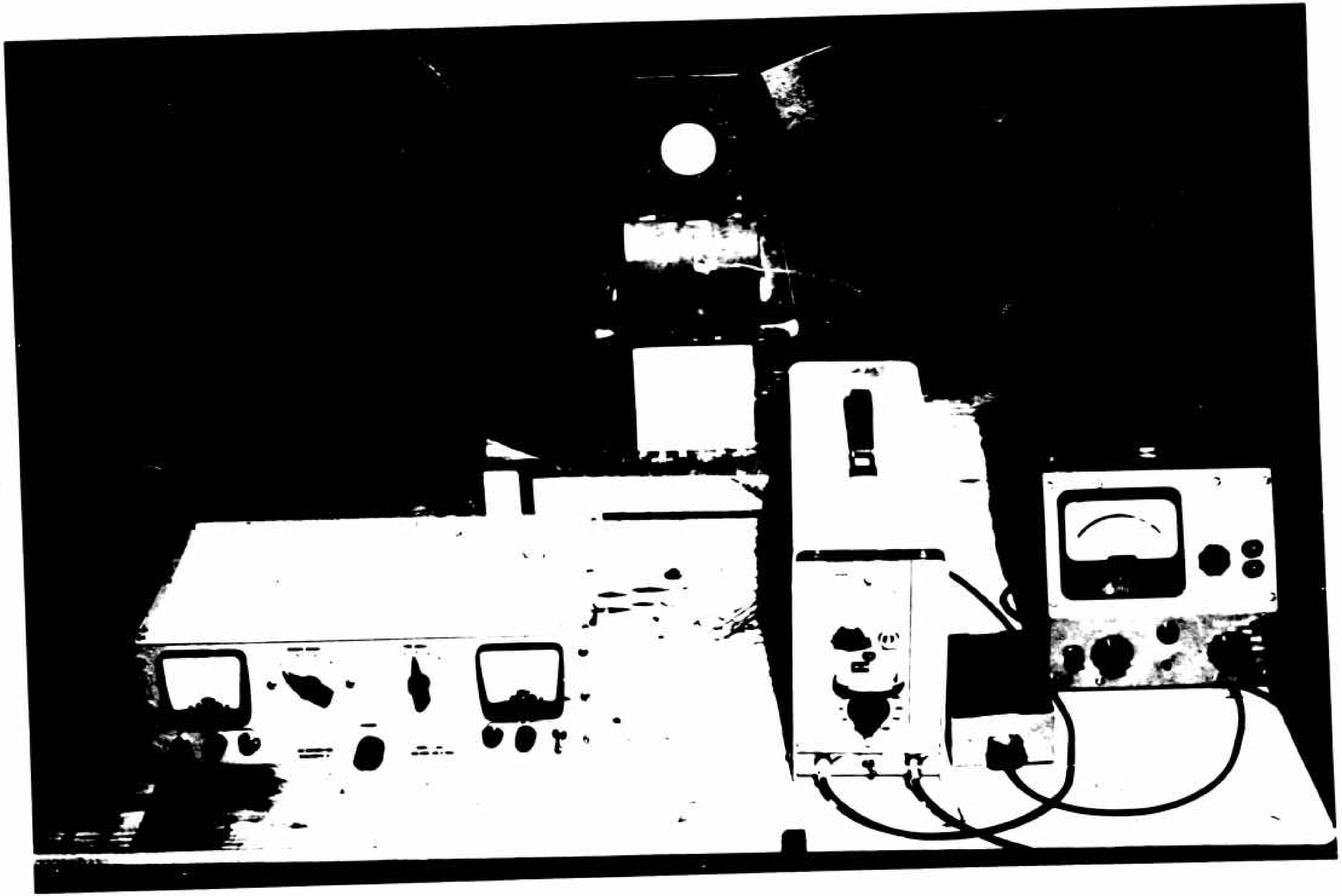


Fig. 5. Flash Tube Receiver

Fig. 6. Wanigans Being Pulled by Tractors on the Greenland Icecap

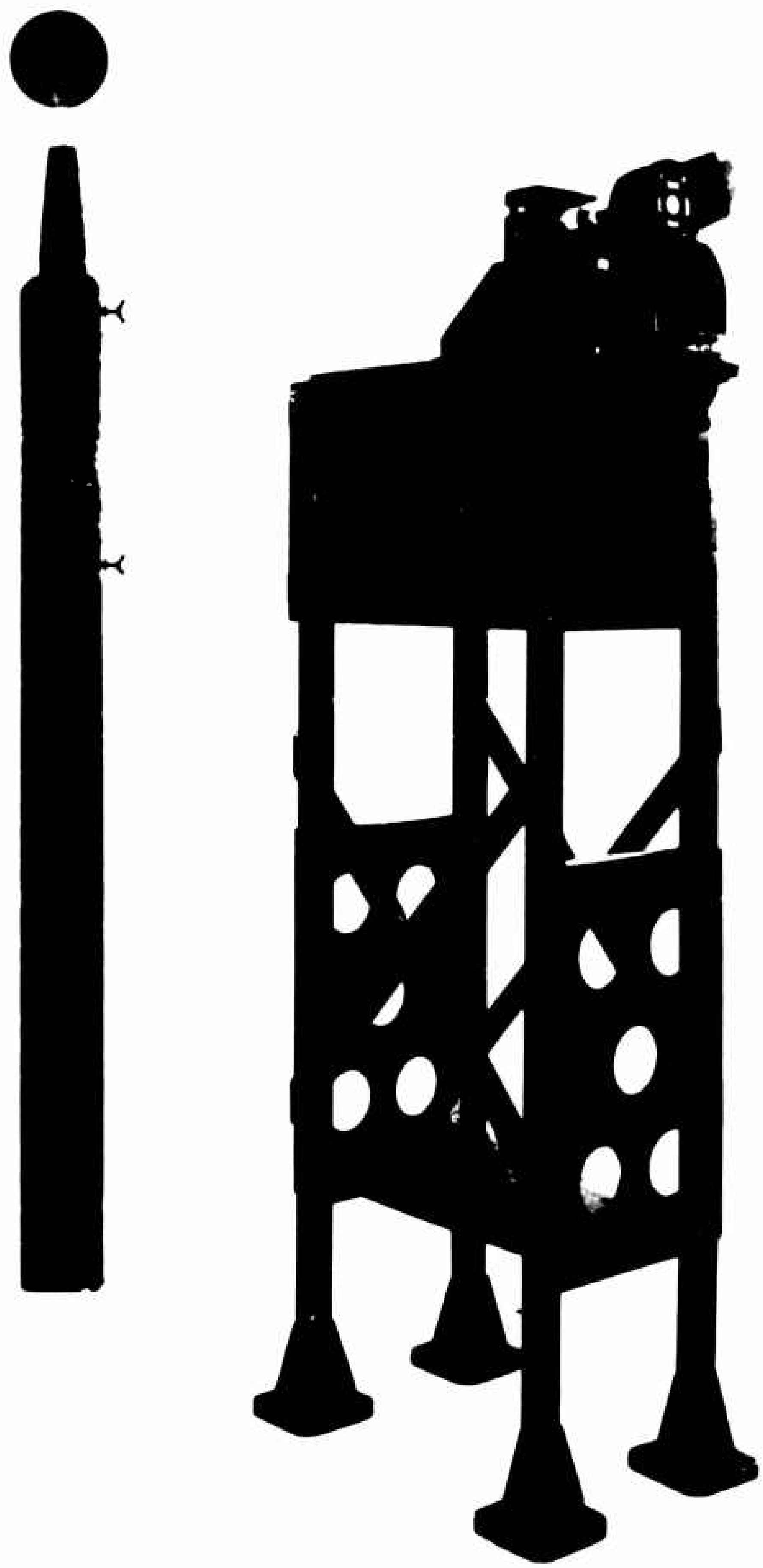


Fig. 7. 4.5-Mile Receiver Stand, showing sensor and occulter mounted unit

Fig. 8. Mobile Occulter Mounted Boom, showing sensor and aligning telescope

The symbols employed in this report, with their corresponding meanings, are listed below:

H = indirect/direct intensity (DI)

NF = no color filter

ND = neutral density (applicable to the visible region)

B = Wratten No. 47 blue-violet gelatin filter

G = Wratten No. 58 green gelatin filter

R = Wratten No. 25 red gelatin filter

IR = Wratten No. 87C infrared gelatin filter

σ D = direct light attenuation coefficient times distance = optical path or depth

$H_{NF,\ B,\ etc/0.13,\ 1.0,\ etc}$ where the letter subscripts refer to the type of filter employed, and the number subscripts refer to the optical depth.

σ with no subscript, as above, indicates no color filter being employed.

Figure 9 indicates the system spectral response employing an RCA photomultiplier with an S-10 response. Figures 10 and 11 indicate the system spectral responses, employing Dumont photomultipliers with an S-11 and S-1 response, respectively. (Figure 4 of the General Electric Flashtube Data Manual, and Appendix A, P. 25, of the 7668-TM-3 M.I.T. report by R. J. Uhl, entitled, "Infrared Spectral Output of Xenon Flashtubes," Apr 58, showing the spectral curve for the FT 617 flashtube at 4000V and 50 uF, were, respectively, employed to obtain Figs. 10 and 11.) A negligible change in wave shape in the visible region in going from 4000 V to 2000 V is assumed, although one would expect some shift to the blue as a result of a slightly higher color temperature. The filter spectral response was obtained from the Eastman Kodak booklet on Wratten filters, except for the infrared region where USAEL spectrophotometer curves of the ND1 and ND2 as well as the visible color filters were employed. Figure 12 indicates H_{NF} vs σ D, where D can be determined by calculating σ as σ = 3/visibility.

The derivation of the assumption $(1 + H_o)\ \frac{\text{total}}{\text{direct}}$ transmittance = H_x is as follows:

(1) Total transmittance = $\frac{I_{T_x}}{I_{O_T}}$, where I_{T_x} = total intensity at distance x from source and I_{O_T} = total intensity close to the source; i.e., at 0.13 or 0.2 mile in this report.

NOTE: Indirect transmittance = $\frac{I_{S_x}}{I_{O_S}}$, I_{S_x} = indirect intensity at distance x, and I_{O_S} = indirect intensity at 0.13 or 0.2 mi.

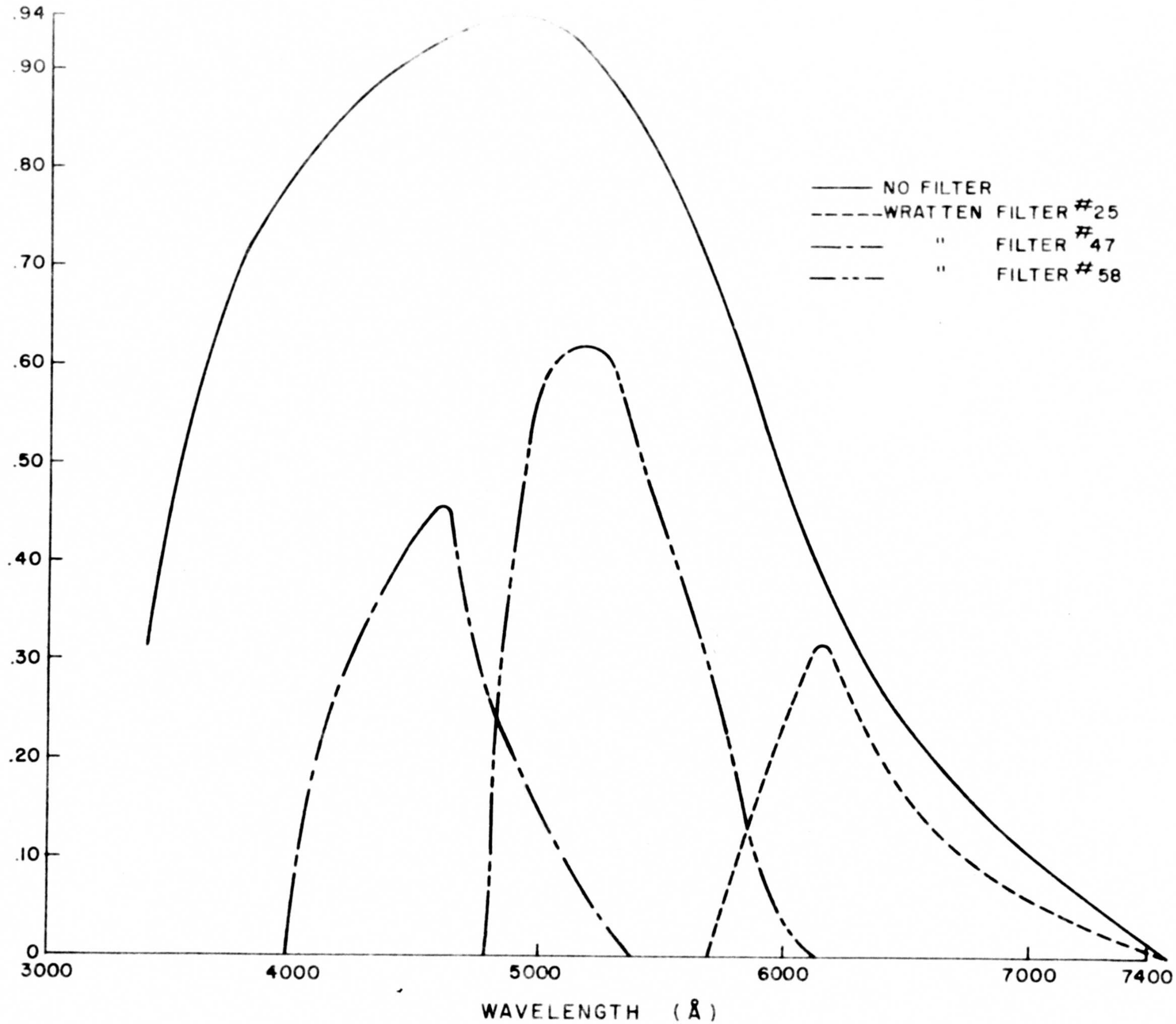


FIG. 9 FT-503 AND S-10 PM SYSTEM SPECTRAL RESPONSE

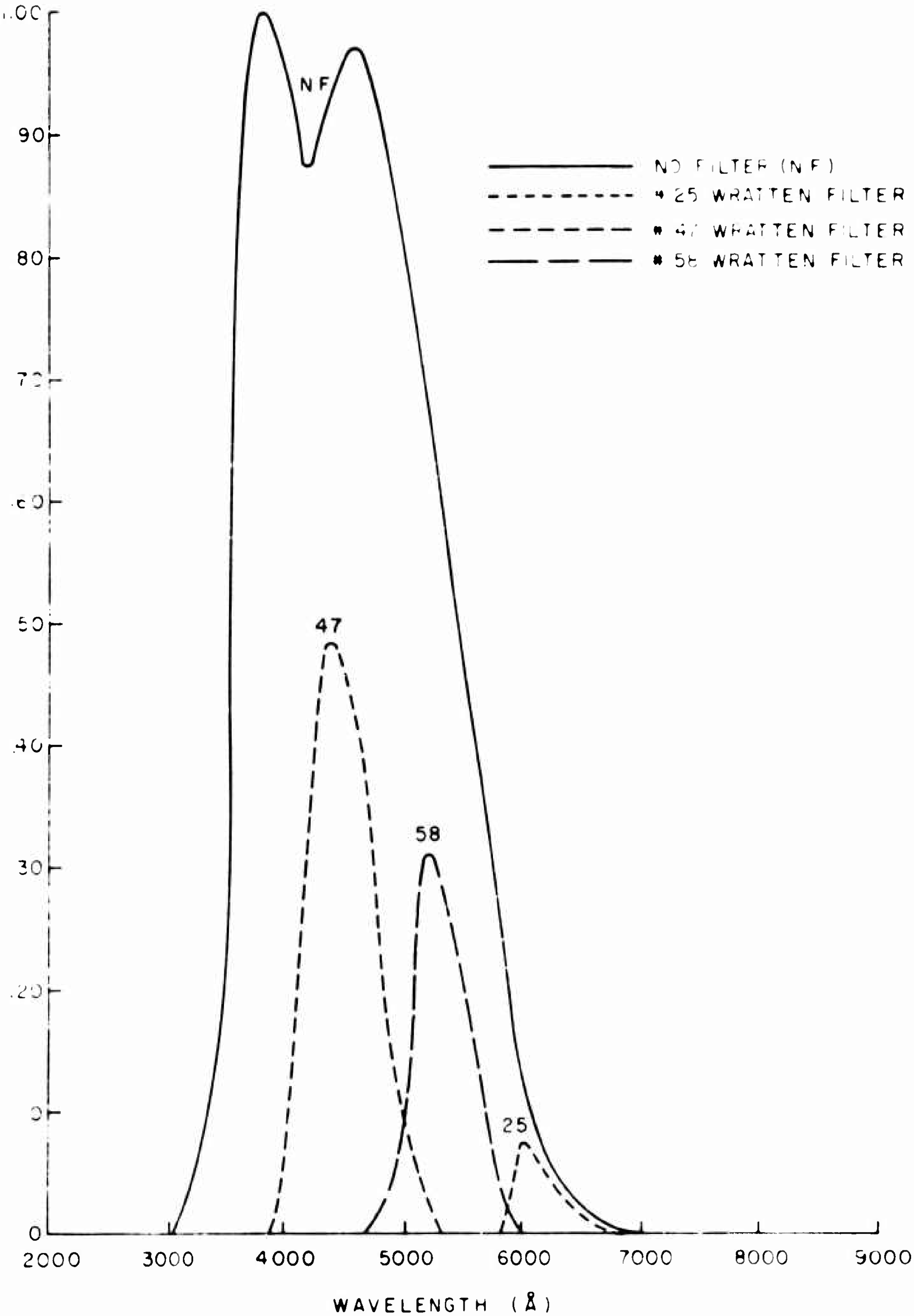


FIG. 10 FT-503 AND S-11 PM SYSTEM SPECTRAL RESPONSE

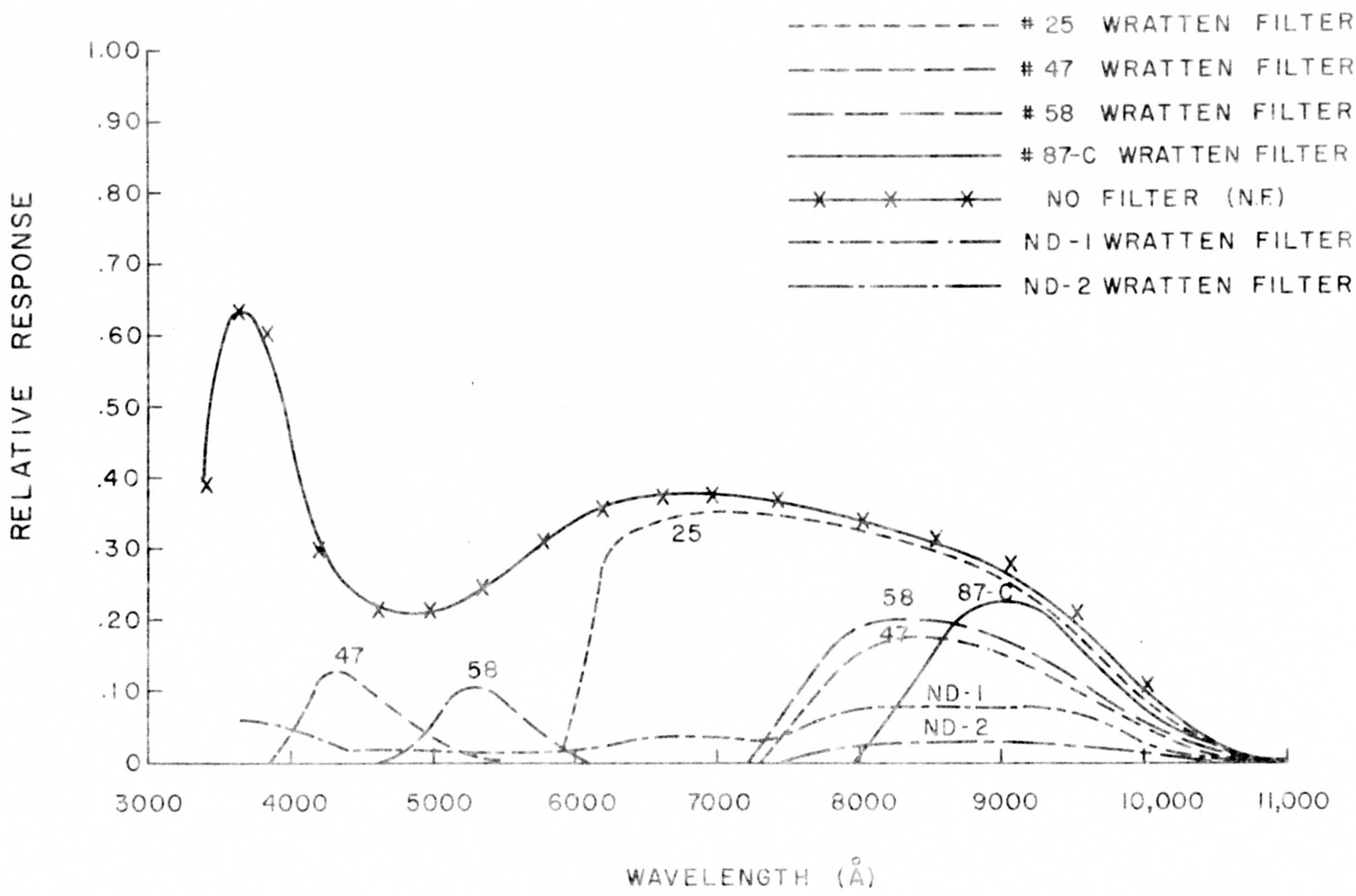
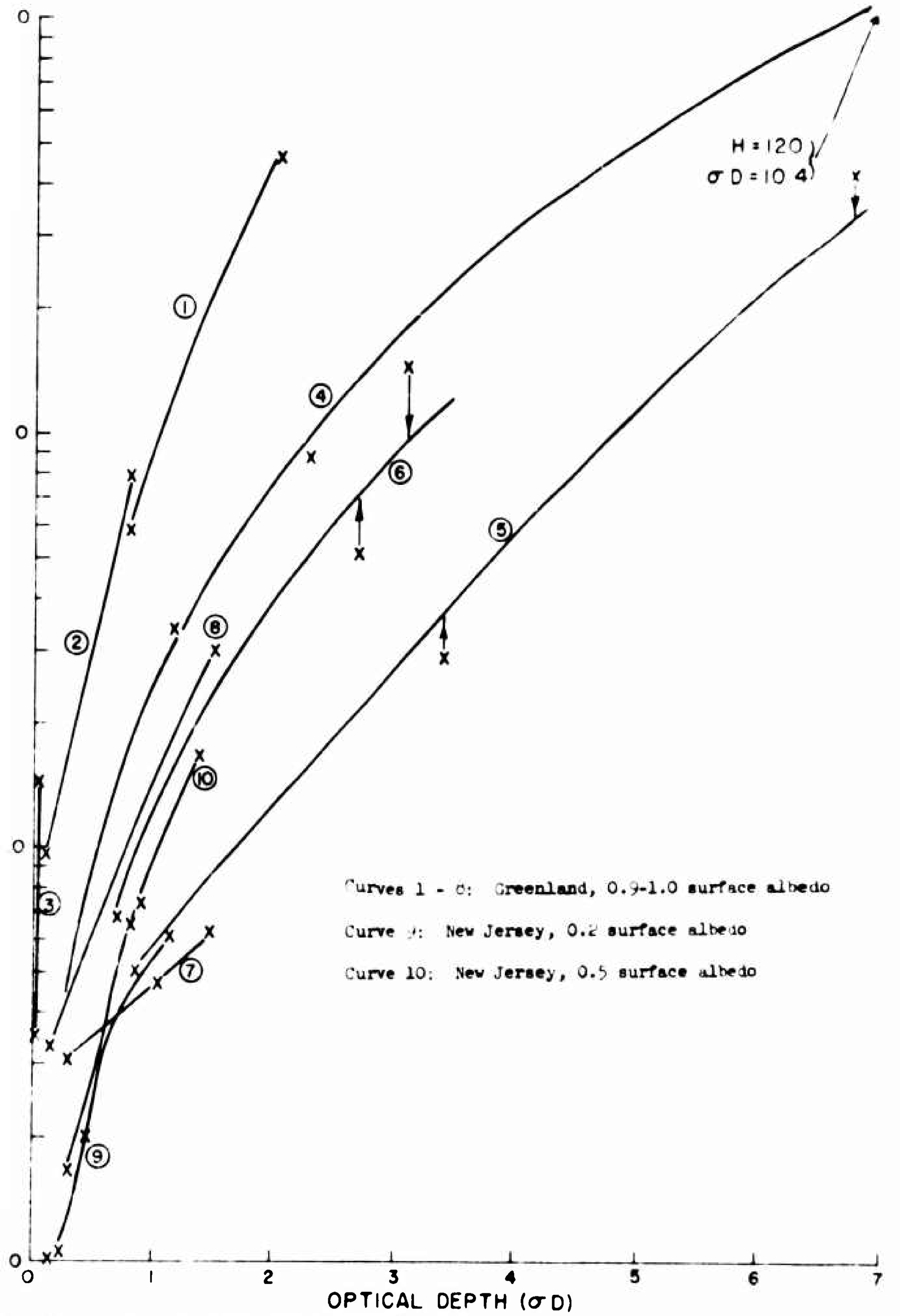


FIG. 11 FT. 503 AND S-1 PM SYSTEM SPECTRAL RESPONSE



G 12 H VS σD FOR DIFFERENT WEATHER AND CLIMATIC CONDITIONS

Curve 1: 27 Oct 62, S-11 PM response, 10/10 fog, 300' ceiling, 1/2 mi visibility. D = 0.2 mi for σ D = 0.80; D = 0.5 mi for σ D = 2.1

Curve 2: 15 Nov 62, S-11 PM response, 2000' overcast, variable scattered ground fog patches, $\sigma_{0.5 - 4.5 \text{ mi}}$ = 0.18/mi (simultaneous measurement). D = 0.5 mi for σ D = 0.09; D = 4.5 mi for σ D = 0.81

Curve 3: 15 Nov 62, as curve 2 except for unlimited visibility conditions. D = 1 mi for σ D ~ 0.01; D = 4.5 mi for σ D ~ 0.05

Curve 4: 17 Nov 62, S-1 PM response, 8/10 cloudiness at 2000', 2/10 ground fog, 1/2 mi visibility. D = 0.13 mi for σ D = 0.31; D = 0.50 mi for σ D = 1.2; D = 1.0 mi for σ D = 2.3; D = 4.5 mi for σ D = 10.4

Curve 5: 25 Nov 62, S-1 PM response, 9/10 to 10/10 fog and very light snow, 1/2 mi visibility. D = 0.13 mi for σ D = 0.88; D = 0.50 mi for σD = 3.4; D = 1.0 mi for σ D = 6.8

Curve 6: 26 Nov 62, S-1 PM response, ground ice fog (-27 to -33°C), 1/2 to 1 mi visibility. D = 0.13 mi for σ D = 0.71; D = 0.5 mi for σ D = 2.7; D = 1.0 for σ D = 3.1

Curve 7: 30 Nov 62, S-1 PM response, ground ice fog (-35 to -42°C), 1 to 2 mi visibility. D = 0.13 mi for σ D = 0.30; D = 0.5 mi for σ D = 1.1; D = 1.0 mi for σ D = 1.5

Curve 8: 14-16 Mar 62, clear skies, good to excellent visibilities. D = 4.5 mi for σ D = 0.17; D = 4.5 mi for σ D = 1.5

Curve 9: Oct-Dec 60, local New Jersey area, clear sky, hazy, surface albedo = 0.2. D = 1.2 mi for σ D = 0.12; D = 1.9 mi for σ D = 0.19; D = 1.9 mi for σ D = 0.43; D = 1.2 mi for σ D = 0.70; D = 1.9 mi for σ D = 1.14

Curve 10: Jan-Feb 61, as curve 9 except for surface albedo of 0.5. D = 1.2 mi for σ D = 0.26; D = 1.9 mi for σ D = 0.43; D = 1.9 mi for σ D = 0.81; D = 1.2 mi for σ D = 0.88; D = 1.[illegible] mi for σ D = 1.42

NOTE: Curves 1 through 8, inclusive, apply to surface albedo conditions of 0.9 to 1.0 in Greenland.

Fig. 12 (contd) Legend for Curves

(2) Direct transmittance $= \frac{I_{D_x}}{I_{O_D}}$, where I_{O_D} = direct intensity close to the source.

$$\frac{(1)}{(2)} = \left(\frac{I_{T_x}}{I_{D_x}}\right)\left(\frac{I_{O_D}}{I_{O_T}}\right) \approx \left(\frac{I_{S_x}}{I_{D_x}}\right)\left(\frac{I_{O_D}}{I_{O_S} + I_{O_D}}\right)$$ where visibility < distance at which I_{S_x} is measured, and where

I_{S_x} (indirect intensity) $= I_{T_x}$ (total intensity). Therefore,

$$\left(\frac{I_{O_S} + I_{O_D}}{I_{O_D}}\right)\frac{(1)}{(2)} = H_x,$$ where visibility < distance x.

$$(1 + H_o)\frac{(1)}{(2)} = H_x.$$

The visibility was frequently ascertained, under restricted visibility conditions, by estimating the maximum distance at which the 150W red light, i.e., about 100 candles, at the 100-ft tower level and the 750W white light at the 200-ft tower level could be seen by the naked eye and applying Bennett's[1] correlation result. Bennett's results indicated that ordinary lights can be used as visibility markers. This conclusion was based on some empirical studies on the relationship between the visual range at night, as estimated from lights of varying candle power, and the visual range during the day. The atmosphere, however, was assumed not to change from day to night.

During weather conditions wherein wide variations in the signal occurred, a greater number of measurements were generally taken to obtain a more effective average. The number of minutes alongside each percent variation curve indicates the time lapse between each set of measurements representing each curve.

A light "duct" effect is herein defined as a light energy trap within an atmosphere bounded by two high albedo surfaces so that the light intensity is comparatively appreciably greater for a 2 PI receiver at a given distance than in an atmosphere with no, or negligible, reflective albedo boundary surfaces and where no atmospheric attenuation takes place. A light "duct type" effect is herein defined as one wherein H, for a given optical depth, is appreciably greater than H in an atmosphere whose boundary surfaces have a much smaller surface reflection coefficient or albedo factor.

Some of the signal variations vs time graphs show more than one indirect or total curve for a given zero base line. For such cases, a different average pertains to each of the curves as a result of generally noticeable rapid visibility fluctuations so that a more realistic average is operative for each time interval. The total signal variations vs time curves show a scintillation effect.

Included in the appendix to this report are a summation chart covering the main results and the total transmittance curves (Fig. 61), where $T_T(R)$ = total transmittance $= \frac{I_T(R)}{I_O} \cdot \frac{(R)^2}{(R_o)^2}$ and R_o = 0.13 or 0.2 mile, so that

T_T (0.13 or 0.2 mi) = 100 percent. "Duct effects" are therefore denoted whenever $T_T(R)$ is equal to or greater than unity.

RESULTS OF TESTS AND ANALYSES OF DATA AND GRAPHS

14 Mar 62, 2130-2330 hours, S-10 Response, 6217 RCA Photomultiplier

Weather conditions: clear skies; 3/4 moon
estimated visibility > 40 miles
10°C inversion between surface and 200 feet
surface winds about 9 knots

Result: $H_{NF} = \left(\frac{\text{indirect}}{\text{direct}}\right)_{NF} = 0.33$; $\left(\frac{\text{indirect}}{\text{total}}\right)_{NF} = 0.25$ (estimated optical depth 0.34 at 4.5-mile distance)

Analysis: The value for H_{NF} is about 0.22 in curve 10 of Fig.12, representing the New Jersey area under clear skies, very light hazy conditions, with snow on the ground such that the effective surface albedo (due to the presence of many trees in the area) is about 0.5, and the interpolated optical path of 0.34. The approximately 50% increase in the H value under Arctic conditions is likely due mainly to the homogeneous surface albedo of unity. However, the effects of a supercritical temperature-lapse rate, i.e., > 8°C/200 meters, which causes light-ray bending towards the earth's surface, may also be of significant contributary nature.

Figure 13 shows rapid fluctuations indicating as much as +70% maximum deviations from the total intensity average and more than a 100% maximum deviation from one total intensity to the next following intensity at the receiver. The absolute maximum deviation in the interval is 125%. The indirect intensity variations considered over a 3/4-minute interval indicate less than a 10% maximum deviation. This sharply varying pattern is accompanied by clear skies, unlimited visibilities, and a +10°C/200-ft inversion.

15 and 16 Mar 62, 2300-0100 hours, S-10 Response

Weather conditions: clear skies
estimated visibility 7 to 10 miles
+16°C inversion between surface and 200 feet
surface winds about 7 knots

Result: $H_{NF} = 3.0$; $\left(\frac{\text{indirect}}{\text{total}}\right)_{NF} = 0.75$ (estimated optical depth of about 1.5 at 4.5 miles)

Analysis: The total radiation received is equivalent to almost one-quarter the total of 14 Mar 62. It is interesting to note that the value for H from curve 10 of Fig. 12 in the New Jersey area for the same optical path is about 1.5. This about 100% increase in the H value under Arctic conditions is probably due to the same factors indicated for Mar 14.

Figure 14 shows moderate variations from the norm such that the maximum total intensity deviation from the norm is +40% and +45% with respect to two successive flashes. The absolute maximum deviation in the interval is 65%. The indirect intensity variations show about a 10% maximum variation from the

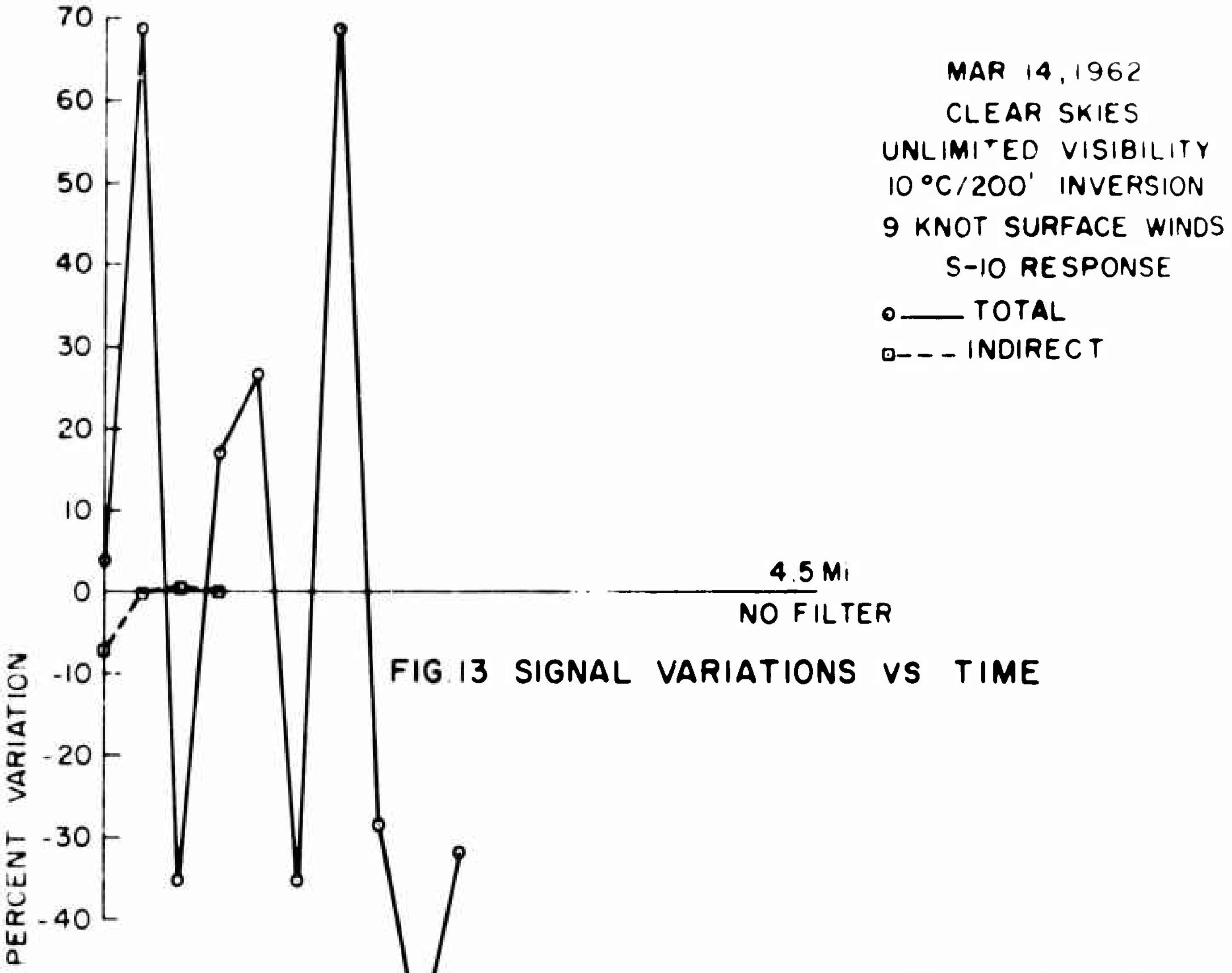


FIG 13 SIGNAL VARIATIONS VS TIME

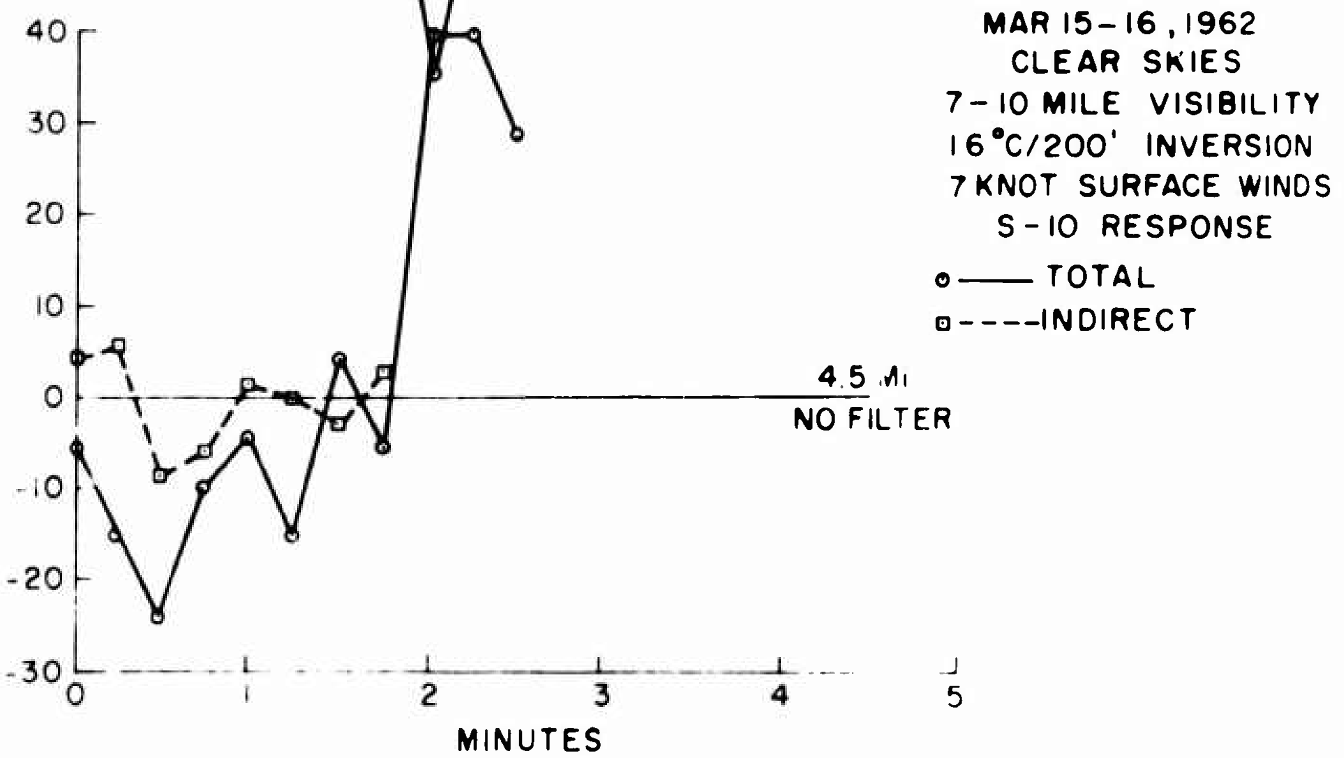


FIG. 14 SIGNAL VARIATIONS VS TIME

norm, while the maximum successive flash variation is about 15%. This pattern is accompanied by clear skies, fair visibilities (7 to 10 miles), and a 16°C/200-ft inversion. Figure 15 compares the temperature height profile with that of the critical temperature lapse rate of 10°C/200 ft. The critical temperature lapse rate occurs when the horizontal light ray follows a path such that its curvature is equivalent to that of the earth's curvature.

<u>24 Mar 62, 0100-0300 hours, S-10 Photomultiplier Response</u>

Weather conditions: light ground fog extending to at least 200 ft with an approximate 1° corona for a 2-diameter halo around full moon

estimated visibility 3 to 4 miles
12 to 13°C inversion between surface and 200 ft
surface winds about 14 knots

Results: 1. $\left(\frac{\text{indirect}}{\text{total}}\right)_{NF,B,G,R} = 0.98 - 1.0$

2. $H_{NF,B,G,R} = 47, \infty, 64, 64$, respectively (estimated optical depth of about 4.5 at 4.5 miles)

3. Indirect $_{NF}$, receiver in vertical plane, i.e., pointing vertically/total $_{NF}$, receiver in horizontal plane, i.e., pointing to light source = 0.36

Analysis: The total or indirect radiation received for 24 Mar is equivalent to about one-third the total on 15 and 16 Mar. Moreover, the indirect/total radiation yield is independent of the wavelength in the visible region. The above results 1 and 2 for interpolation of Fig. 9 would seem to indicate the predominance of multiple scattering associated with a surface albedo of unity, giving rise to a total and indirect light yield as practically synonymous. It is interesting to note the simultaneous presence of a supercritical temperature lapse rate.

Figure 16 indicates relatively small deviations resulting in not more than a -20% change from the norm and a maximum 30% successive flash variation for both indirect and total intensities independent of visible wavelengths. This similar magnitude variation effect for the indirect and total intensity could very well have been due to the presence of scattered ground fog patches in addition to the background noise in the presence of twilight from the north sky. This type of pattern is accompanied by light ground fog, relatively poor visibilities, and a +12°C/200-ft inversion. Figure 17 compares the temperature height profile with the critical lapse rate.

<u>25 Mar 62, 0100-0300 hours, S-10 Photomultiplier Response</u>

Weather conditions: light mist with light blowing snow
estimated visibility of 10 to 15 miles
+8 to 9°C inversion between surface and 200 ft
surface winds about 17 knots, ENE

CAMP CENTURY, GREENLAND
MAR. 15, 1962

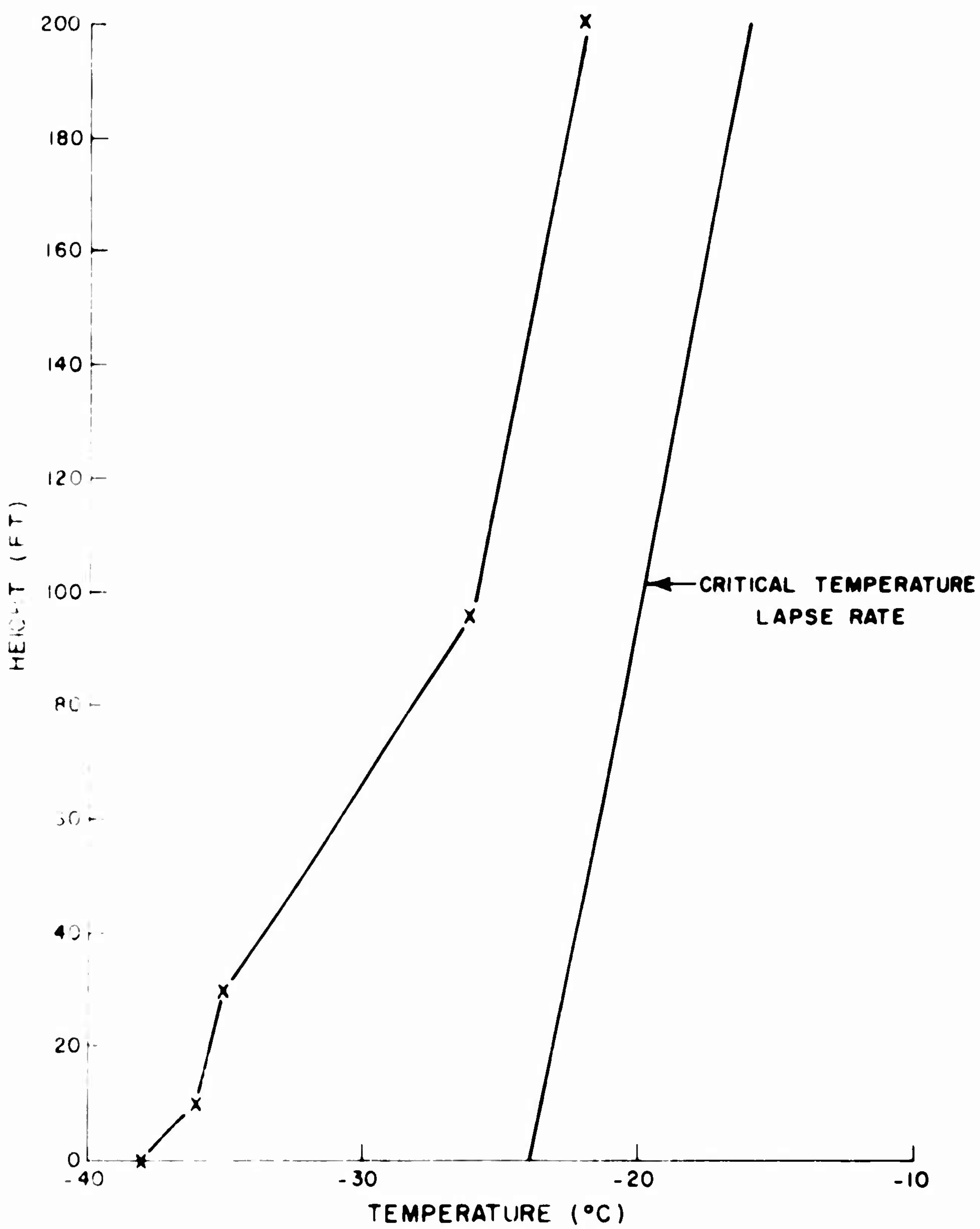


FIG. 15 TEMPERATURE VS HEIGHT PROFILE

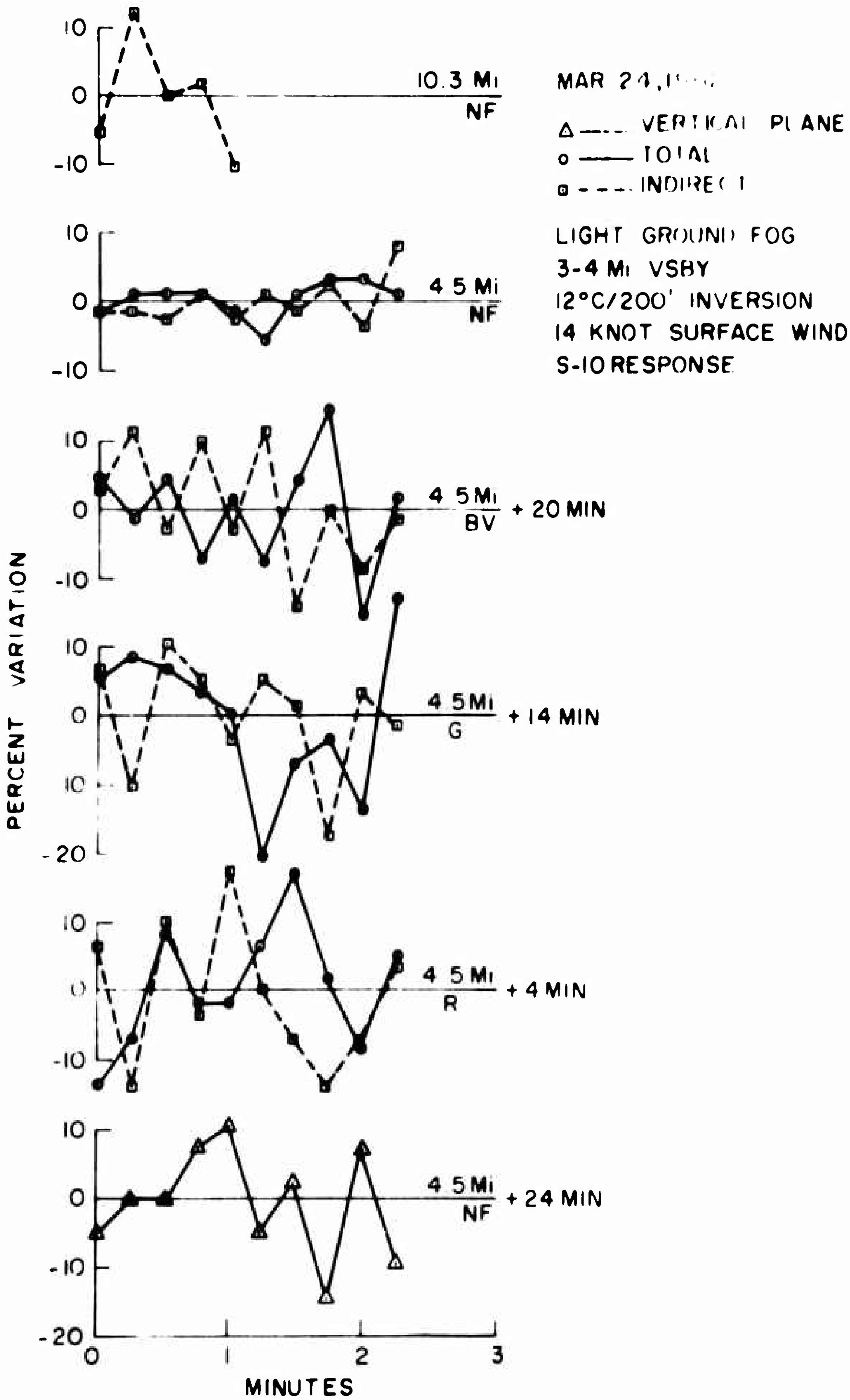


FIG. 16 SIGNAL VARIATIONS VS TIME

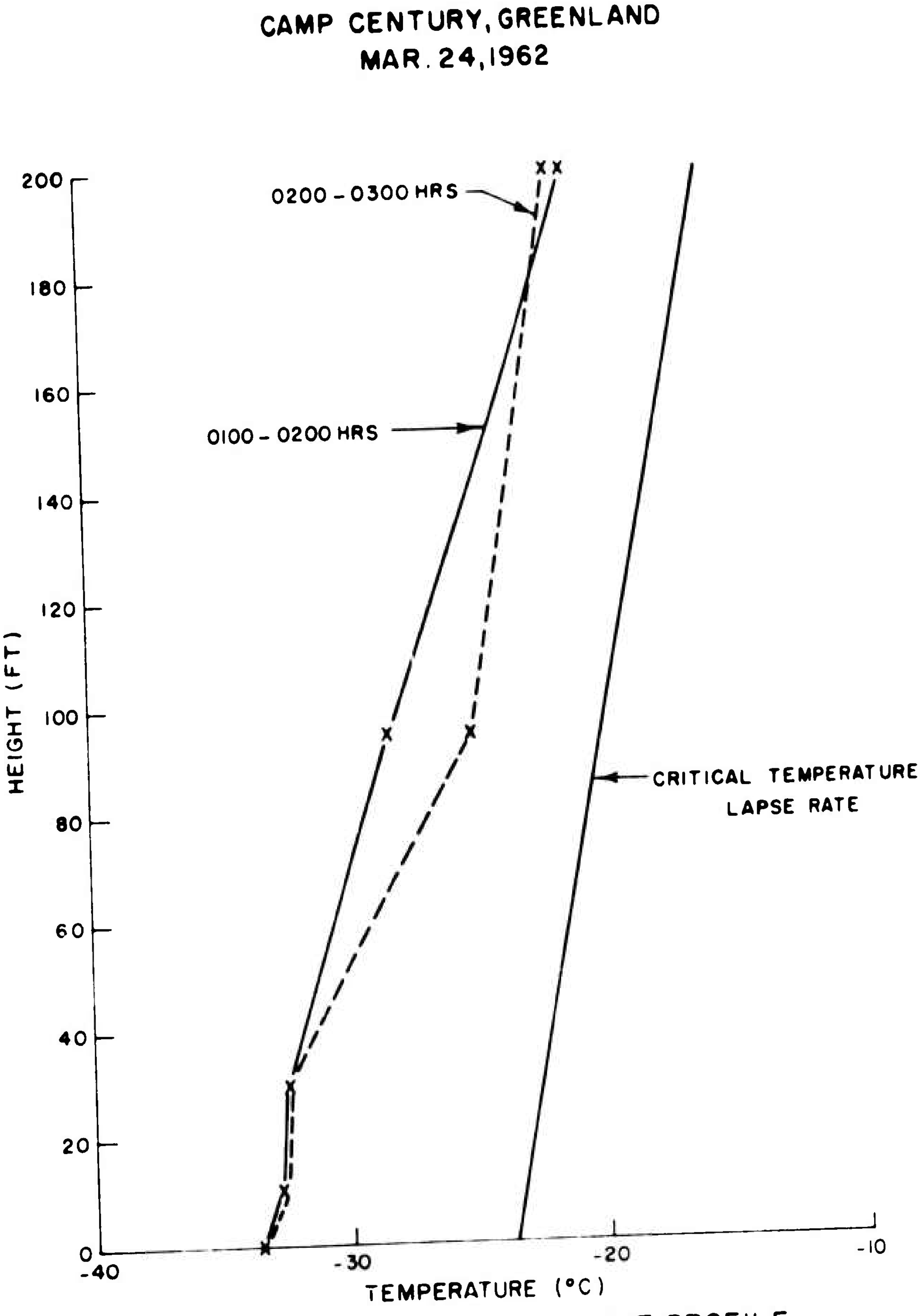


FIG. 17 TEMPERATURE VS HEIGHT PROFILE

Results: 1. $H = (\text{indirect}/DI)_{NF} = 1.4$ (DI = direct intensity; estimated optical depth of 1.1 at 4.5 miles)

2. $H = (\text{indirect}/DI)_B = 2.4$

3. $H = (\text{indirect}/DI)_G = 1.0$

4. $H = (\text{indirect}/DI)_R = 0.95$

5. $$\frac{\text{Indirect}_{NF}\text{, receiver in vertical plane}}{\text{Total, receiver in horizontal plane}} = 0.14$$

6. $$\frac{\text{Indirect}_{NF}\text{, receiver in vertical plane}}{\text{Direct, receiver in horizontal plane}} = 0.33$$

Analysis: The total received for 25 Mar is equivalent to about one-third the total on 24 Mar. Assuming σ (the direct light attenuation coefficient) as proportional to the ratio of Indirect/DI, it can be concluded that the effective aerosol droplet radius is less than 1/2 micron, as calculated by Foitzik[2] by means of the Mie scattering theory. It is also noteworthy that a significant portion of the scattered light arrives from the vertical plane under fairly good visibility conditions and clear skies. The combined effects of a high surface albedo, multiple scattering path, and a sufficiently steep temperature inversion would be contributing factors. It is also interesting to note that the value of H from Fig. 12 in the New Jersey area for the same optical path is 1.1; an approximately one-third increase is indicated under Arctic conditions.

Figure 18 indicates some of the moderate variations from the norm such that the maximum total intensity deviation is +70%, and a maximum 83% successive flash variation results. The absolute maximum deviation in the interval is 103%. The maximum variations in the vertical plane, i.e., where the receiver is facing vertically upward, is about 8% of the average total radiation as compared to 70% where the receiver is in the horizontal plane, i.e., where the receiver is facing the source. This pattern is associated with light mist and light blowing snow, 10 to 15 mile visibilities, and an 8 to 9°C/200-ft inversion. Figure 19 compares the temperature height profile with the critical lapse rate.

27 Mar 62, 0000-0300 hours, S-10 Photomultiplier Response

Weather conditions: ground ice fog; full moon not visible
estimated visibility $1\frac{1}{2}$ miles
surface winds about 12 knots
temperature of -38°C

Results: 1. $H_{NF,BV,G,R} = 26, 20, \infty, 12$, respectively for an NF estimated optical depth (σD) of 9.0

2. $(\text{Indirect}/\text{total})_{NF,B,G,R} = 92 - 100\%$ at 4.5 miles

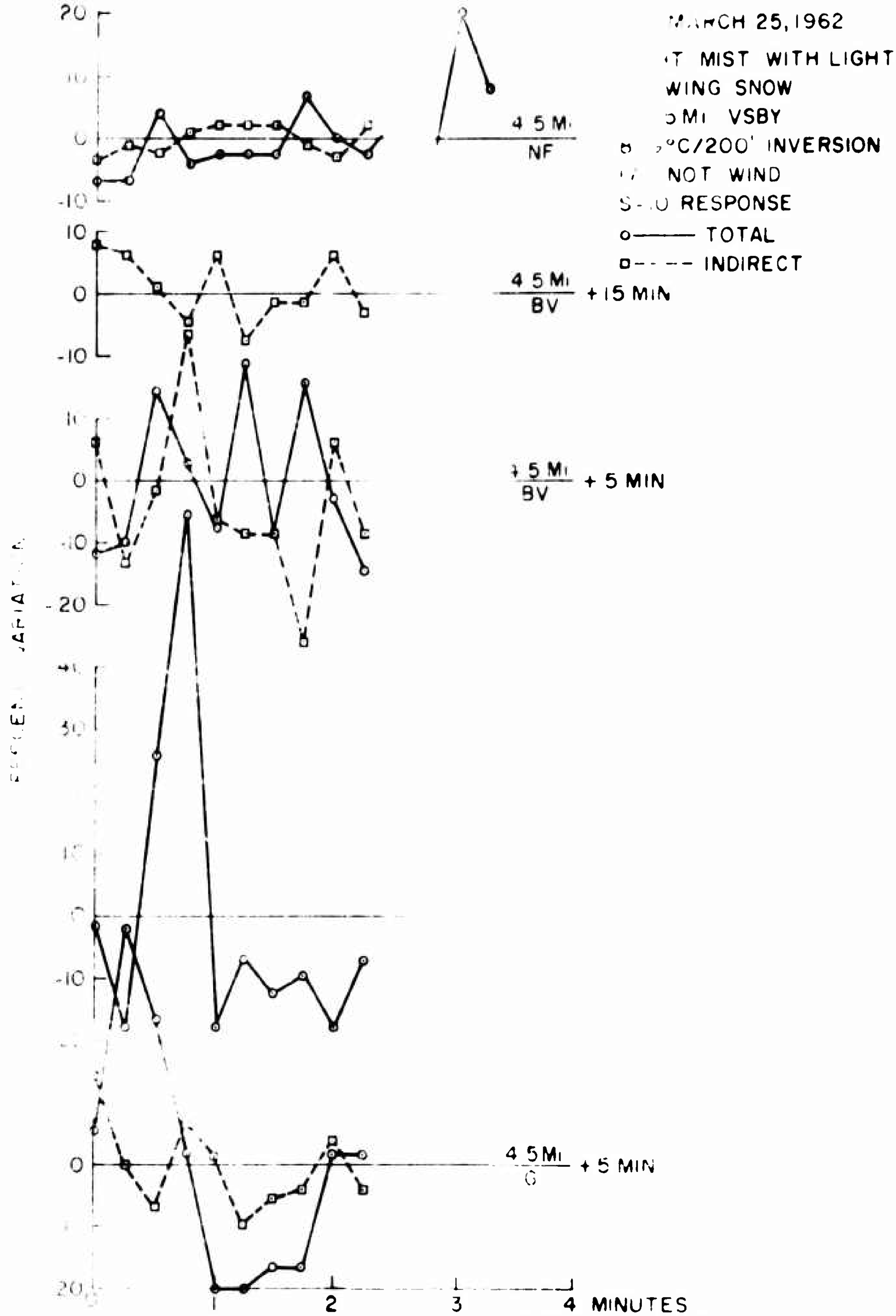


FIG. 18 SIGNAL VARIATIONS VS TIME

CAMP CENTURY, GREENLAND
MAR. 25, 1962

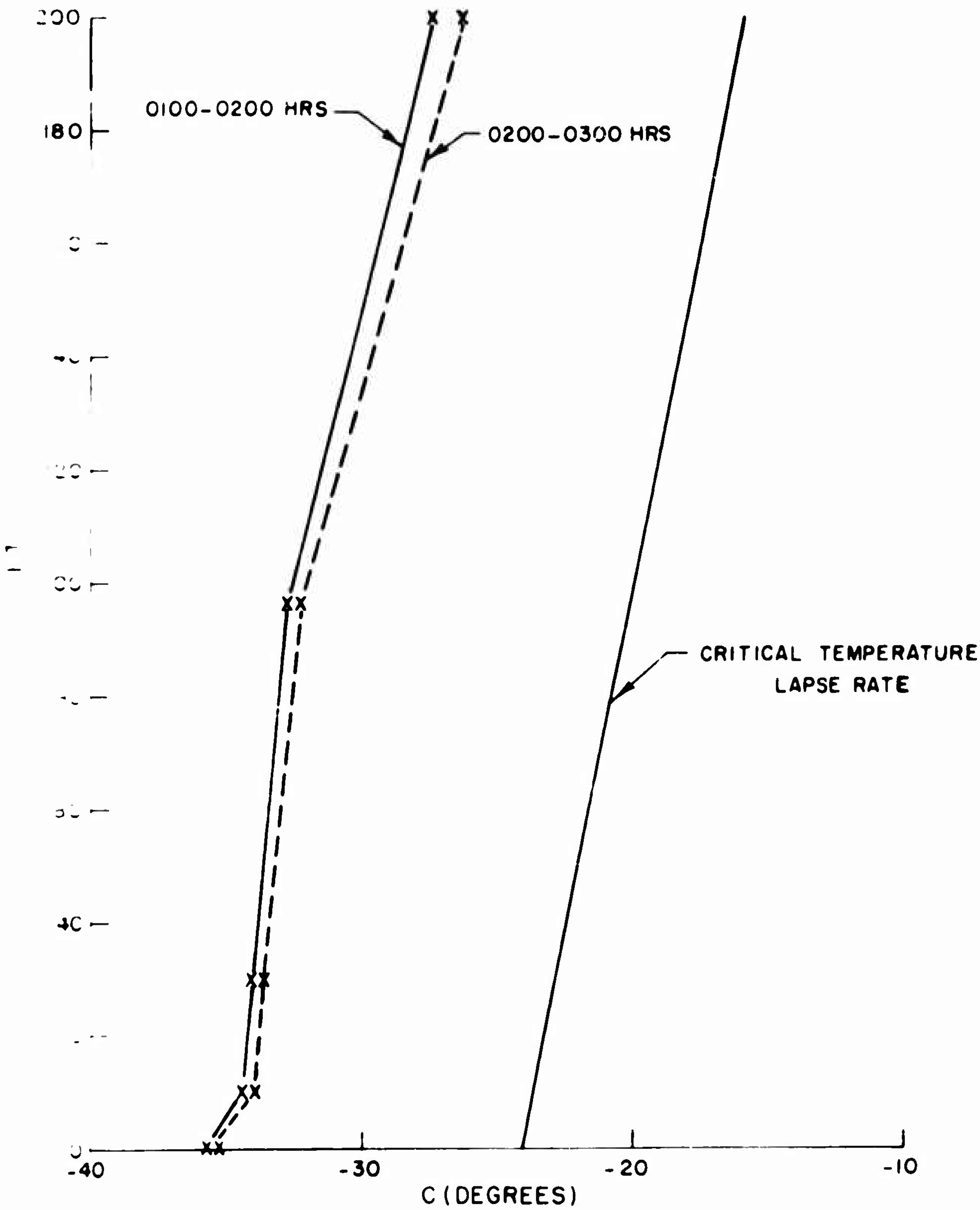


FIG. 19 TEMPERATURE VS HEIGHT PROFILE

3. Indirect_{NF}/Mar 27 = 0.43 $(\text{total})_{NF}$/Mar 25 = 0.78 Indirect_{NF}/Mar 25

4. Indirect_{B}/Mar 27 = 0.52 $(\text{Total})_{N}$/Mar 25 = 0.77 Indirect_{B}/Mar 25

5. Indirect_{G}/Mar 27 = 0.41 $(\text{Total})_{G}$/Mar 25 = 0.87 Indirect_{G}/Mar 25

6. Indirect_{R}/Mar 27 = 0.45 $(\text{Total})_{R}$/Mar 25 = 1.0 Indirect_{R}/Mar 25

7. No detectable signal for NF (no filter) case in vertical plane; however, it can be stated that $\sim$ 1/3 the total or scattered is received with receiver facing light source, i.e., in horizontal plane.

Analysis: The value of H_{NF} in Fig. 12 in the New Jersey area for an optical depth of about 9 is too difficult to interpolate, and therefore no comparison is attempted in this case. It is particularly significant that almost one-half the total radiation on a fairly good visibility night as 25 Mar can reach a target about $4\frac{1}{2}$ miles away by means of the indirect light under poor visibility conditions such as existed the night of 27 Mar.

Figure 20 indicates maximum deviations of +40% from the norm, green filter, for both the total and indirect intensities, with an absolute maximum of 60% during the period. This pattern is associated with fog at a -38°C temperature and $1\frac{1}{2}$ mile visibility. The similarity of the magnitude of variations for both the total and indirect radiation could be attributed largely to the predominance of background noise from twilight that was always present, which at its maximum gave rise to a noise level 90% that of the signal. The noise level varied from about 15% of signal when the twilight was at a minimum to about 90% when at its maximum.

<u>27 Oct 62, 0135-0305 hours, S-11 Response</u>

Weather conditions: sky obscured in 10/10 fog with 300-ft ceiling becoming 400 to 500 ft towards end of test

estimated visibility, 1/2 to 3/4 mile
surface winds, 10 to 13 knots, SE

Results: 1. H_{NF}/0.2 mile = 5.8 for an optical depth (σ D) of 0.84

2. H_{NF}/0.5 mile = 46 for an optical depth (σ D) of 2.1;

H_{NF} = 7.6 (10 minutes later)

3. σ 0.2 - 0.5 mile = 4.2/mile prior to fog lift

Analysis: These results are plotted in Fig. 12, curve 1. The region where the indirect/direct ratio rapidly increases still shows a steeply increasing slope at H = 46 so that the direct radiation is but a negligible portion of the total, i.e., < 1% at an optical depth of about 3.

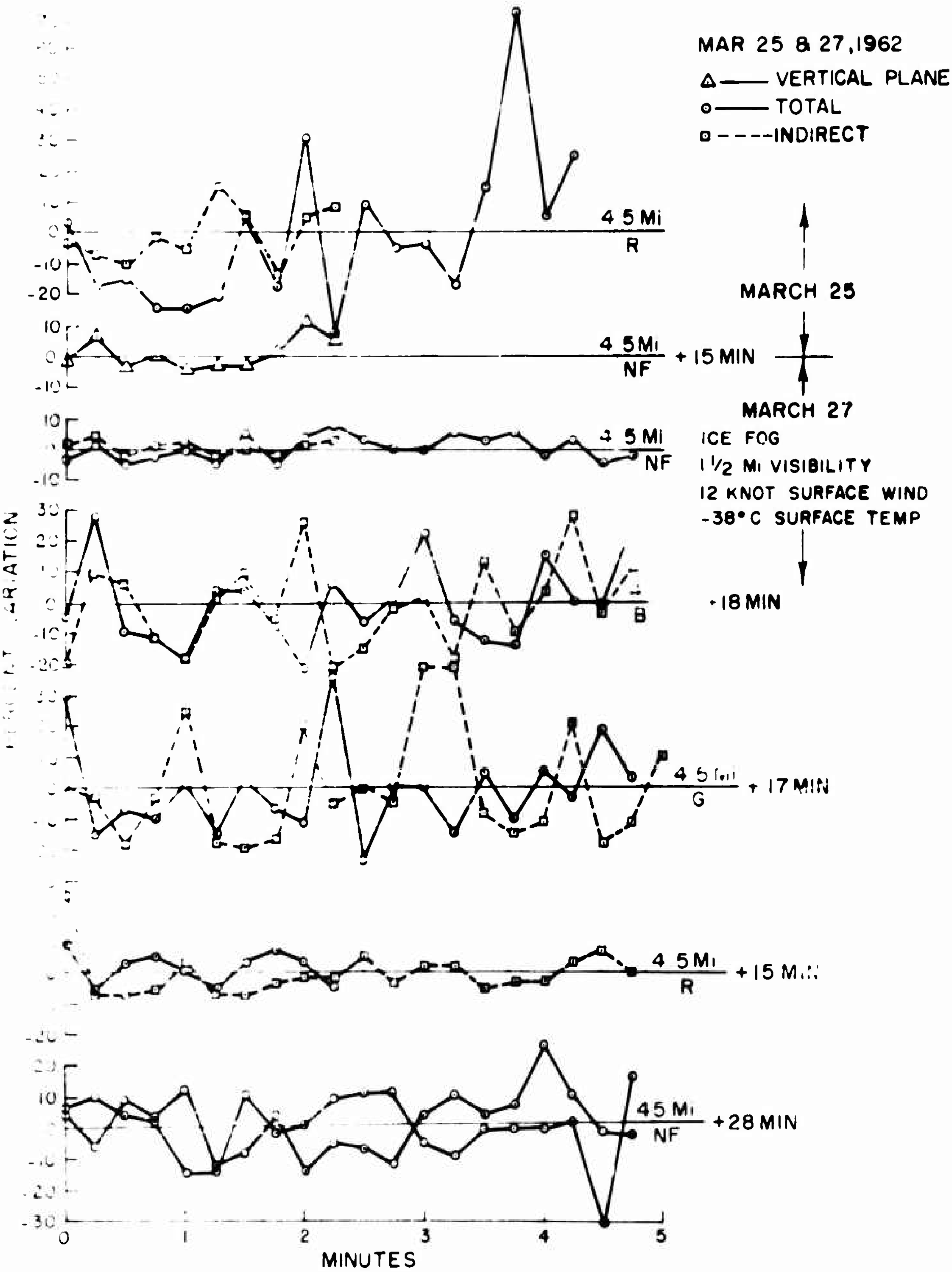


FIG 20 SIGNAL VARIATIONS VS TIME

About ten minutes after the above results were obtained at the 0.5-mile point, the fog lifted to about 400 to 500 feet, with H_{NF} dropping from 46 to 7.6, accompanied by about a 150% increase in the direct component.

Figure 21 indicates very small fluctuations not exceeding ±5% from the norm. This pattern is associated with a fog base at 300 to 500 feet and 1/2 to 3/4 mile visibility.

29 Oct 62, 0145-0545 hours, S-11 and S-1 Responses

Weather conditions: variable amounts of ground fog, 2/10 to 3/10 coverage becoming 6/10 to 8/10 towards end of test

variable visibility between 3 and 10 miles, and becoming > 50 miles briefly

SE winds, 8 to 10 knots

Results: 1. $\sigma_{0.5 - 1.0 \text{ mi}} = 0.04$/mi (scattered fragments of ground fog, i.e., about 2/10 at 1 mile);
at 0.5 mi, $H_{NF}/0.5 = 0.061$, $\sigma D = 0.02$

2. At 1.0 mi, $H_{NF}/1.0 = 0.080$; $\sigma D = 0.44$

3. At 4.5 mi, $H_{NF}/4.5 = 2.3$; $\sigma D = 1.80$ ($\sigma_{NF/1-4.5 \text{ mi}} = 0.40$/mi)

$H_B/4.5 = 1.93$, $\sigma D = 1.71$ ($\sigma_{B/1-4.5 \text{ mi}} = 0.38$/mi)

$H_G/4.5 = 1.02$, $\sigma D = 1.26$ ($\sigma_{G/1-4.5 \text{ mi}} = 0.28$/mi)

$H_R/4.5 = 0.88$, $\sigma D = 1.26$ ($\sigma_{R/1-4.5 \text{ mi}} = 0.28$/mi)

NOTE: Variable amounts of ground fog between 2/10 to 3/10 coverage with about 3/10 coverage at the time of the NF (no filter) measurements, and 2/10 for the color filter measurements. The above results were obtained with a 6292 Dumont photomultiplier, i.e., S-11 response.

4. At 1.0 mi, $H_{IR}/1.0 = 0.70$

$H_{B + IR}/1.0 = $ [illegible]

5. At [illegible].5 mi, $H_{B + IR}/4.5 = 16.4$; [illegible]

($\sigma_{B + IR/1 - 4.5 \text{ mi}} = 1.1$/mi)

$H_{IR(0.72 - 1.1\mu)}$/[illegible] $= 22.2$; $\sigma D = $ [illegible].75

($\sigma_{IR/1 - 4.5 \text{ mi}} = 1.5$/mi)

Results 4 and 5 were obtained with a 6911 Dumont multiplier phototube having an S-1 response, when ground fog coverage had increased to 6/10 to 8/10.

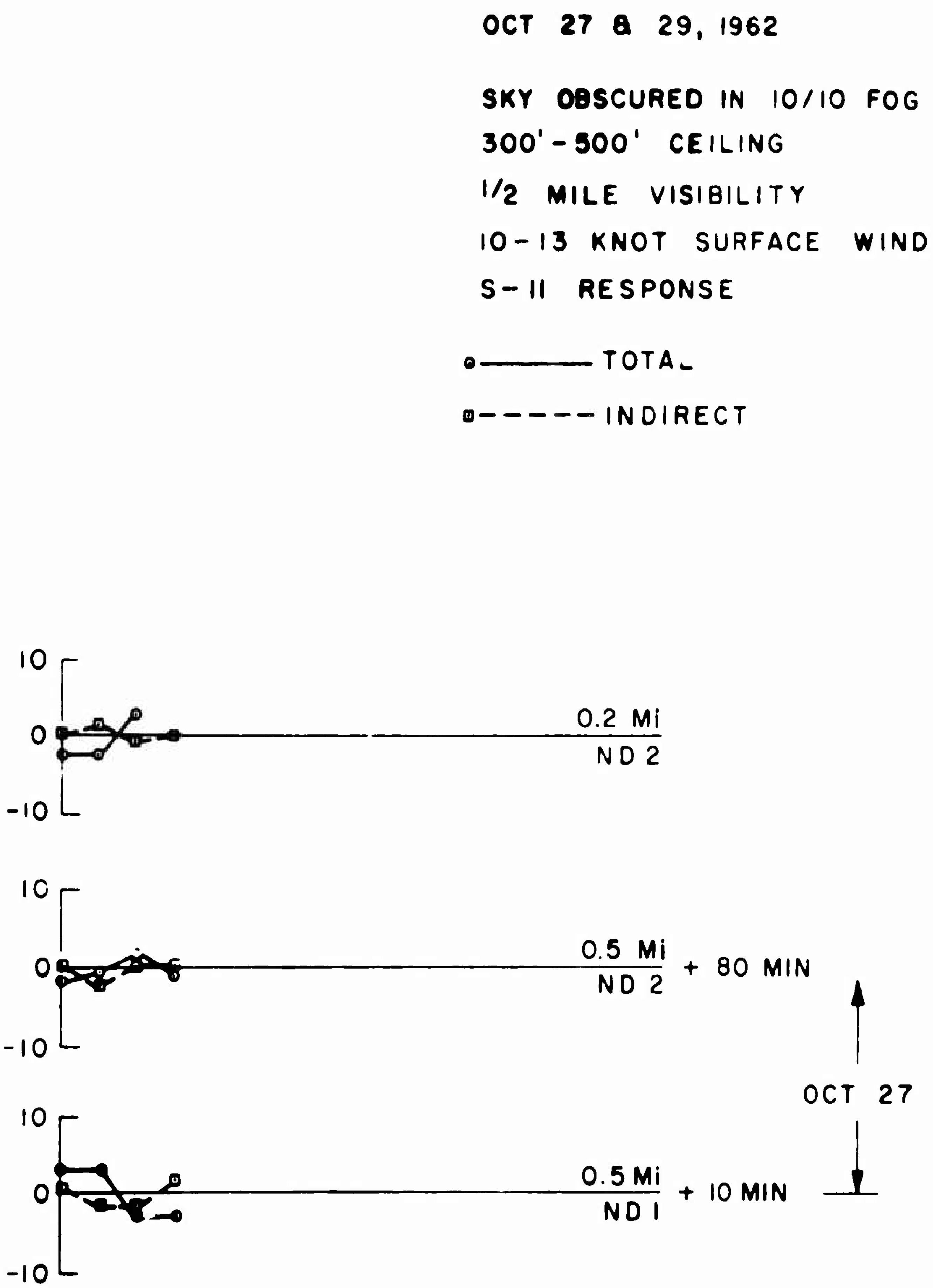


FIG. 21 SIGNAL VARIATIONS vs TIME

About five minutes elapsed between the IR and IR + B measurements at a given distance.

Analysis: It is interesting to note in result 5, at 4.5 miles, that σ_{IR} is about 40% greater than σ_{B+IR} and that H_{IR} is about 40% greater than H_{B+IR}; while at one mile, H_{B+IR} is about 40% greater than H_{IR}. This effect seems to be due to the significantly greater ratio of the indirect to absorption effects for the near IR over a distance of 4.5 miles.

Figure 22 indicates a "duct effect" reaching a maximum of over 300% at 4.5 miles. The graphs of response vs range for the blue, indirect green, and red spectral regions indicate that the total and indirect transmittances are independent of wavelength. The total transmittances for the different spectral regions are about the same as for a non-attenuating atmosphere with a negligible surface albedo. Figure 22 also indicates that the indirect energy decreases at a rate of more than 300% that of the total energy decrease for about 1/2 mile. Beyond the first mile to 4.5 miles, the total energy decreases at a much more rapid rate so that at an approximate distance of ten miles there is very little difference in the amounts of the total and indirect energy.

Figure 23, depicting transmittance vs distance, indicates the indirect transmittance exceeding the total beyond a distance of about 3/4 mile. Good visibilities at close to source distances becoming relatively poorer at the greater distances account for the curves' unusual relative shapes. The total transmittance, consisting mainly of the direct transmittance, drops more rapidly than the indirect for close to source good visibility conditions. But as the visibility lowers with distance in an inhomogeneous atmosphere, in this case dropping sharply at the greater distances from the source, the total transmittance drops at a much faster rate than the indirect.

Figures 24a-d indicate fluctuations not exceeding +38%, or -27% from the norm, under 8 to 10 mile visibilities and +10% or -8% under 3 to 4 mile visibilities. There seems to be little fluctuation magnitude differences with distance under the poor visibility conditions, since at the greater distances there is a greater indirect-to-direct ratio which overcomes the effect of refractive index fluctuations for the direct light at greater distances. This fluctuation pattern is associated with scattered-to-broken ground fog, 3 miles to greater than 50 miles visibility, and a -0.2°C to a +3°C/200 ft temperature inversion shown in Fig. 25.

<u>2 Nov 62, 0125-0325 hours, S-1 Response</u>

Weather conditions: sky obscured in 8/10 fog, with very light falling snow
estimated visibility 3/4 to 1 mile over a 4.5-mi path
south winds, 9 to 10 knots

Results: 1. H_{IR}/4.5 mi = 12 (0125 hrs) = 24 (0135 hrs)

2. H_{B+IR}/4.5 = 10 (0155 hrs) = 19 (0310 hrs)

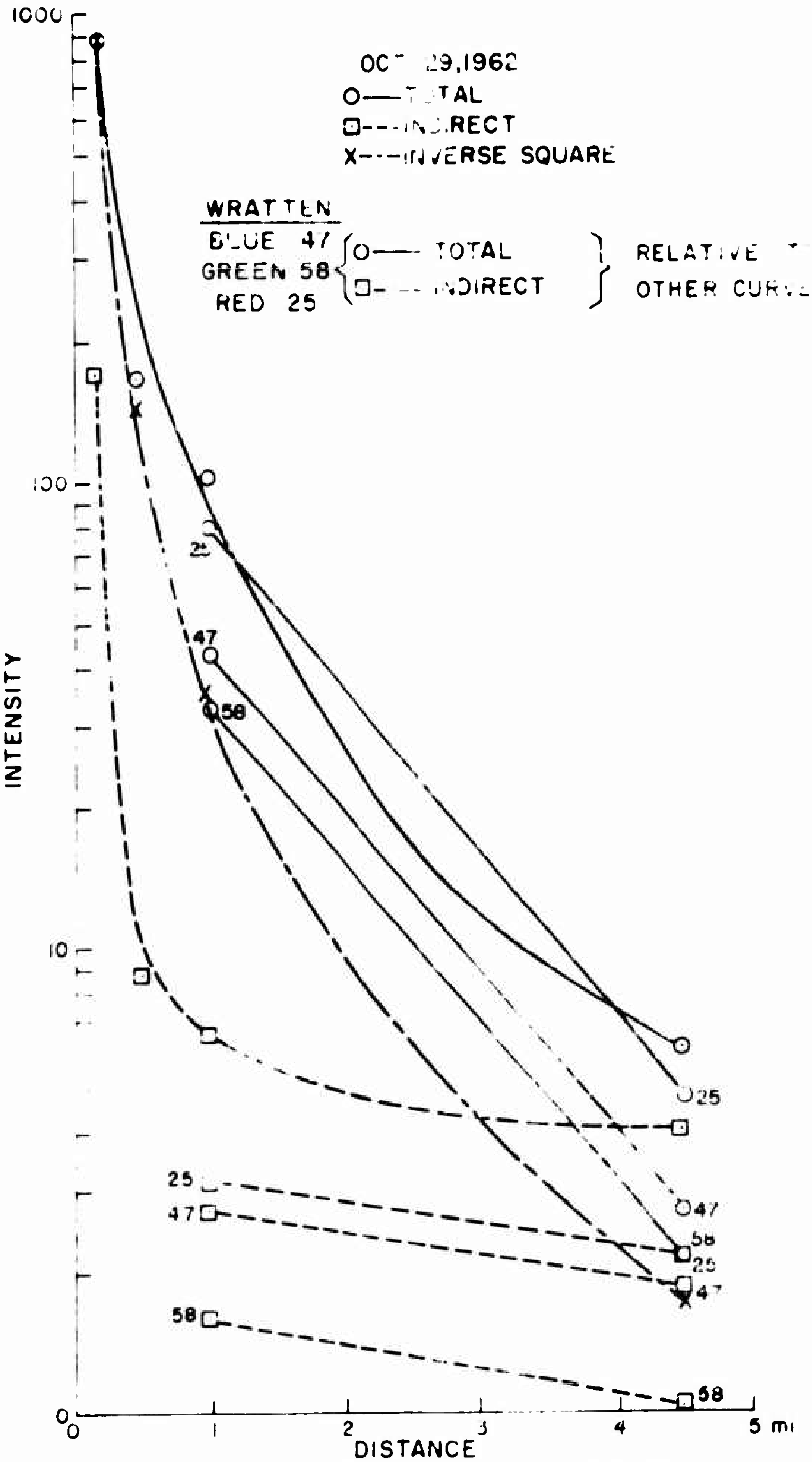


FIG. 22 INTENSITY VS DISTANCE

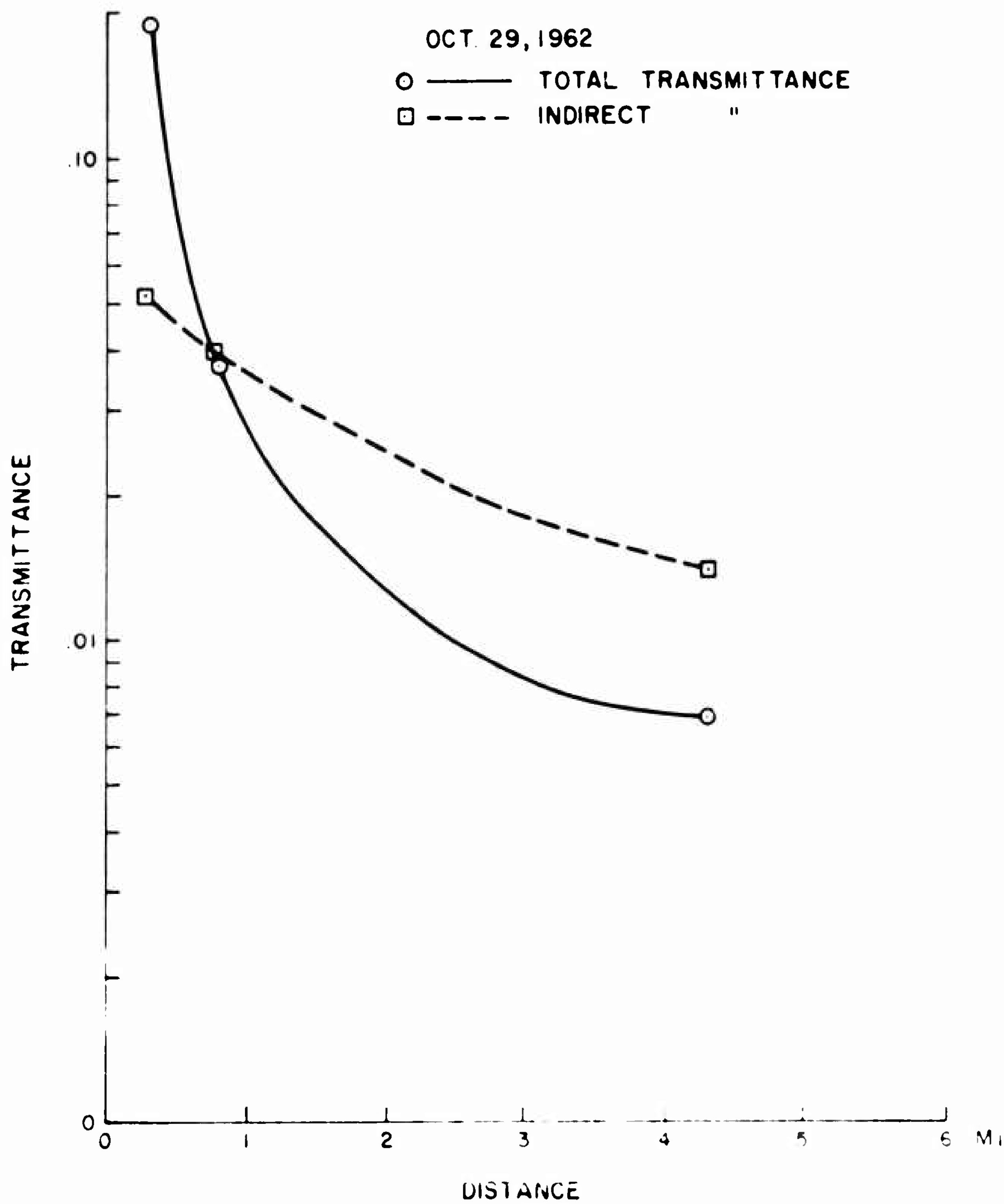


FIG. 23 TRANSMITTANCE VS DISTANCE

OCT. 29, 1962
SCATTERED TO BROKEN GROUND FOG
3 - > 50 Mi VSBY
8 - 10 KNOTS SURFACE WINDS
S11 & S1 P.M.

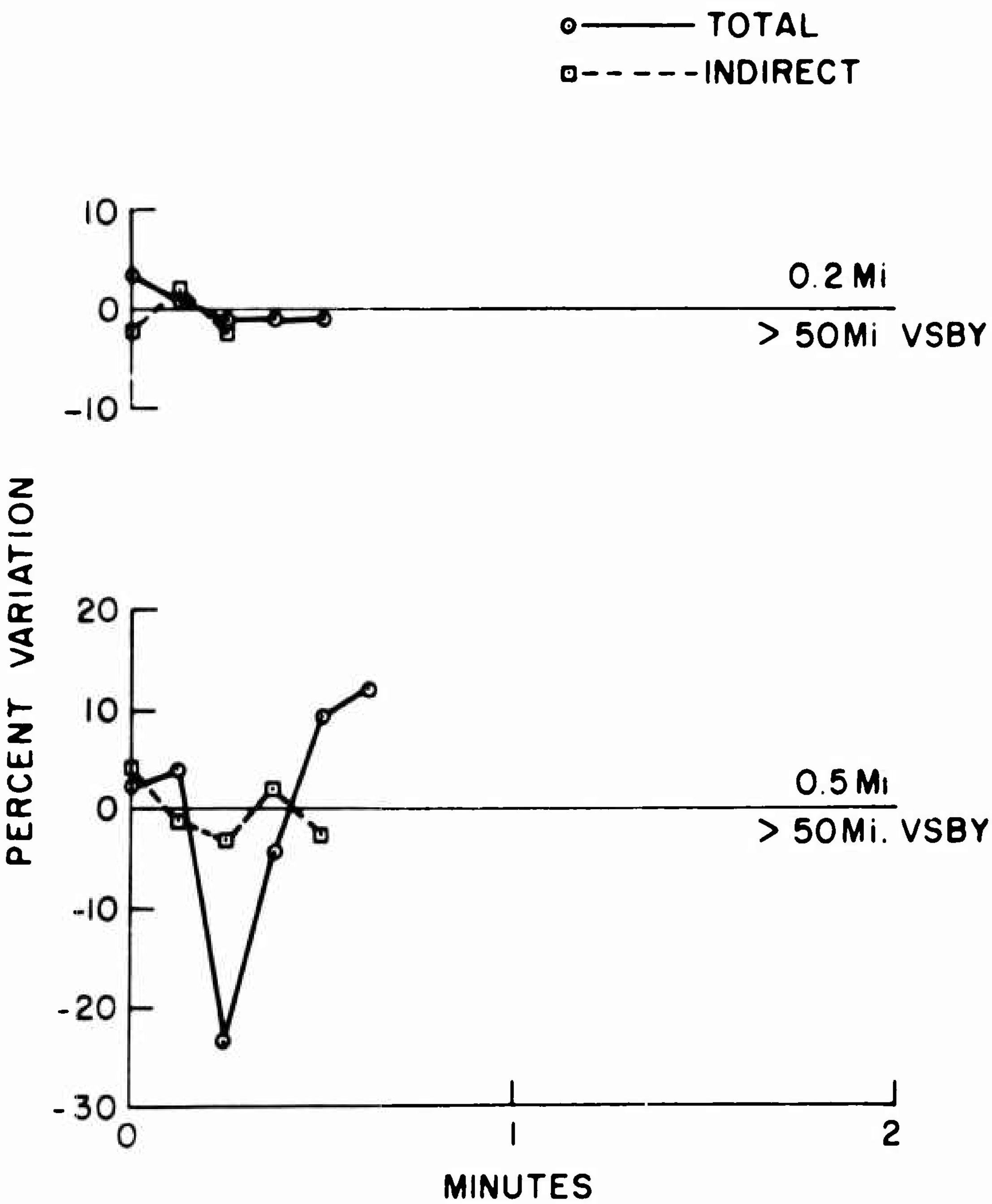


FIG. 24 a SIGNAL VARIATIONS VS TIME

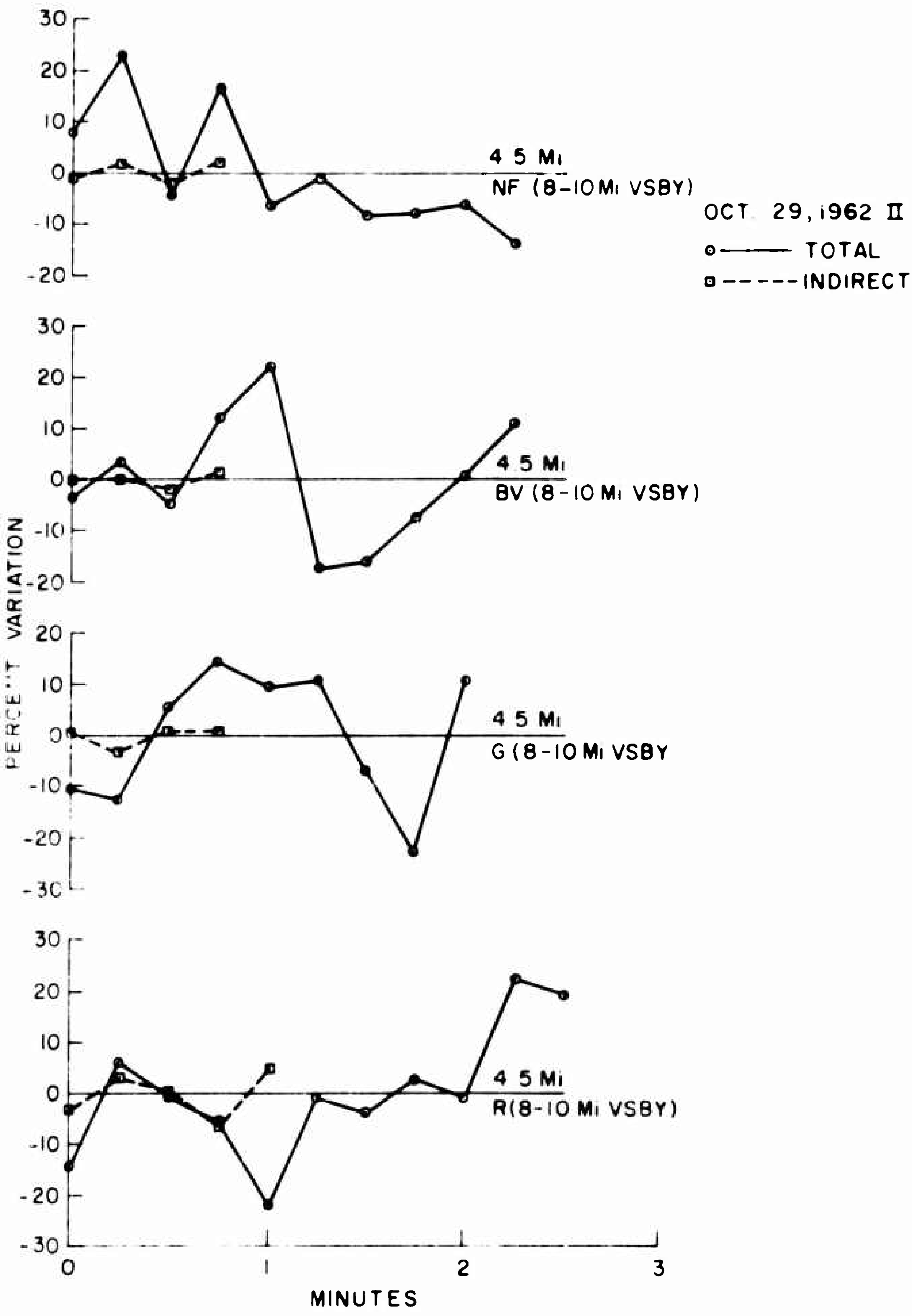


FIG. 24b SIGNAL VARIATIONS VS TIME

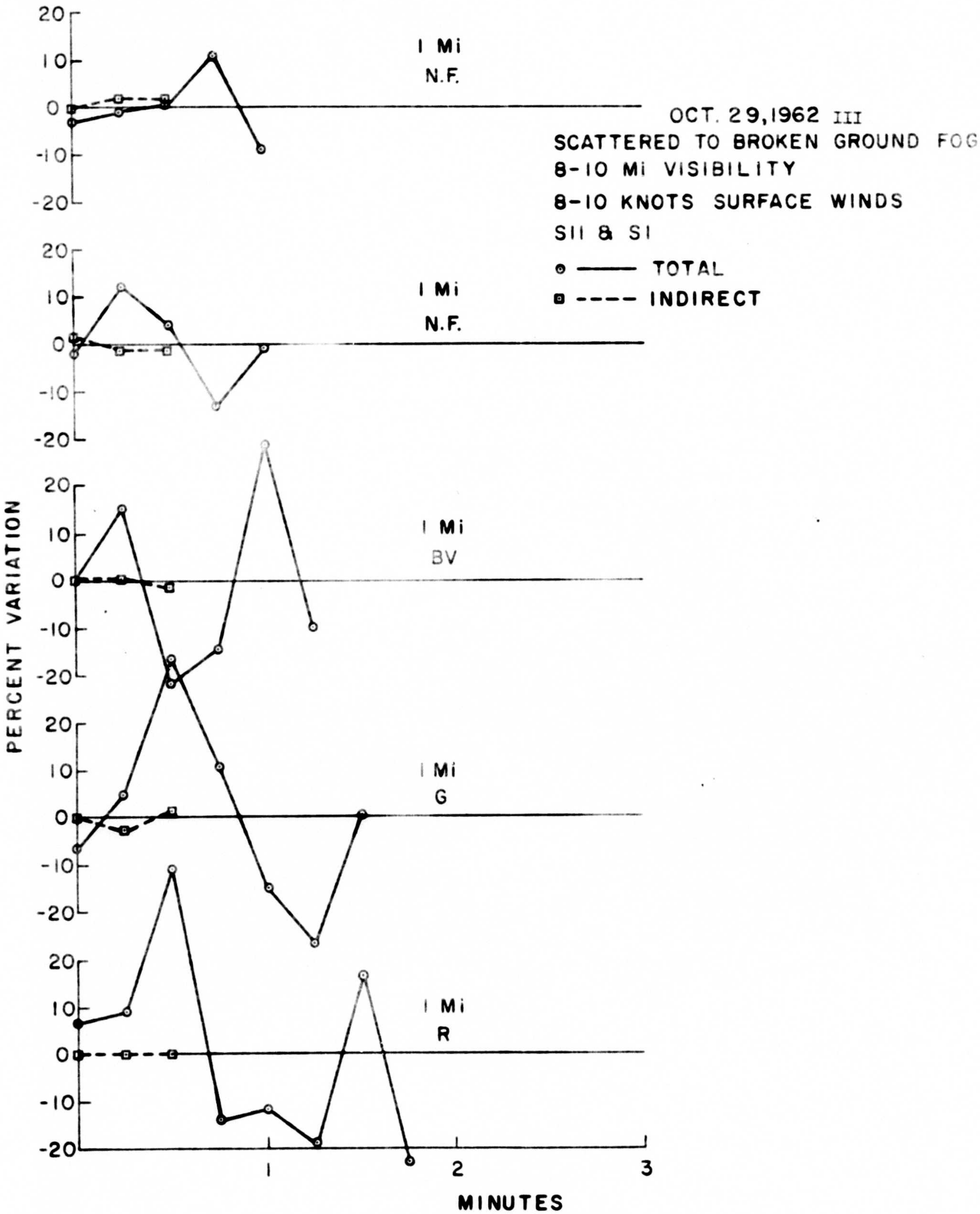


FIG. 24c SIGNAL VARIATIONS VS TIME

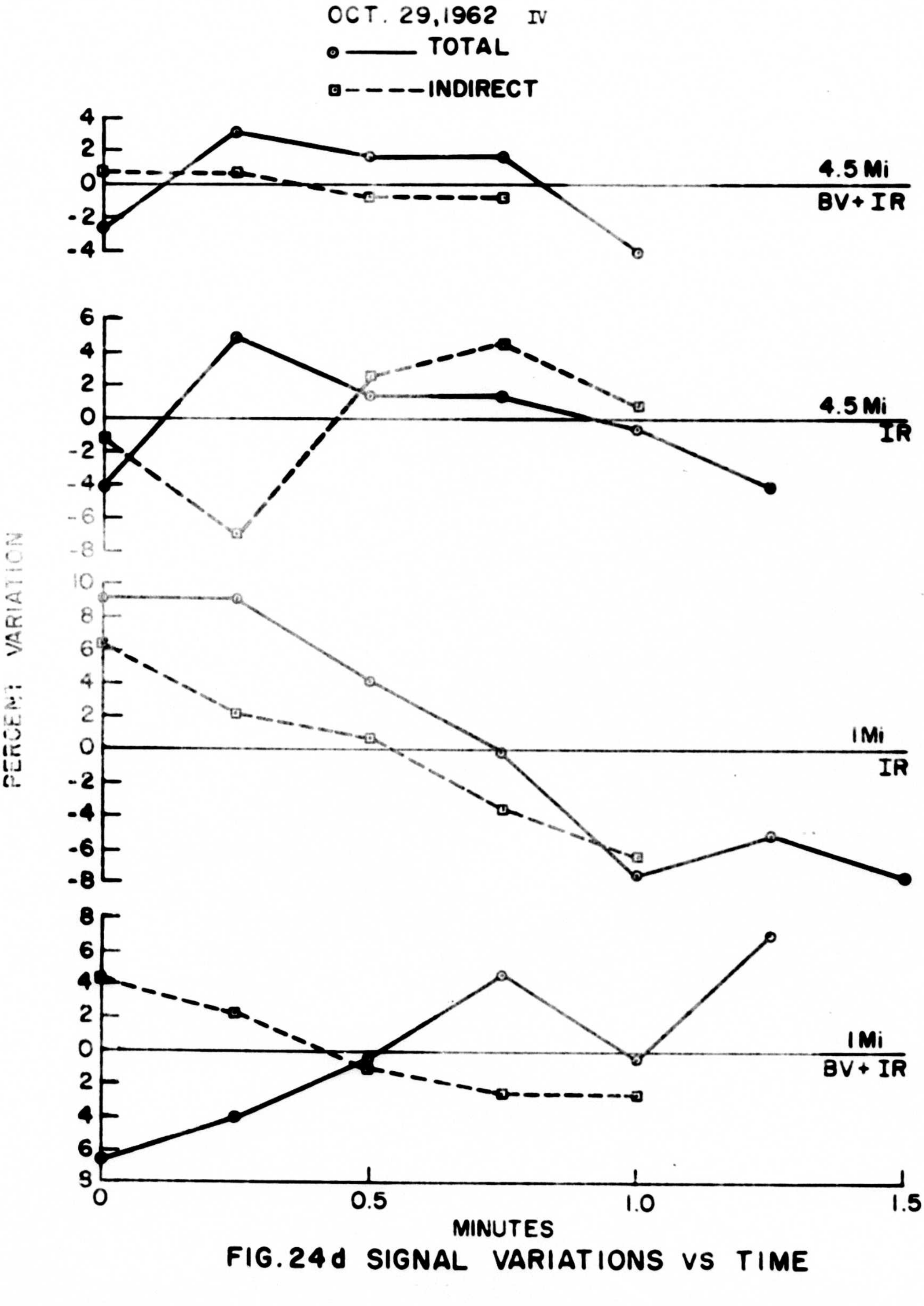
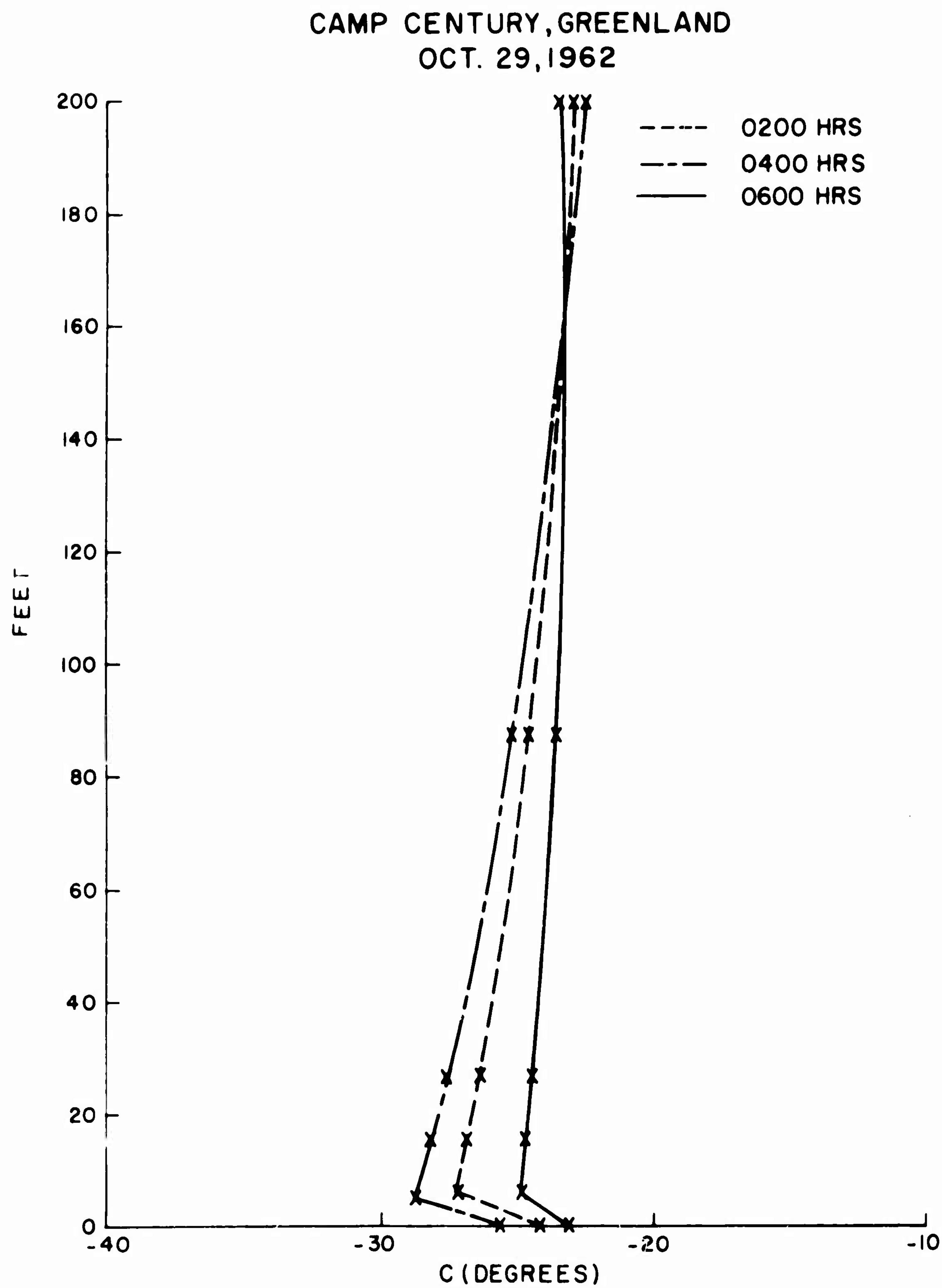


FIG. 24d SIGNAL VARIATIONS VS TIME



TEMPERATURE VS HEIGHT PROFILE

FIG. 25

3. $H_{B + IR/4.5}$ = 20 (0218 hrs)

4. Total $_{R + IR/4.5}$ = 91% indirect $_{R + IR}$ (0238 hrs)

5. $H_{R + IR/4.5}$ = 20 (0243 hrs)

6. Total $_{NF/4.5}$ = 90% indirect NF (0245 hrs)

7. Total $_{IR/4.5}$ = indirect IR (0255 hrs)

8. Total $_{B/4.5}$ = 95% indirect B (0300 hrs)

9. $H_{NF/4.5}$ = 13 (0321 hrs)

NOTE: Above results were obtained with a 6911 Dumont photomultiplier, i.e., S-1 response.

ANALYSIS: It is interesting to note in Fig. 26-a the rapid variations occurring in fog and very light falling snow within as short as a 2-minute interval over a 4.5-mile path, where the indirect can exceed the total radiation, with each averaged over 2-minute intervals at a 5/minute flash rate. It is safe to assume in this case that the total and the indirect continuous type radiation are equal for all visible and near infrared wavelengths, since the 4.5-mile distance exceeds the visibility by a factor of about 5. However, for any short pulse type radiation, the indirect radiation from one pulse can readily exceed the total from a subsequent pulse.

Figs. 26a-c indicate maximum fluctuations of +33% and -25% from the norm which occurs for the indirect infrared component at 4.5 miles. The total intensity maximum fluctuation in this spectral region is +19% and -23%. The other spectral regions indicate a somewhat smaller fluctuation spread. The magnitudes for the indirect and total intensity fluctuations differ little; this factor may be attributed to the combined effects of fog and light falling snow. The fluctuation pattern is associated with 8/10 fog coverage, 3/4-mile visibility, light falling snow, and a -0.3°C temperature spread between the surface and 200 feet, and -0.07°C between the surface and 87 feet at 0100 hours becoming -0.2°C and -0.5°C, respectively, two hours later.

<u>7 Nov 62, 0015-0135 hours, S-1 Response</u>

Weather conditions: 10/10 sky obscured in rapidly varying scattered ground fog with 8/10 to 9/10 stratocumulus at about 1200 feet

estimated visibility 1/2 mile

SE winds, 10 to 13 knots

Results: 1. $H_{NF/0.2\ mi}$ = 0.98 (0015-0022 hrs) σ D = 1.3

2. $H_{NF/0.5\ mi}$ = 1.02 (0125-0135 hrs) σ D = 3.2

($\sigma_{0.2 - 0.5\ mi}$ = 6.5/mi)

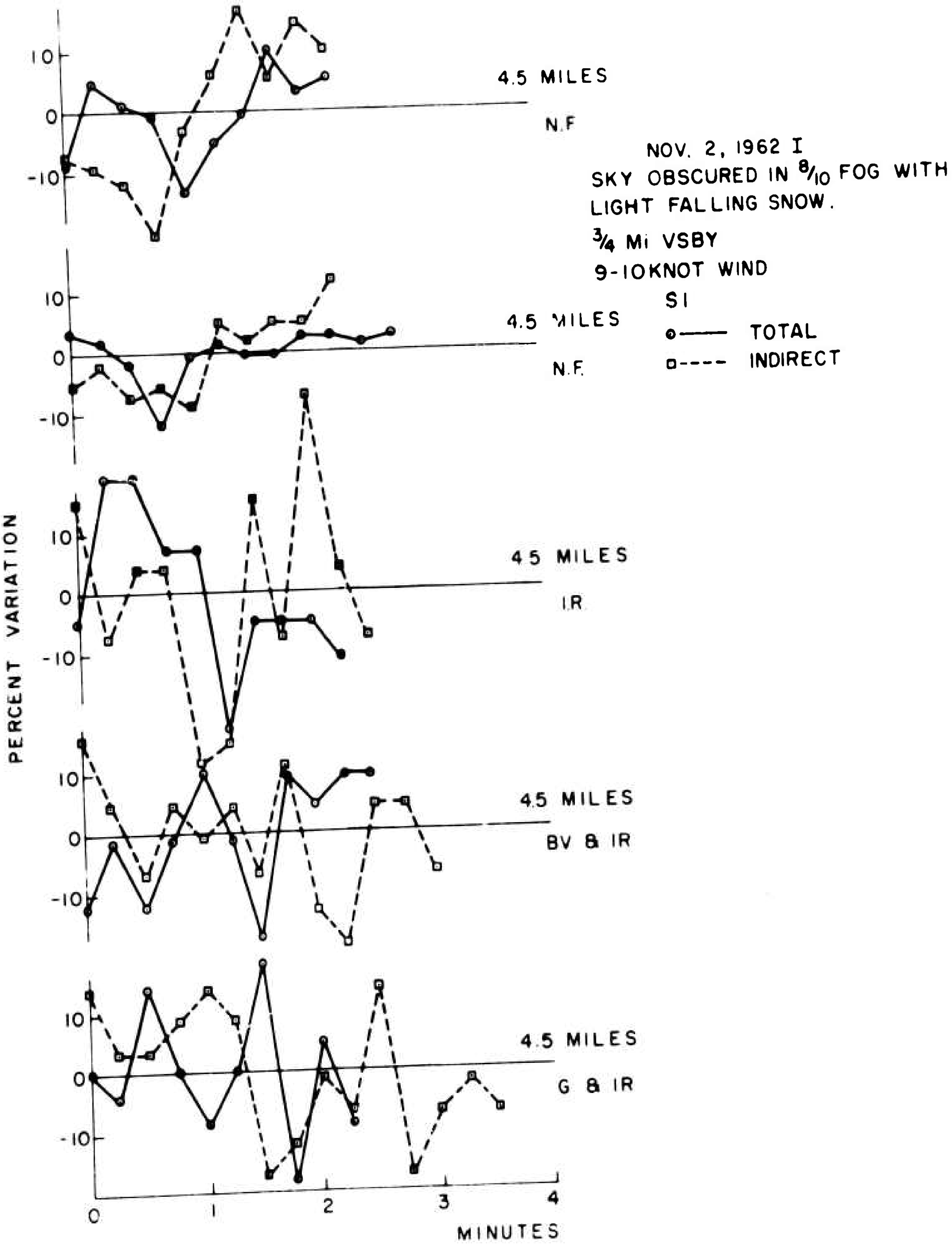


FIG. 26 (a) SIGNAL VARIATIONS vs TIME

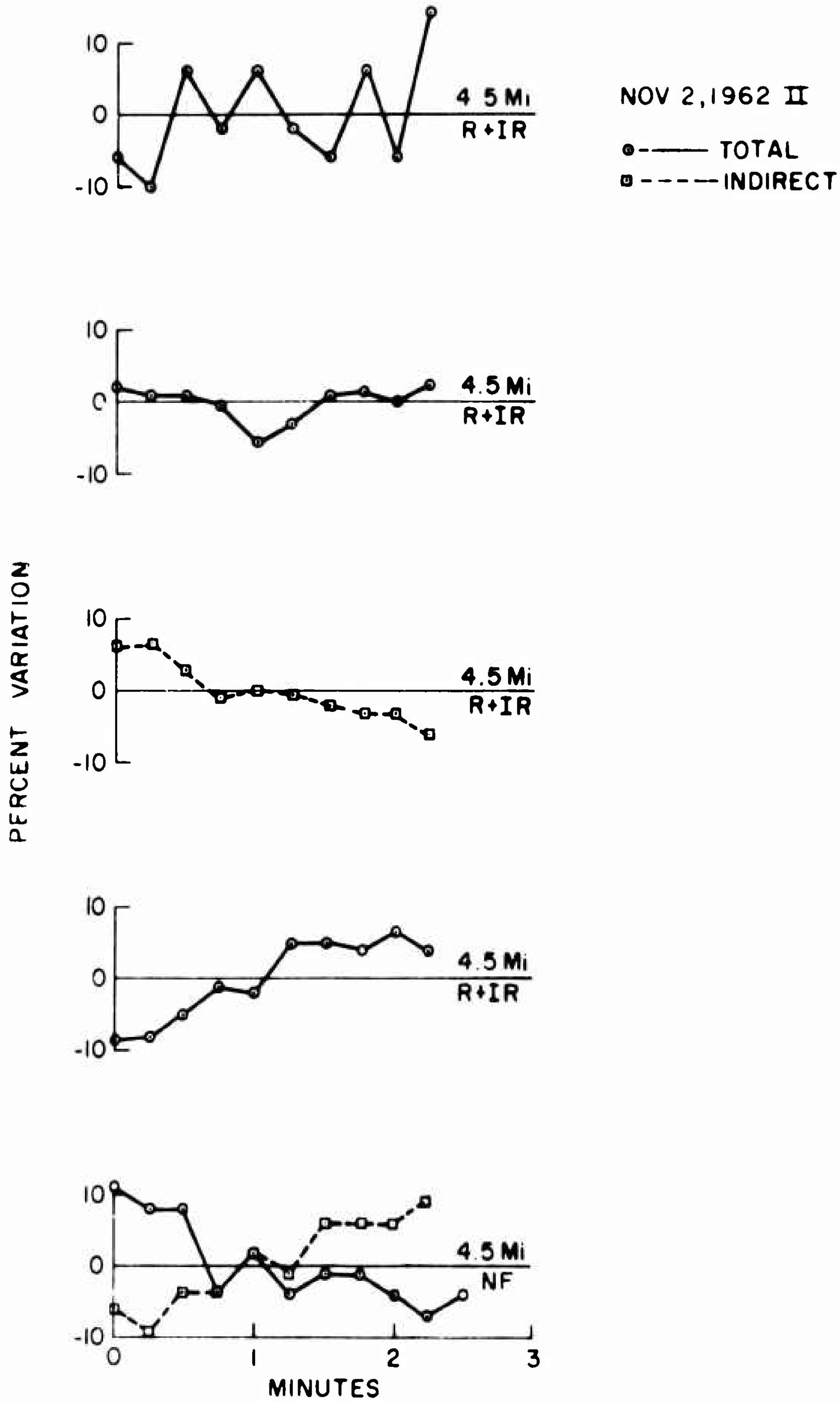


FIG. 26b SIGNAL VARIATIONS VS TIME

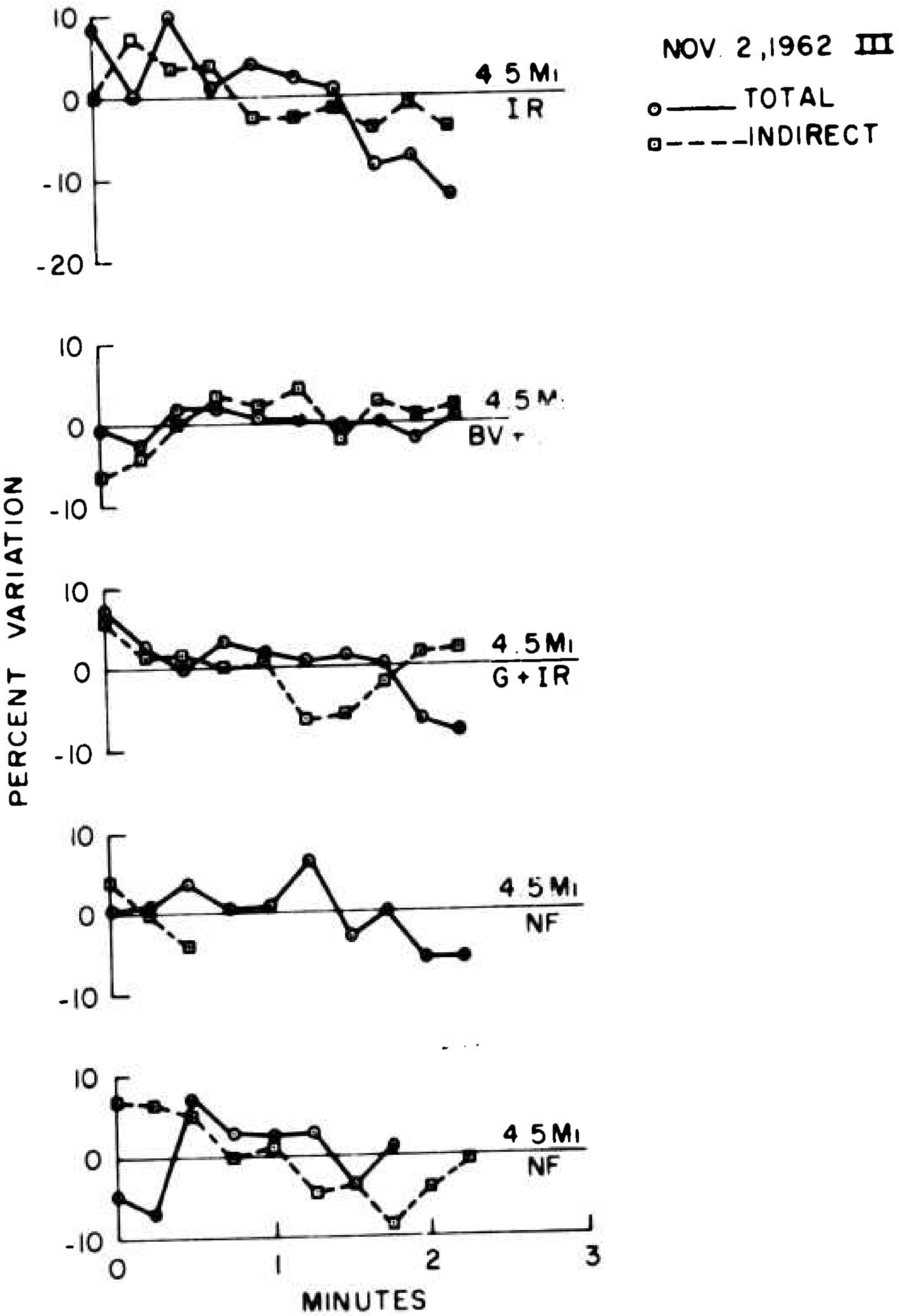


FIG. 26c SIGNAL VARIATIONS VS TIME

NOTE: The results were obtained with a 6911 Dumont photomultiplier, i.e., S-1 response.

Analysis: There is little difference between the H factors for an optical depth of 1.3 or greater within 1/2 mile of the source, seemingly due to the effects of multiple scattering in the presence of some ground fog and a low cloud deck.

Figure 27 indicates maximum fluctuations of +17% and -12% and +11% and -22% for the indirect and total intensities, respectively, at the 0.2 and 0.5 mile distances. The indirect fluctuations exceeding the total could be due to the scattered ground fog, which varied both in space and time. This fluctuation pattern is associated with 8/10 to 9/10 clouds at 1200 feet, with scattered ground fog, 1/2 mile visibility, a surface to 200 feet temperature spread of +3.2°C and a surface to 87 feet temperature difference of +1.8°C at 0000 hours and +0.4°C and 0.1°C, respectively, two hours later.

8 Nov 62, 0000-0145 hours, S-1 Response

Weather conditions: sky partially obscured by varying amounts of scattered ground fog (with 10/10 thin cirrostratus clouds) at the beginning of test up to 1-mile measurements, and becoming clear afterwards

visibility of about 2 miles at 1/2-mile point, improving towards >50 miles between the 1 and 4.5-mile distances

single and double images of ground lights observed at about the 2-mile point, with uppermost image appearing about 70 feet from surface; +12°C to +13.5°C gradient (1.5°C increase occurred over a 75-minute interval)

ESE winds, 4 to 6 knots

Other weather observations: At the start of the test a faint corona of about 1/2 degree diameter appeared around the 100W red light at the 100-ft tower level. A light halo existed around the surface floodlights at Camp Century, while a light ground fog was noticeable up to about 70 feet. There was very little noticeable ground fog at the one-mile point, and this appeared within 40 or 50 feet of the ground. However, about 15 minutes later, the ground fog had obscured the surface floodlights. About 10 minutes later, single and even occasionally double images of the two visible surface floodlights appeared about 70 feet from the surface near the two-mile point. Five minutes prior to this refractive phenomenon, light ground fog was observed to a height of about 90 feet through an 8-power telescope.

Results: 1. $H_{NF}/0.13 = 0.42$; $\sigma D = 0.21$

2. $H_{NF}/0.5 = 0.38$ ($\sigma_{0.13 - 0.5 \text{ mi}} = 1.59$/mi); $\sigma D = 0.80$

3. Ten minutes later than 2, above: $H_{NF}/0.5 = 0.23$ ($\sigma_{0.13 - 0.5}$ = 1.67 mi); $\sigma D = 0.84$

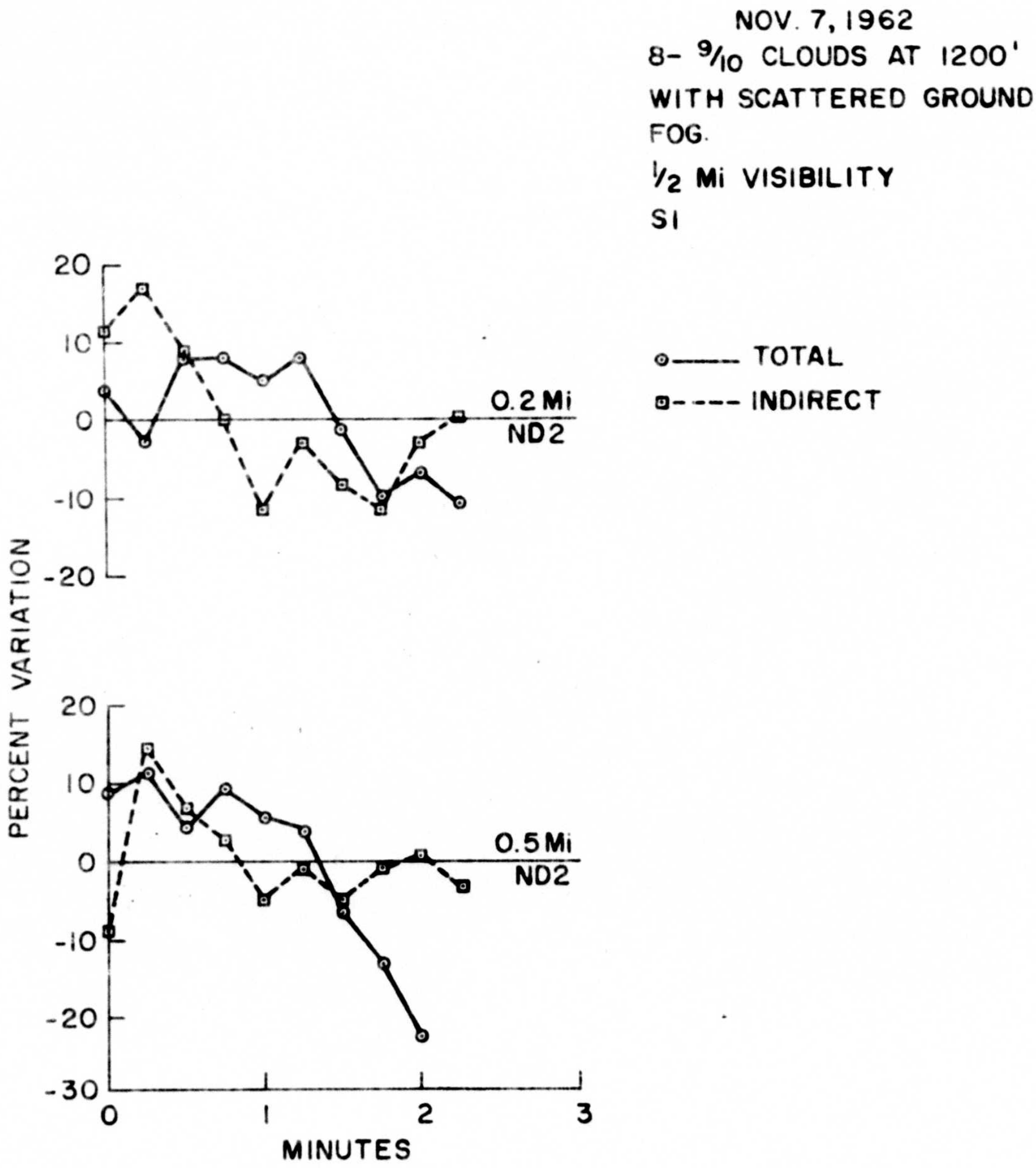


FIG. 27 SIGNAL VARIATION VS TIME

4. Ten minutes later than 3, above: $H_{NF} = 0.04$ ($\sigma = 1.54$/mi); $\sigma D = 0.77$

5. $\sigma_{(0.13 - 0.5 \text{ mi})} = 1.59 \rightarrow 1.67 \rightarrow 1.54$/mi in about 25 minutes

6. $H_{NF/1} = 0.54$ ($\sigma_{0.5 - 1 \text{ mi}} = 1.46$/mi); $\sigma D = 1.5$

7. $H_{NF/4.5} = 0.31$ ($\sigma_{1 - 4.5 \text{ mi}} = 0.27$/mi); $\sigma D = 0.12$

NOTE: The above results were obtained with a 6911 Dumont photomultiplier, i.e., S-1 response

Analysis: Scattered ground fog caused the relatively high H values at the 0.13-and initially at the 0.5-mile points. However, it is interesting to note that σ changed but slightly during about 25 minutes at the 0.5-mile point, yet H dropped rapidly in that time by almost one order of magnitude. This can perhaps best be explained by the deterioration of the ground fog above the light source, i.e., 100 feet.

It can also be noted from Fig. 28 that the indirect intensity begins to decrease at a more rapid rate than the total at about one mile and continues to do so until at least the 4.5-mile point. The ratio of the inverse square (no atmospheric attenuation and negligible surface albedo) to the total intensity equals 2.25 ±6%. The indirect transmittance curves of Fig. 29 show the expected increasingly smaller drop with distance than the total transmittance.

Figs. 30a-c indicate the extreme variations that can occur under certain weather conditions. These extreme variations or fluctuations occur at 4.5 miles under excellent visibility conditions and steep temperature vertical gradients. Maximum total intensity variations of +160% and -80% from the norm appear at 4.5 miles with a greater than 50-mile visibility, and a 12.0°C inversion between the surface and 200 feet and a 10.3°C inversion between the surface and 87 feet. The indirect variations did not exceed ±10% from the norm. About 15 minutes later the variation increased sharply to +325% and -60% from the norm. It was during an hour's interval, including this period, that the temperature inversion was becoming steeper so that 15 minutes after the above variations occurred a 13.5°C inversion occurred between the surface and 200 feet, while a +13.3°C inversion occurred between the surface and 87 feet.

9 Nov 62, 0000-0200 hours, S-1 Response

Weather conditions: sky obscured by 10/10 fog, with about a 700-ft ceiling and scattered patches in the vicinity of the 200-ft tower level

variable visibility from about 3 miles to > 50 miles, -1.4 to -1.6°C gradient (vertical)

S winds, 3 to 5 knots

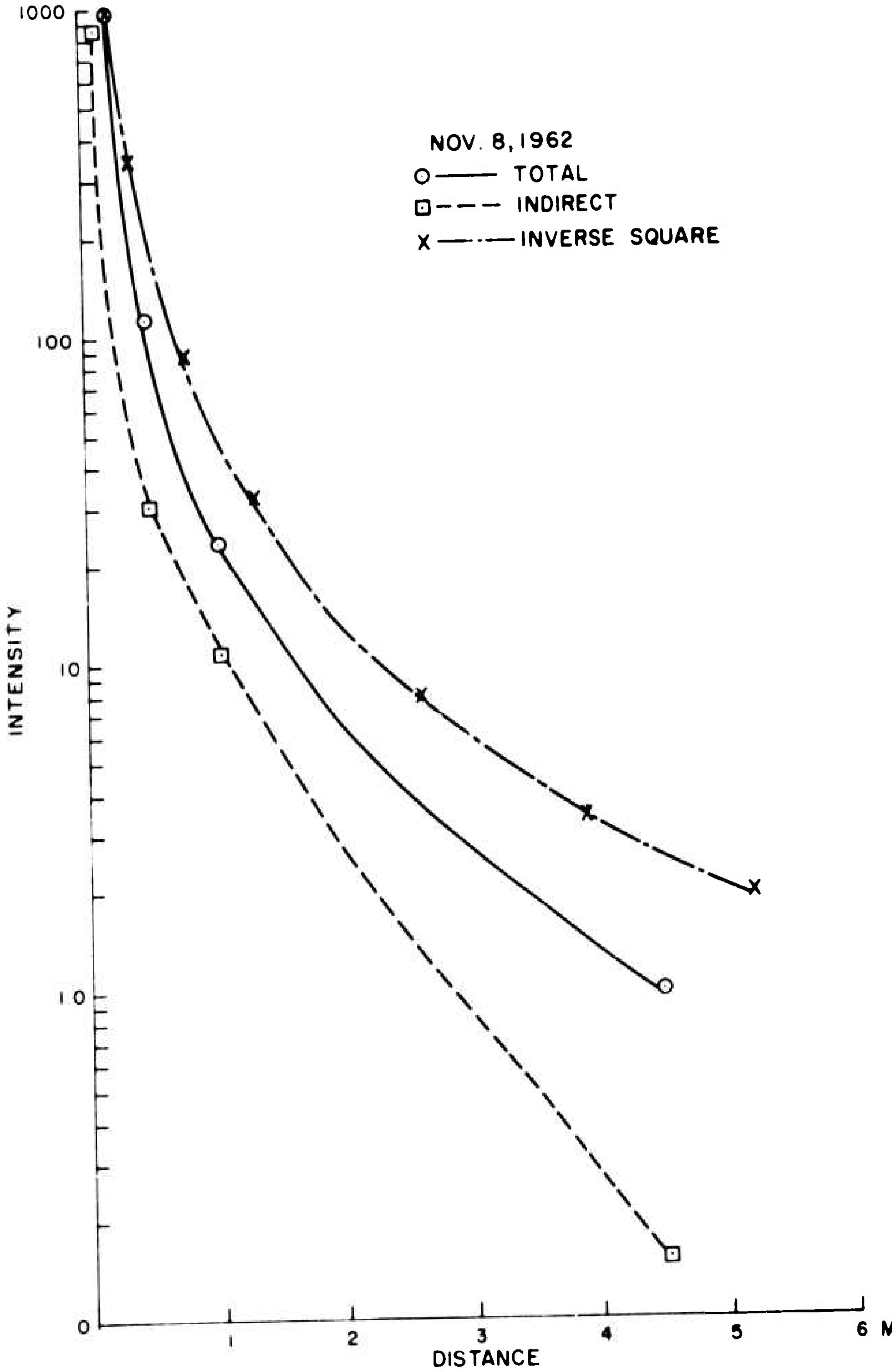


FIG. 28 INTENSITY VS DISTANCE

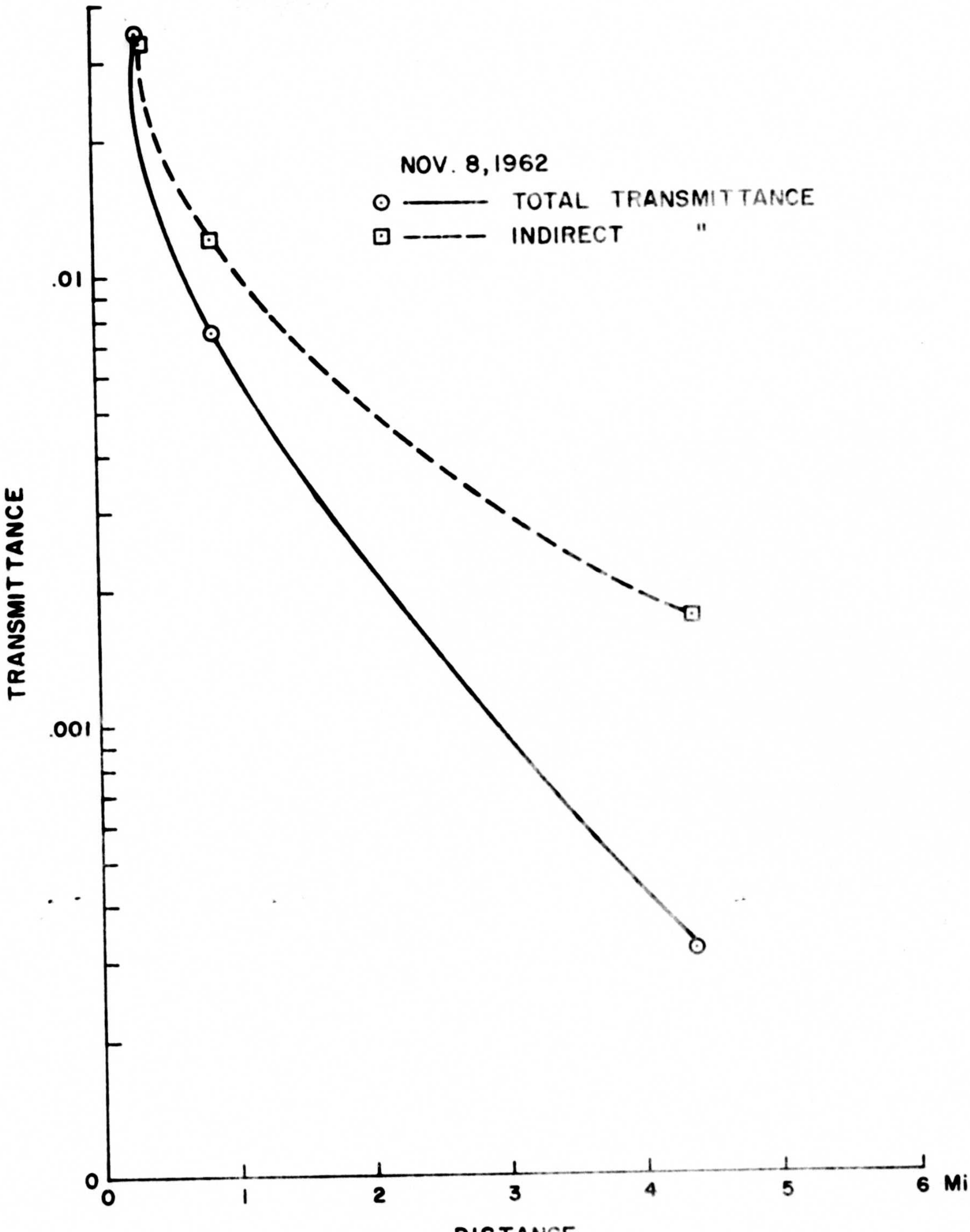


FIG. 29 TRANSMITTANCE vs DISTANCE

NOV. 8, 1962 I

SCATTERED GROUND FOG BECOMING CLEAR

10/10 HIGH THIN CLOUDS

2 MILE VISIBILITY BECOMING 250 MILES

AT 4.5 MILE POINT

S-1 RESPONSE

■ - - - - INDIRECT

● ——— TOTAL

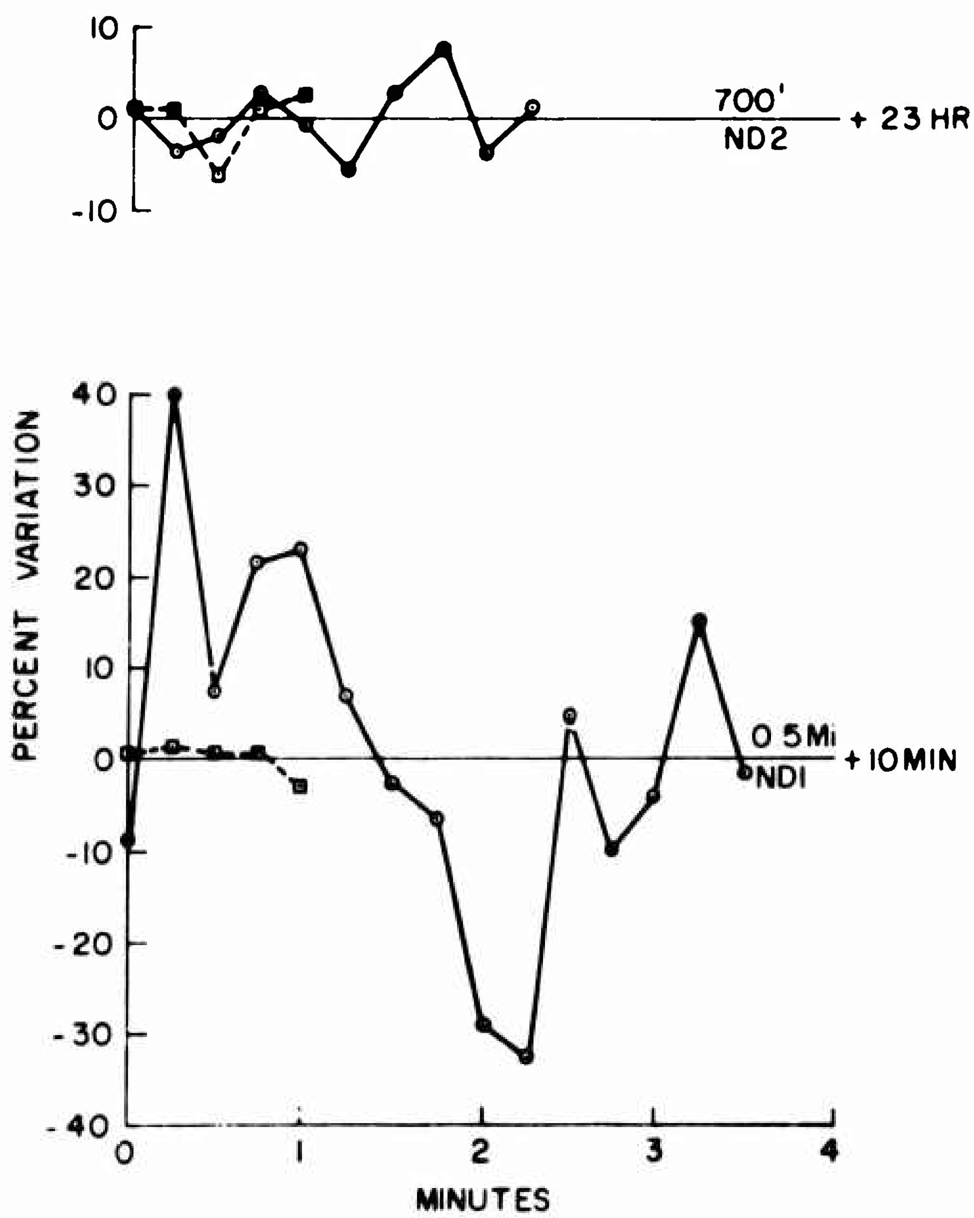


FIG 30a SIGNAL VARIATIONS VS TIME

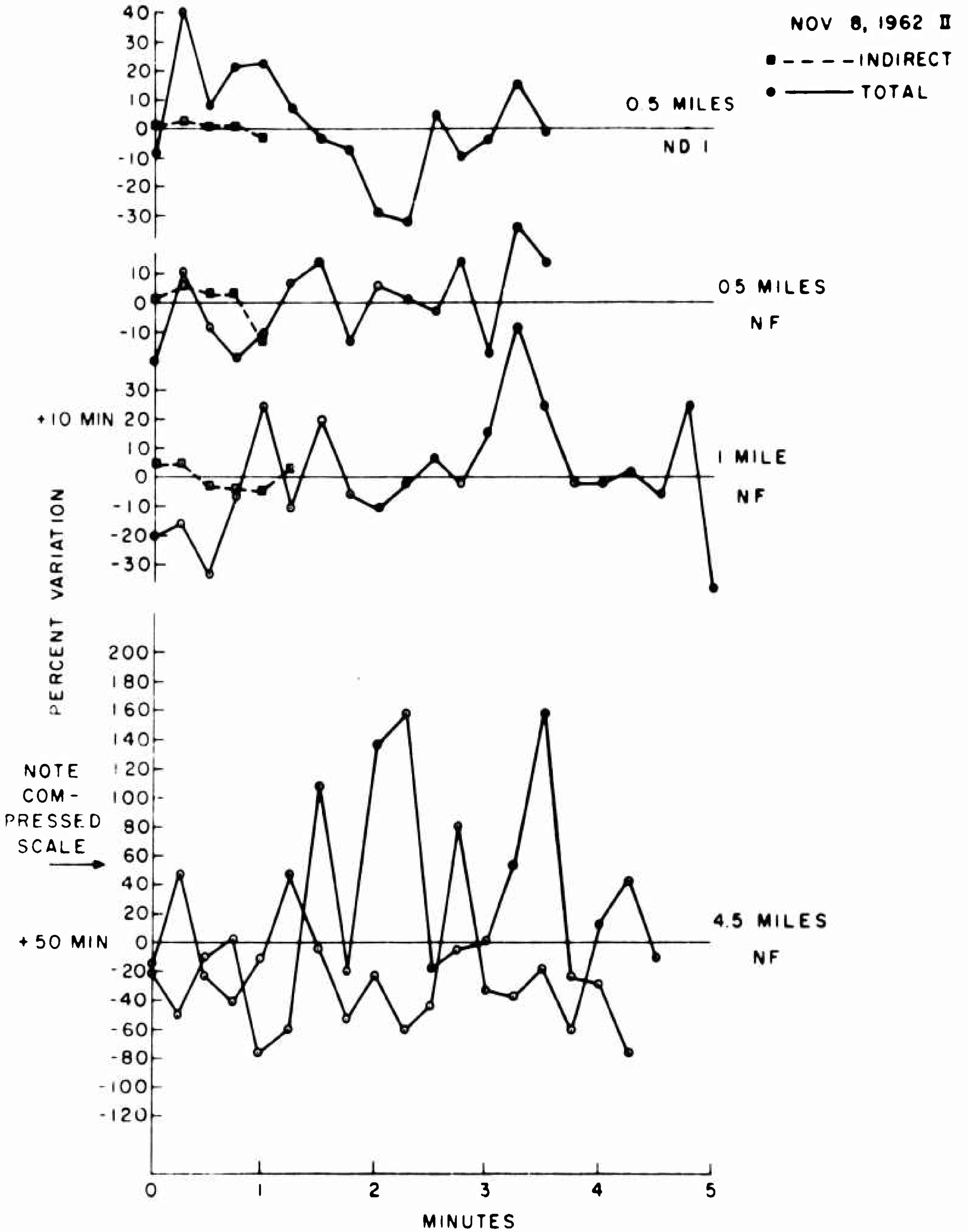


FIG. 30 (b) SIGNAL VARIATIONS vs TIME

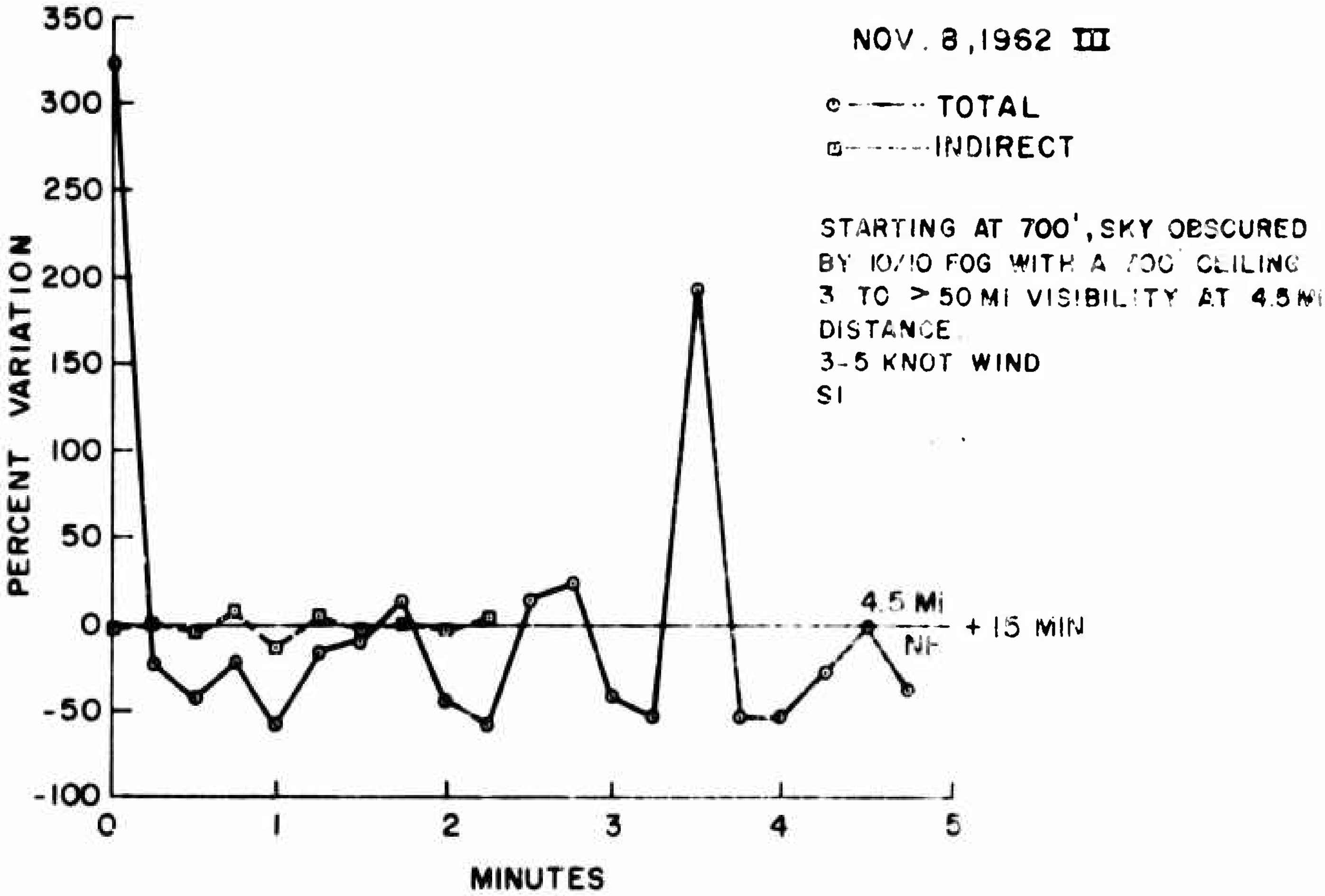


FIG. 30c. SIGNAL VARIATION VS TIME

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Results: 1. $H_{NF/0.13}$ = 0.42 (2335 hrs); σ D = 0.0065

2. $H_{NF/0.5}$ = 1.02 (σ 0.13 - 0.5)= 0.05/mi (2335-2350 hrs); σ D = 0.025

3. $H_{NF/1.0}$ = 1.55 (σ 0.5 - 1.0) = 1.1/mi (0006 hrs); σ D = 1.1

4. $H_{NF/4.5}$ = 0.36 (σ 1.0 - 4.5) = 0.12/mi (0006-0100 hrs); σ D = 0.54

5. No response above noise at 7.6 miles (0200 hrs)

Analysis: The wide variability of the direct attenuation coefficients and corresponding H values would seem to indicate the presence of scattered fog patches between the ground and light source at the 100-ft level. This variation in H would also be due, in part, to the variation in the fog ceiling.

Figure 31 indicates another unusual example of the indirect intensity dropping more rapidly with distance than the total so that the total transmittance, Fig. 32, becomes greater than the indirect transmittance at distances beyond about 2-1/4 miles. The total intensity is greater than the inverse square intensity to about two miles distance, beyond which the inverse square to total intensity ratio increases rapidly beyond unity. Figure 32 shows an increasingly lower indirect transmittance than total transmittance beyond about two miles.

Figure 33b indicates large maximum total intensity variations of +55% and -34% from the norm at 4.5 miles under visibility conditions of >50 miles and a temperature lapse rate or vertical temperature gradient between -1.4 to -1.6°C between the surface and 200 feet, and -1.9°C between the surface and 87 feet. One of the curves of Fig. 33b (+3 minute interval) indicates total variations with respect to two different norm values. It is interesting to note the much greater variation occurring the night before under similar visibility conditions, but a much steeper temperature vertical gradient of +13.5°C and +13.3°C between the surface and 200 feet and 87 feet, respectively. The maximum indirect variations of +12% and -20% from the norm occurred at 4.5 miles.

11 Nov 62, 0200-0300 hours, S-11 Response

Weather conditions: five-mile surface, estimated visibility in ice fog, with sky covered by 10/10 cirrostratus; low-level fog patches

temperature: -33 to -37°C

SSE winds, 5 to 6 knots

Results: 6292 photomultiplier tube, S-11 response, at 1000V, plus amplifier at 100 gain, employed at 4.5-mile site, but no signal nor flash was observed.

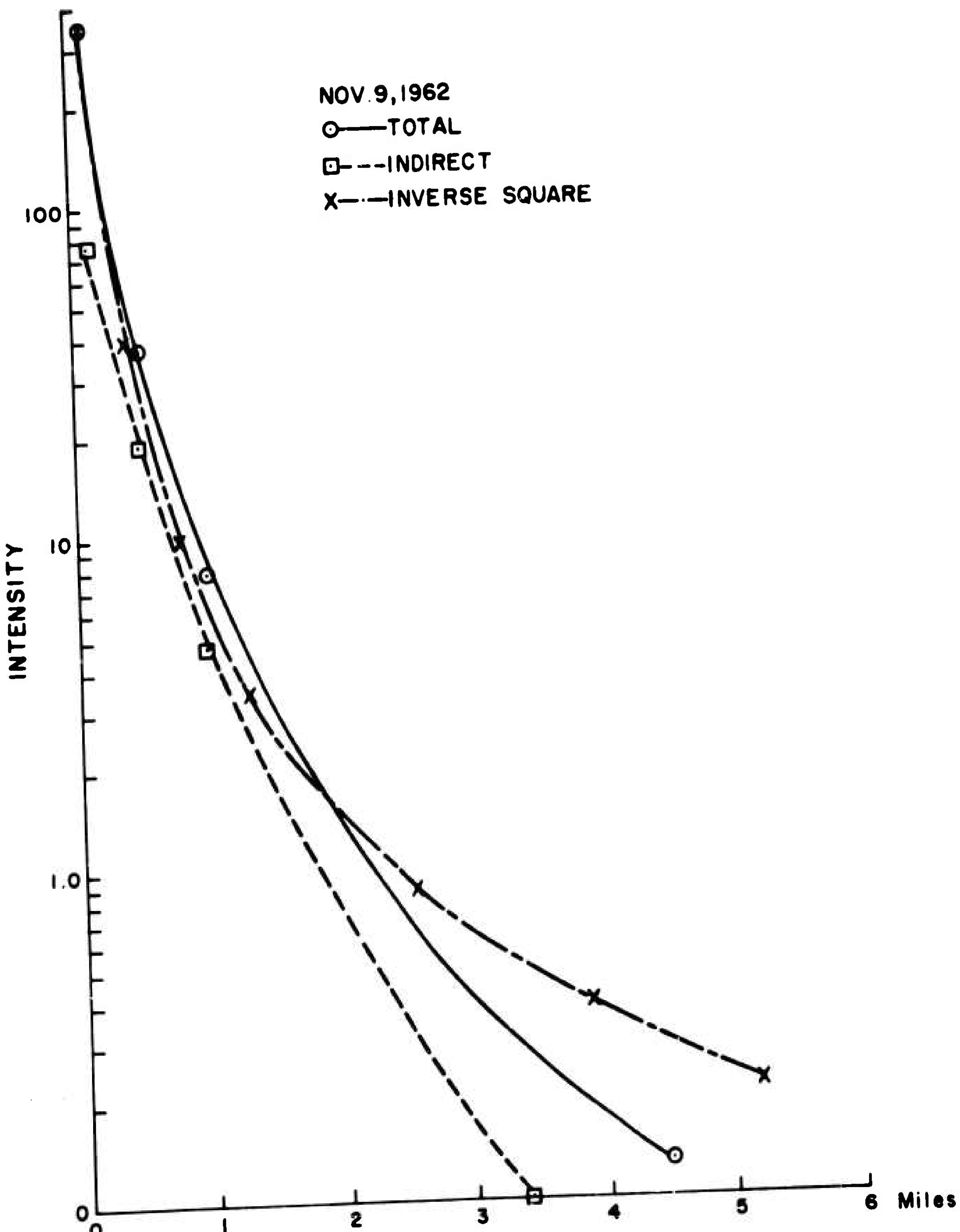


FIG. 31 INTENSITY VS DISTANCE

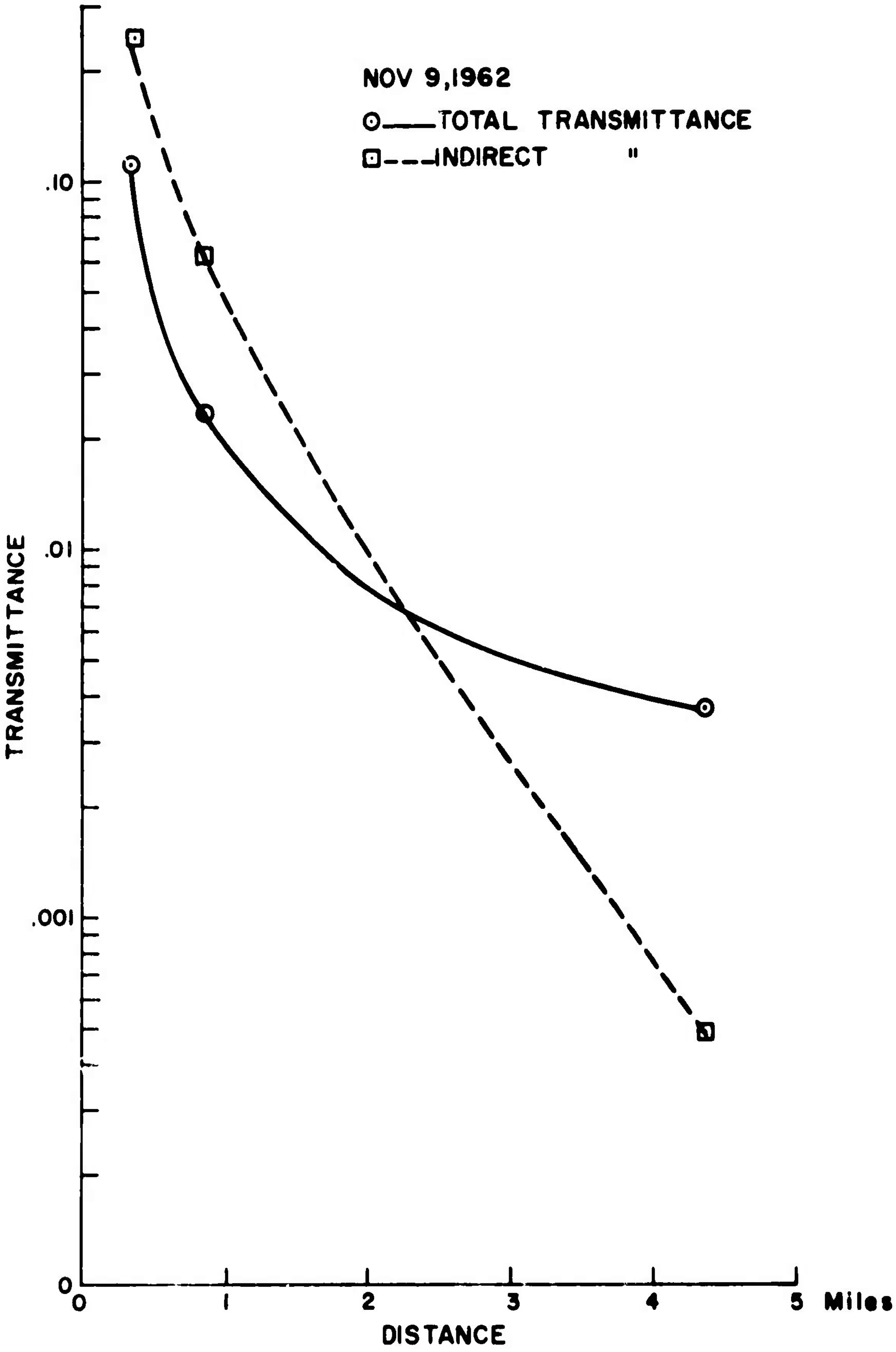


FIG. 32 TRANSMITTANCE VS DISTANCE

NOV. 9, 1962
STARTING AT 700', SKY OBSCURED BY 10/10 FOG WITH A 700' CEILING 3 TO > 50 Mi VISIBILITY AT 4.5 Mi DISTANCE.
3-5 KNOT WIND
SI

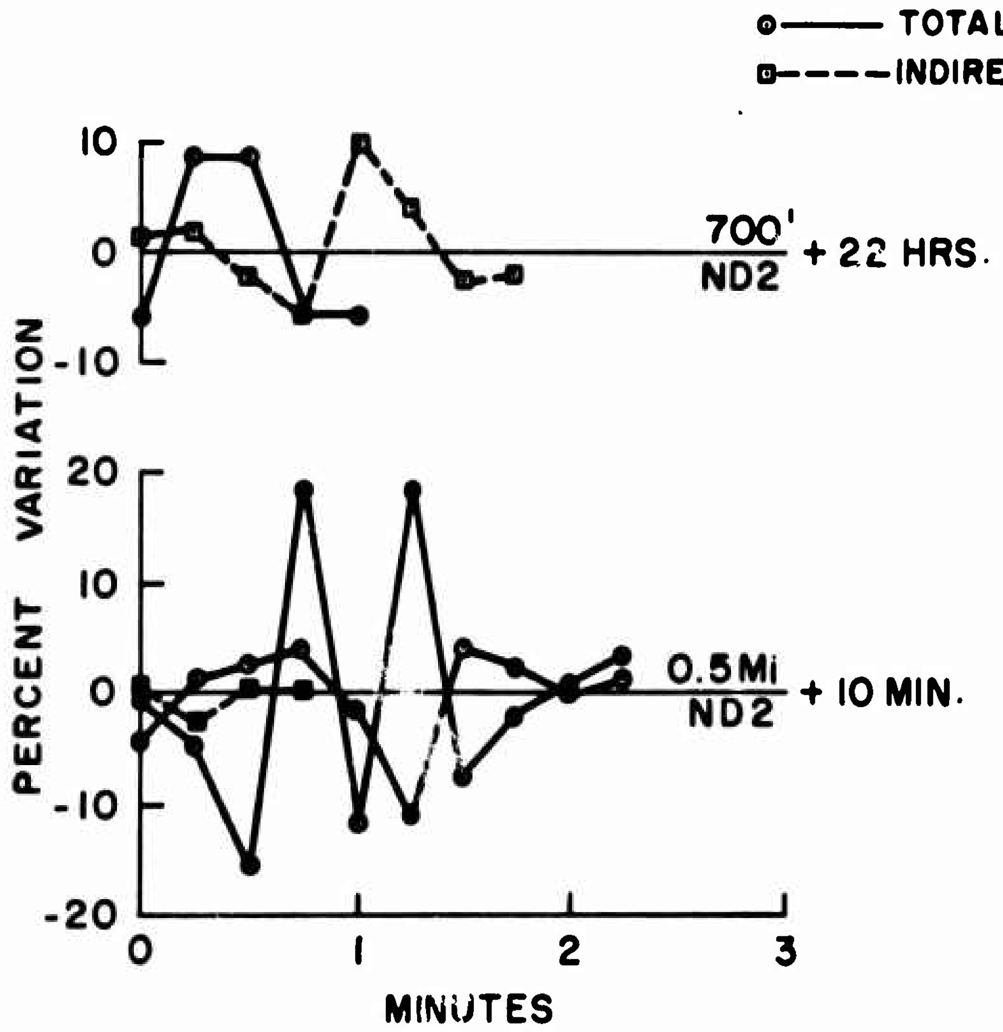


FIG. 33a. SIGNAL VARIATIONS VS TIME

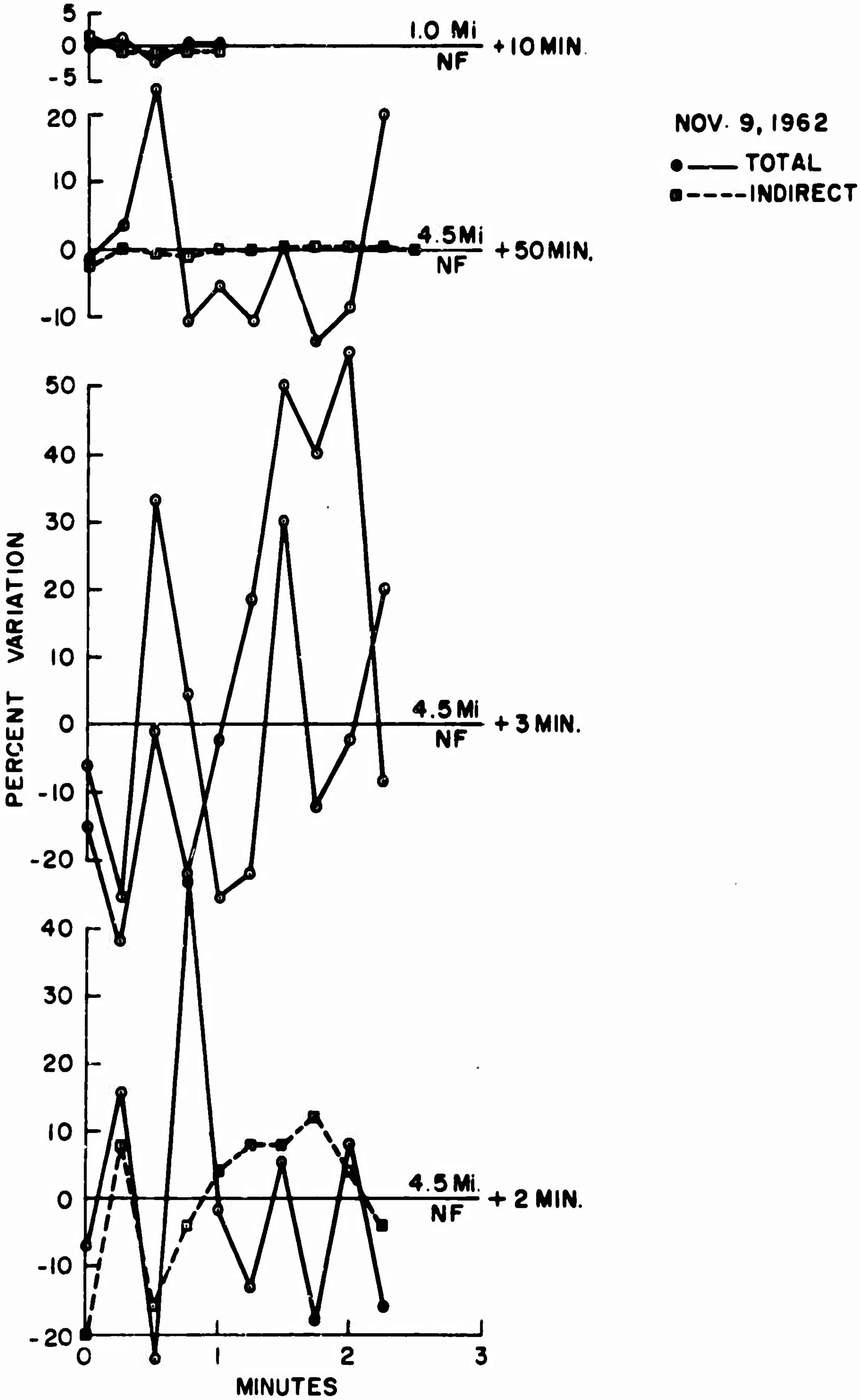


FIG. 33b SIGNAL VARIATIONS VS TIME

Analysis: Surface lights could be seen at a 4.5-mile distance. A ceiling balloon run indicated an unlimited ceiling, yet many thin stratus patches seemed to be present. A full moon was partially observed through cirrostratus. The light was left flashing until about 3/4 mile from Camp Century, and then only the indirect flash was observed. It seems reasonable, therefore, to conclude that the light source itself was surrounded by drifting fog patches.

<u>13 Nov 62, 0118-0548 hours, S-11 Response</u>

Weather conditions: varying scattered fog patches between Camp Century tower and 7.6-mile point, with about a 3000-ft overcast ceiling, and fog occasionally dropping to the 100-ft level

visibility ranging between 3/5 mile and unlimited; +0.3°C and -0.4°C gradient (vertical)

SSW surface winds at 8 knots

Some Personal Weather Observations: At 0.13 mile, the ground lights of the one-mile-long airstrip were clearly visible, while a slight corona was observed around the 750W incandescent tower light at the 200-ft level. At the 0.5-mile point there was a medium thick fog about the 200-ft light, while a weak corona was noted around the ground lights. At the one-mile point the top of the tower appeared clear during the first 35 readings and then became partially obscured by fog during the last five readings. About seven minutes later the tower lights at the 200-ft level and the 100W red-colored lights at the 100-ft level were barely visible. Five minutes later the tower lights became visible as the observers departed for the 4.5-mile wanigan.

At the 4.5-mile wanigan site, a full moon with about a $2\frac{1}{2}°$ corona diameter, as at the 0.13-mile point, was visible at an elevation of about 30 degrees to the SW. The 200-ft tower light was barely visible, and about 30 minutes later became invisible to the naked eye, while the reflected light of the light flash was still clearly visible. At the 7.5-mile point the light flash was no longer visible, while a $3\frac{1}{2}°$ corona diameter was observed and the wind had increased (11 knots reported by the Camp Century station).

Results: 1. $H_{NF}/0.13 = 0.60$, $\sigma D = 0.078$

2. $H_{NF}/0.5 = 4.0$ ($\sigma_{0.13 - 0.5} = 4.9$ mi); $\sigma D = 2.4$

$H_{NF}/0.5 = 1.68$ about 15 minutes later ($\sigma = 1.47$/mi); $\sigma D = 0.74$

3. $H_{NF}/1.0 = 0.97$, $\sigma_{0.5 - 1}$ mi negative

4. $H_{NF}/4.5 = 12.8$ ($\sigma_{1 - 4.5}$ mi $= 0.36$/mi); $\sigma D = 1.62$

Analysis: This is an example of the wide variability in the relationship between the direct and indirect light radiation as well as the direct attenuation coefficient as a result of the relatively rapid fog patch variations in the close vicinity of the light source.

The graphs of Fig. 34 indicate similar intensity variation with distance for the indirect and total radiation up to about one mile wherein the respective transmittances retain a significantly unchanged ratio from about 0.2 to 7.6 miles. The total intensity is significantly greater than the inverse square intensity between about 1 mile and 7 miles, which is probably indicative of good visibility and extensive cloud-cover situations on the Greenland icecap. Figure 35 depicts a somewhat more rapid decrease of total than indirect transmittance with distance beyond about the 1-mile point.

Figs. 36a-b indicate maximum total and indirect variations not exceeding about ±20% from the norm. Figure 36-b curves indicate indirect or total variations with respect to more than one subsequent norm value. The weather situation was such that analysis was extremely difficult in the presence of variable fog patches near 100 feet. This could well account for the indirect intensity 20% variations at 700 feet (0.13 mile). The temperature vertical gradient lay between +0.3°C and -0.4°C and 0.0°C and -0.7°C for the surface to 200-ft and 87-ft heights, respectively.

14 Nov 62, 0355-0757 hours, S-11 Response

Weather conditions: partly cloudy with 2-3/10 stratocumulus at about 2000 ft, scattered fog patches at about 200 ft, and variable high cloudiness (3 - 7/10 cirrostratus) becoming 8 - 9/10 stratocumulus at about 2500 ft with 1 - 2/10 low-level fog and ice fog towards the end of test at the 4.5-mile location

estimated visibility varying from about 1½ to 4 miles

-20°C in ice fog (between 0730 and 0800 hrs); +1.6°C to +3.5°C gradient

SE surface winds, 4 to 9 knots

Some Personal Weather Observations: At 0.13 mile at 0400 hours, light fog was observed drifting irregularly past the 200-ft tower lights. There were partly cloudy skies with a full moon to the SSW. At the 0.5-mile point at 0415 hours, the ground and tower lights appeared very clear. A thin halo of about 10 diameters appeared around the moon. At 0428 hours the 200-ft tower lights were still visible, but within some fog; while there was some halo around the surface lights. At 1.0 mile at 0450 hours the sky appeared clear except for the moon halo noted above and a thin fog around the surface and 100-ft tower lights. At about the 2-mile point at 0508 hours the tower lights at 200 feet were obscured by fog, while the surface and 100-ft lights appeared in the clear. At 0555 hours, at the 4.5-mile position, the moon was almost completely obscured by overcast, and neither the tower lights nor the light pulse was visible. Low cloudiness with scattered fog occurred between 0615 and 0757 hours.

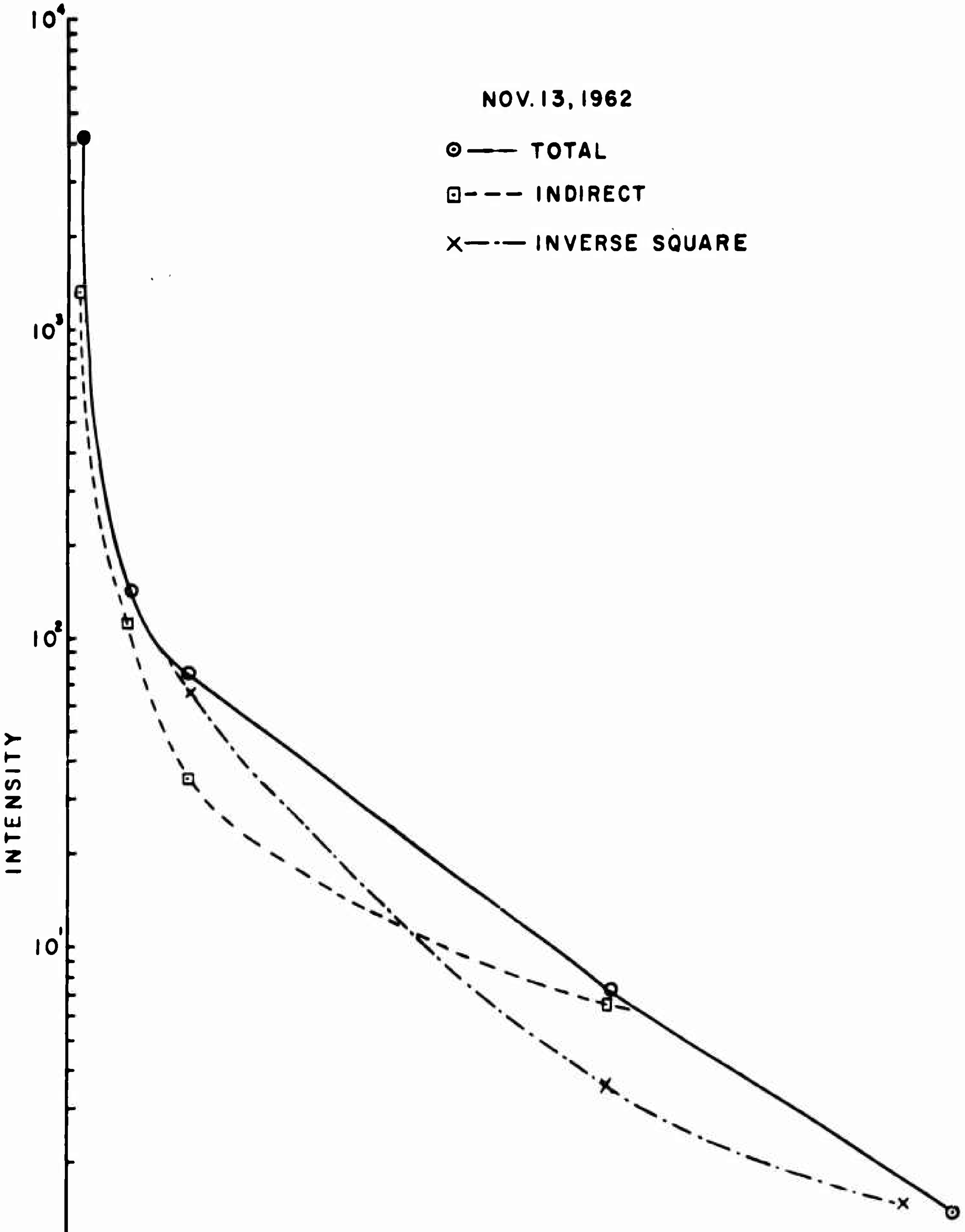


FIG. 34 INTENSITY VS DISTANCE

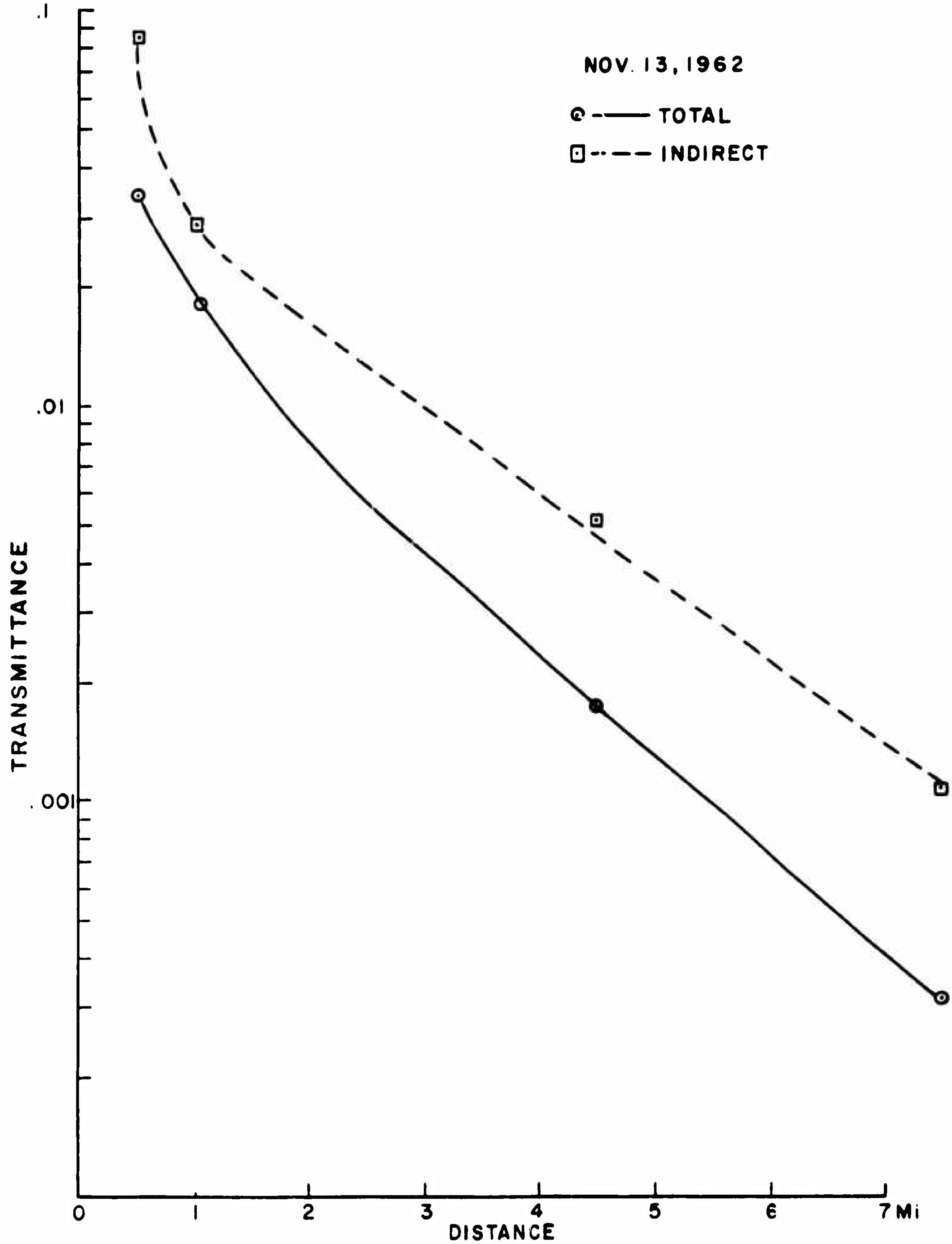


FIG. 35 TRANSMITTANCE VS DISTANCE

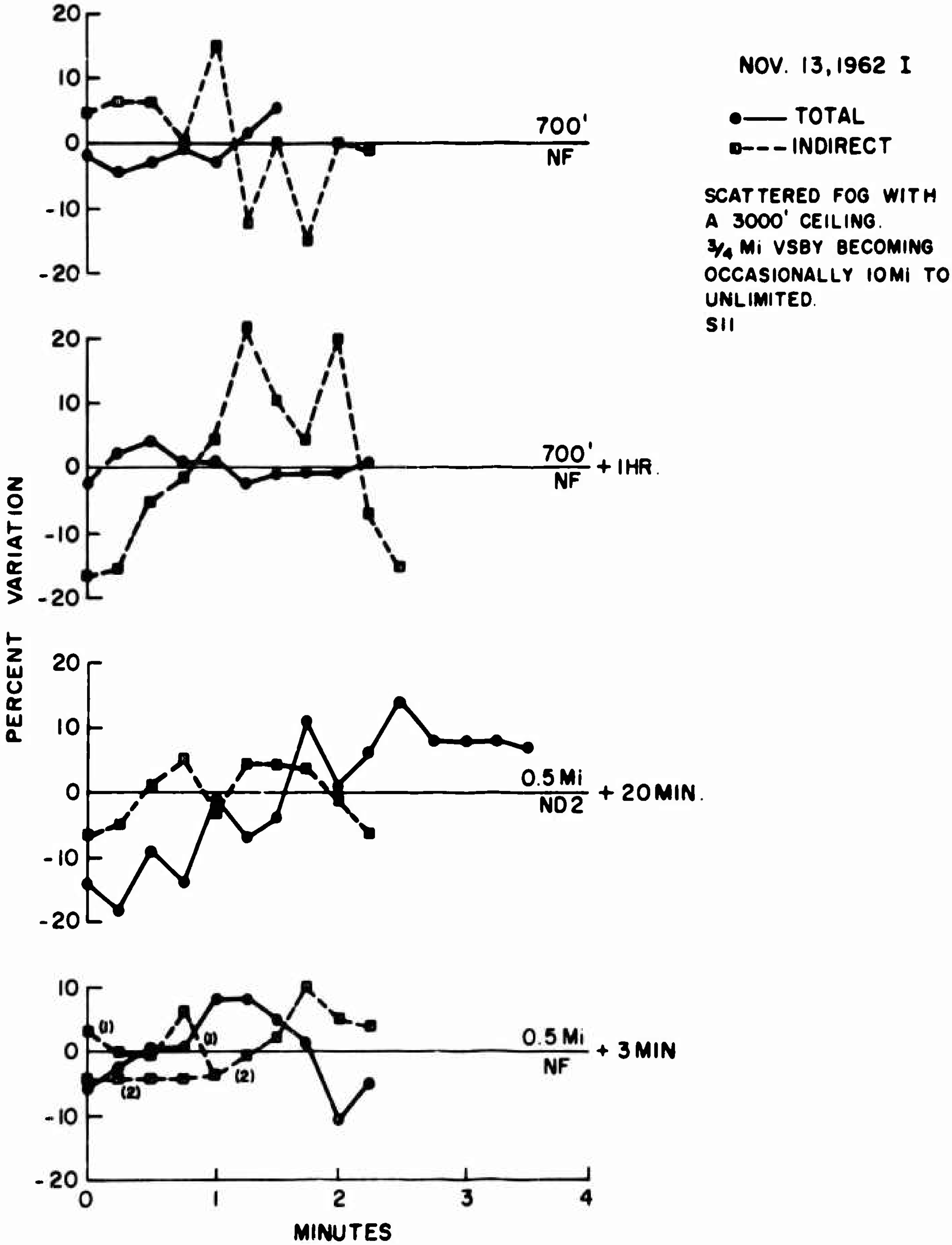


FIG. 36a SIGNAL VARIATIONS VS TIME

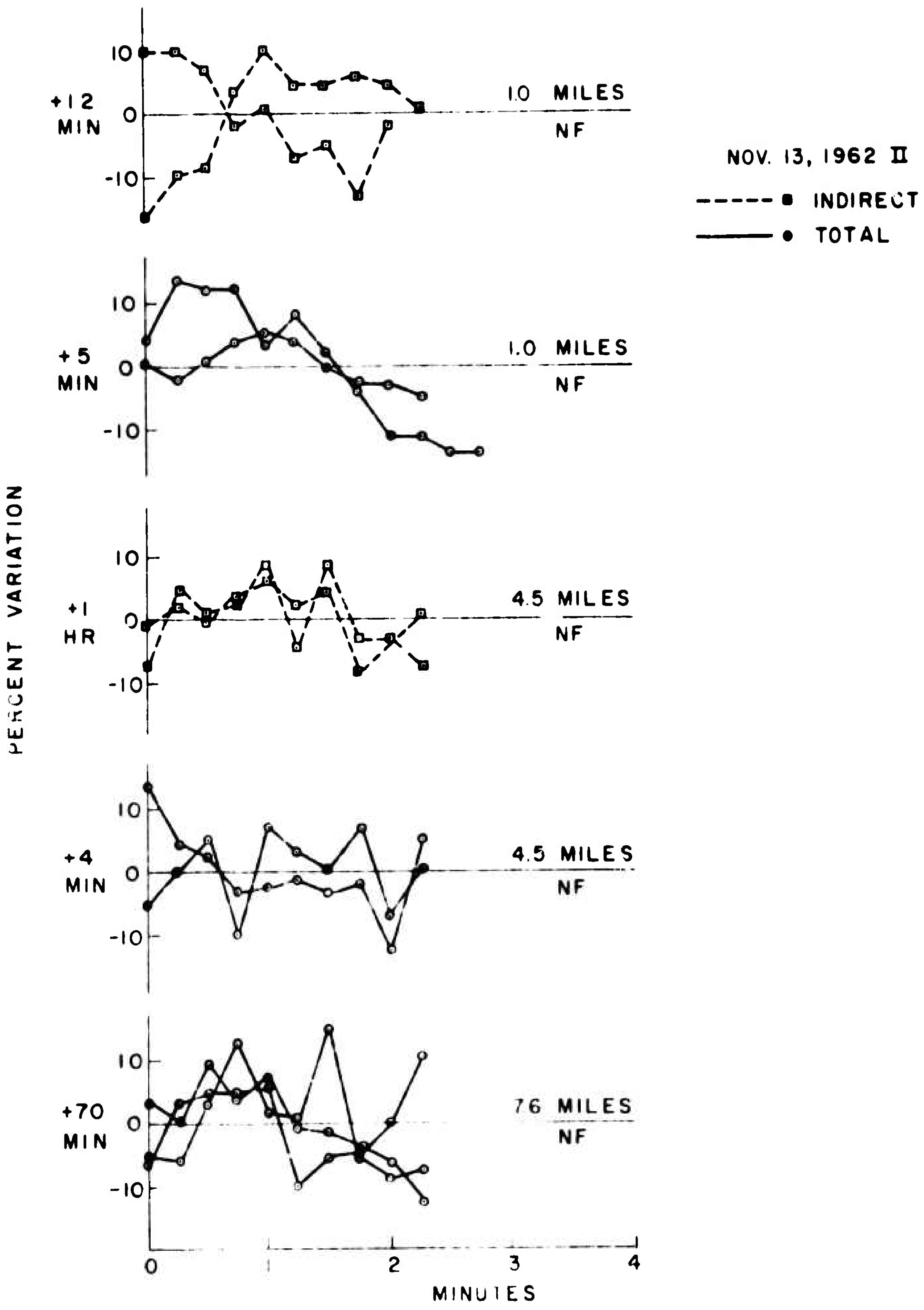


FIG. 36 (b) SIGNAL VARIATIONS vs TIME

Results: 1. $H_{NF}/0.13$ = 0.19 (0355-0400 hours); σ D = 0.42

2. $H_{NF}/0.5$ = 0.97 (0415-0430 hours), ($\sigma_{(0.13 - 0.5)}$ = 2.2/mi); σ D = 1.1

3. $H_{NF}/1.0$ = 1.07 (0442-0451 hours), ($\sigma_{(0.7 - 1.0)}$ = 0.68/mi); σ D = 0.68

4. Total intensity, NF, unchanged at the 4.5-mile point for at least six minutes (0600 to 0606) by 60% about 90 minutes later, i.e., 0736 hours

Analysis: Figure 37 shows the total intensity decreasing at a faster rate than the indirect for the initial 0.5-mile distance. The rate of decrease is almost identical between about 0.5 and 1 mile. The inverse square/total intensity increases gradually from 1 to 2½ in the first two miles and becomes almost a constant of 4 at three miles and beyond.

The indirect transmittance drops less rapidly with distance than the total transmittance, as shown in Fig. 38.

At the 0.5-mile point the original data indicated an increase of the indirect intensity by about 40% because of the appearance of increasing fog patches near the 200-ft level. This increase occurred in about 10 minutes. At the 4.5-mile point a 60% increase of the total intensity occurred in about 90 minutes, during which time a low overcast at about 2500 feet and scattered ice fog patches occurred.

Figure 39 indicates relatively small variations, with a maximum of +15% from the norm for the indirect and slightly less for the total intensity. However, fog conditions near the 100-ft level complicated analysis. The vertical temperature gradient between +1.6°C and +3.5°C, and +2.1°C and +0.8°C, prevailed between the surface to 200-ft and 87-ft levels, respectively.

<u>15 Nov 62, 0147-0826 hours, S-11 and S-1 Photomultiplier Response</u>

Weather conditions: broken to overcast stratocumulus at about 2000 ft, with thin scattered and varying ground fog patches from surface to at least 200 ft from 0140 to 0315 hours, remaining broken to overcast at about 2000 feet with < 1/10 scattered ground-fog patches by 0345 and remaining so until end of test period

variable visibility from about 3 to 15 miles until 0300 hours, becoming unlimited by 0330 hours; +0.9°C to +3.3°C gradient (vertical)

E-ESE winds, 2 to 6 knots

Some Personal Weather Observations: At 0.13 mile at 0200 hours, a 3½ degree corona was observed around a three-quarter moon. The 100-ft and 200-ft tower

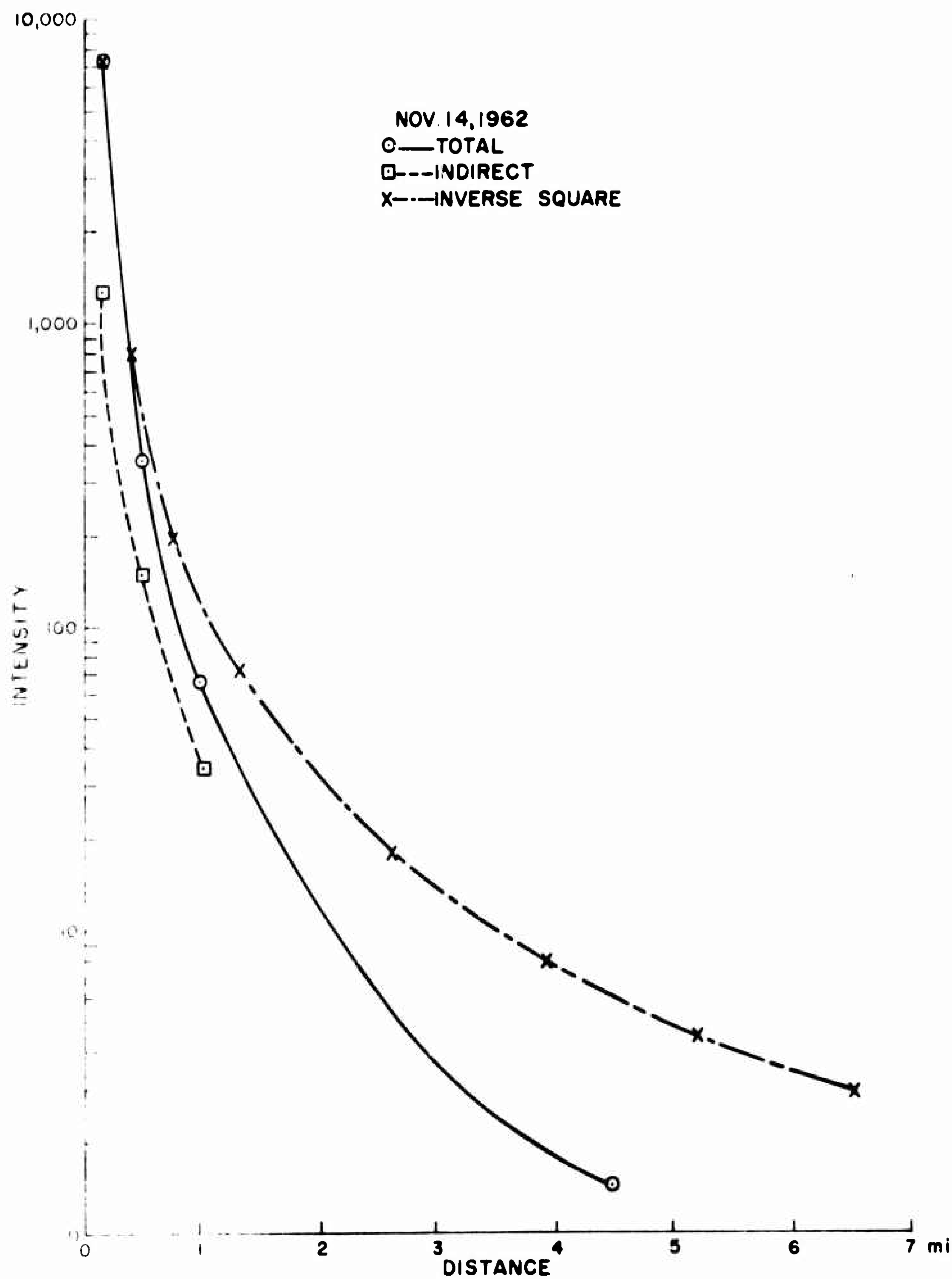


FIG. 37 INTENSITY VS DISTANCE

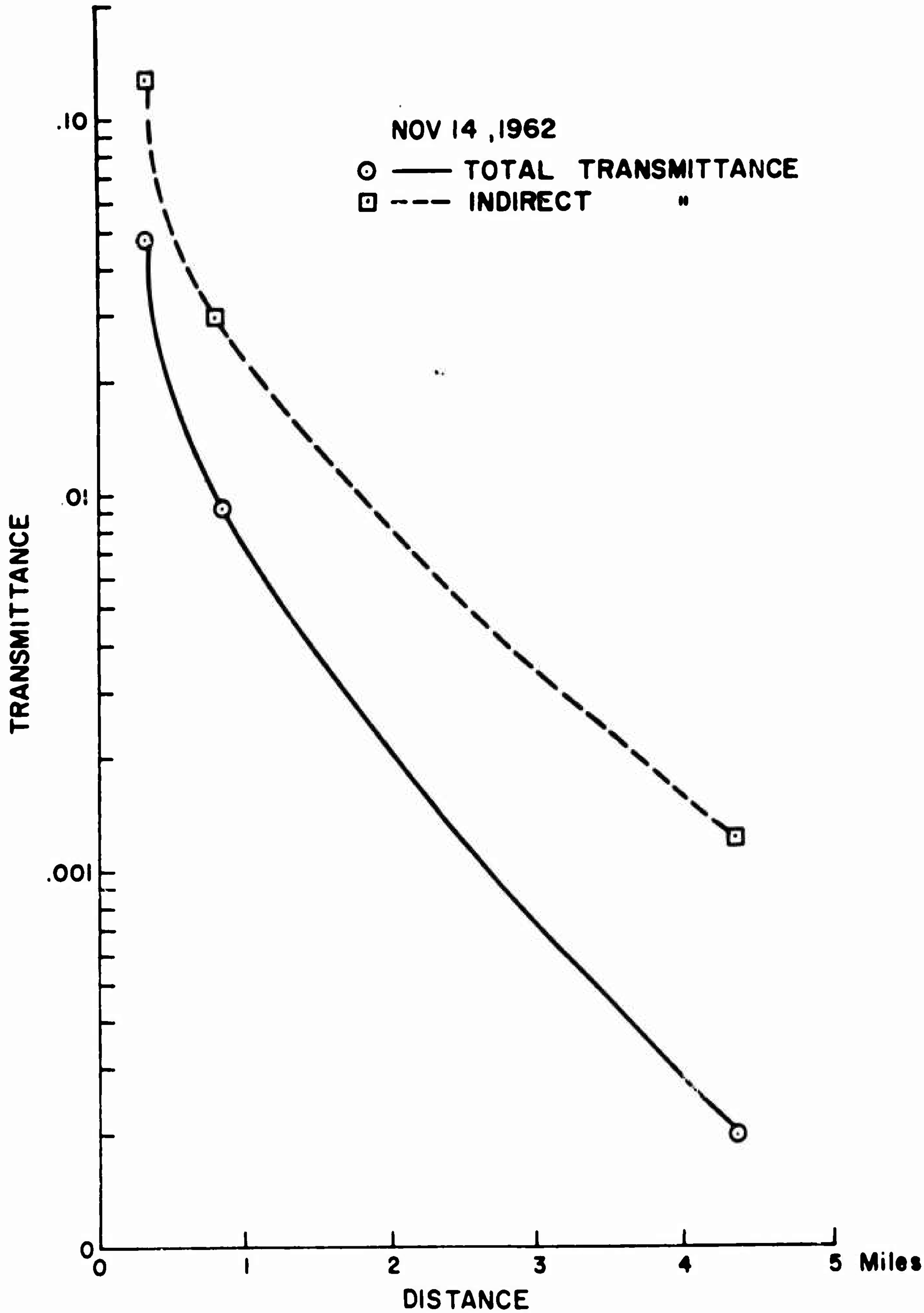


FIG. 38 TRANSMITTANCE VS DISTANCE

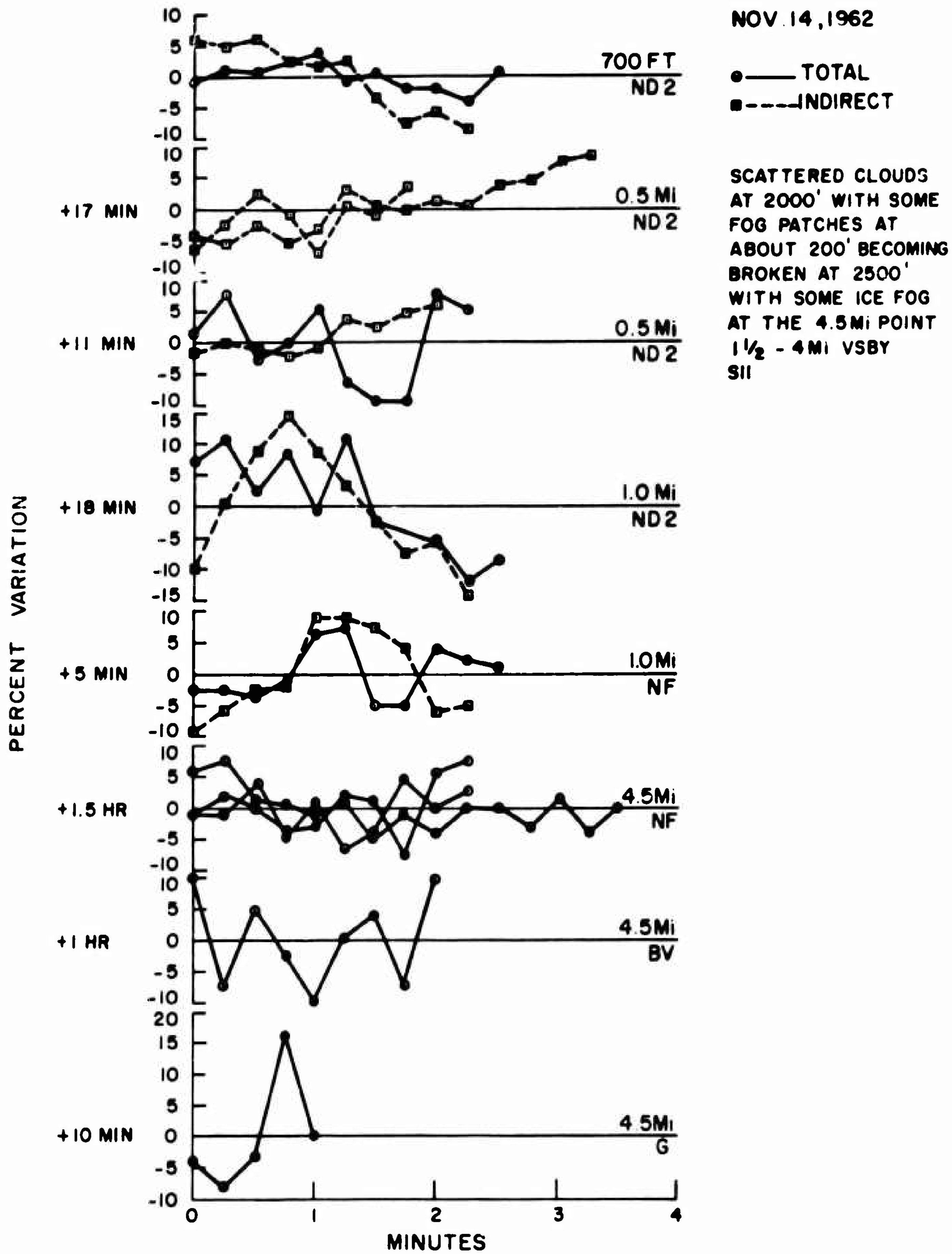


FIG. 39 SIGNAL VARIATIONS VS TIME

lights were clearly visible. The sky was overcast at 0.5 mile at 0300 hour the 200-ft and the 100-ft tower lights were in very thin fog, while the surface lights were clearly visible. The sky was overcast at one mile at 0400 hours; an approximately 7-diameter halo still appeared around the moon. The surface and tower lights were clearly visible with the skies cloudy. All lights appeared very clear between 0500 and 0800 hours at 4.5 miles, while the light pulses seemed noticeably reflecting from a low cloud deck.

At 0147 hours, no lights nor the direct flash was visible from the 4.5-mile fixed wanigan position, while at 0155 hours the surface lights were visible. At 0204 hours, both surface lights became visible; and at 0212 hours, all tower lights became clearly visible. The tower lights were no longer visible at 0253 hours, and by 0310 hours the tower and surface lights became obscured until about 0330 hours when all lights became visible, and broken low clouds were observed.

Results: 1. S-11: $H_{NF}/0.5 = 0.95$; $\sigma D = 0.09$

$H_{NF}/4.5 = 8.0$; $\sigma D = 0.81$

$(c_{(0.6 - 4.5)} = 0.18$/mi at 0250 hrs)

(simultaneous measurements at 0.5 and 4.5 mi)

2. S-11: $H_{NF}/1.0 = 0.35$

$H_{NF}/4.5 = 1.45$

$\sigma_{(1 - 4.5)}$ is negative at 0330 hours

(simultaneous measurements at 1 and 4.5 mi)

3. At 4.5 mi with S-11 Photomultiplier No. 1 Response (RCA 5819):

0208 hrs: $H_{NF} = 3.4$
0231 hrs: $H_B = 0.97$
0248 hrs: $H_{NF} = 8.0$
0318 hrs: $H_{NF} = \infty$, i.e., all indirect
0334 hrs: $H_{NF} = 1.45$
0503 hrs: $H_{NF} = 1.02$
0520 hrs: $H_B = 1.05$
0533 hrs: $H_B = 0.86$
0546 hrs: $H_R = 1.1$
0600 hrs: $H_{NF} = 1.25$

4. At 4.5 mi with S-11 Photomultiplier No. 2 Response (Dument 6292):

0503 hrs: $H_{NF} = 0.72$
0524 hrs: $H_B = 1.1$
0546 hrs: $H_B = 1.2$
0605 hrs: No response in the red region

5. At 4.5 mi with S-1 Photomultiplier No. 1 Response (Dumont 6911):

0715 hrs: $H_{NF} = 0.75$
0732 hrs: $H_B + IR = 0.61$
0752 hrs: $H_G + IR = 0.57$
0804 hrs: $H_R + IR = 0.67$
0819 hrs: $H_{IR} = 0.25$

6. At 4.5 mi with S-1 Photomultiplier No. 2 Response (Dumont 6911):

0718 hrs: $H_{NF} = 0.83$
0736 hrs: $H_B + IR = 0.97$
0747 hrs: $H_G + IR = 0.42$
0755 hrs: $HR + IR = 0.88$
0808 hrs: $H_{IR} = 0.60$
0824 hrs: $H_{NF} = 0.77$

Analysis: Figure 12 shows a ratio of indirect/direct, i.e., H factor, of greater than 8 for an optical depth of 0.81 with about a 2000-ft overcast and surface albedo of 1 as compared to the H value of 0.45 for the same optical depth locally (with 1.9 range) with about a 0.2 surface albedo and light hazy atmosphere. The total inverse square intensity decreases more rapidly with distance than either the total or indirect intensity beyond a distance of about one mile, as shown in Fig. 40, indicating a duct effect. However, when it is obvious that the visibility is low at the close-to-source distances and high at the greater distances, "duct effects" can be erroneously deduced.

The total transmittance in Fig. 41 decreases at a less rapid rate than the indirect transmittance for about the first mile, and the reverse becomes evident beyond one mile so that the indirect transmittance becomes slowly asymptotic between 1 and 4.5 miles.

The variability of H is apparently due to the relatively rapidly varying visibility and cloud factors as well as the atmospheric scintillation effects as noted in Figs. 42a-k. The variation of H_{NF} at 0503 hours may be due to the rounding off of the time to the nearest minute when there was actually a finite time difference of perhaps 1/2 minute. A contribution may also result in this case from a difference in the spectral response curves for the Dumont photomultiplier (S-11 response), i.e., the Dumont 6292 as compared to the RCA photomultiplier (S-11 response), i.e., the RCA 5819. The latter was used at the time when the available Dumont photomultiplier tube suddenly became inoperative.

Fog conditions in the vicinity of the 100-ft tower level, until about 0330 hours, complicated analysis. However, after 0330 hours the visibility improved to unlimited, and it is noteworthy that the graphs obtained from data recorded after 0400 hours show a generally sharp increase in the fluctuation magnitudes. Maximum total intensity variations of +160% and -55% from the norm appear in Fig. 42-d, with the average close to 40%. There appears to be no significant percent changes of fluctuation magnitudes due to wavelength in all cases; i.e., percentage fluctuation magnitude changes appear to

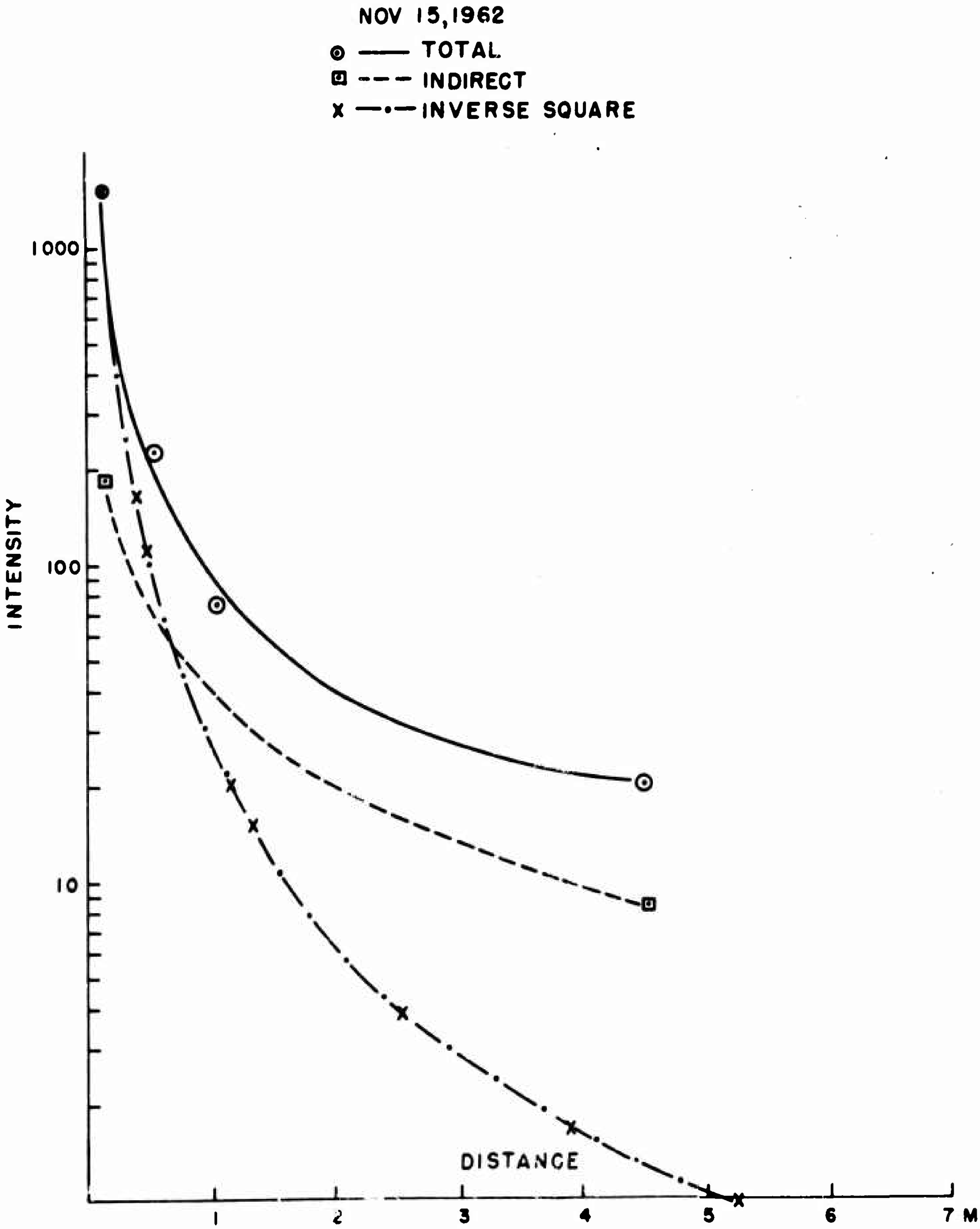


FIG. 40 INTENSITY VS DISTANCE

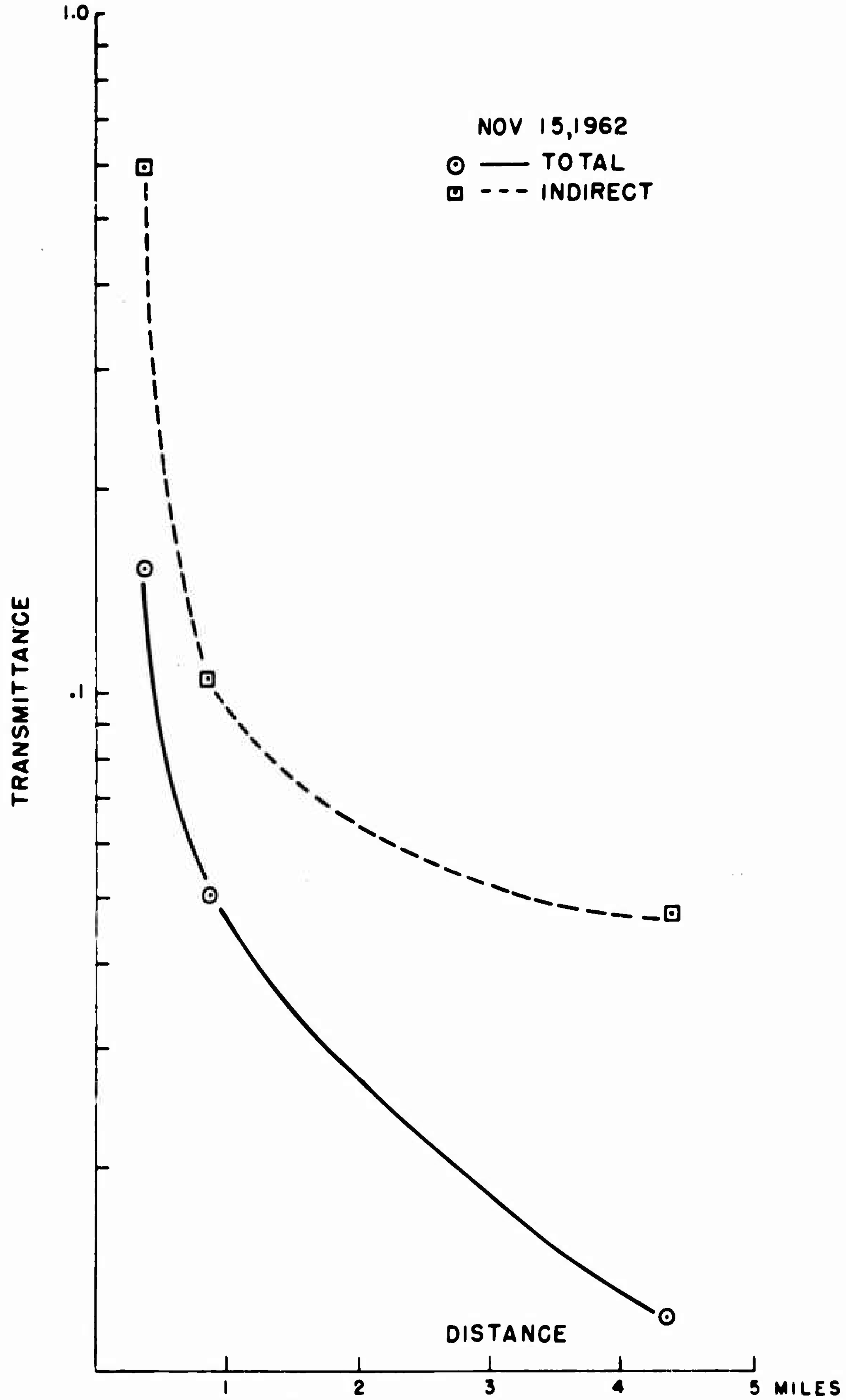


FIG. 41 TRANSMITTANCE VS DISTANCE

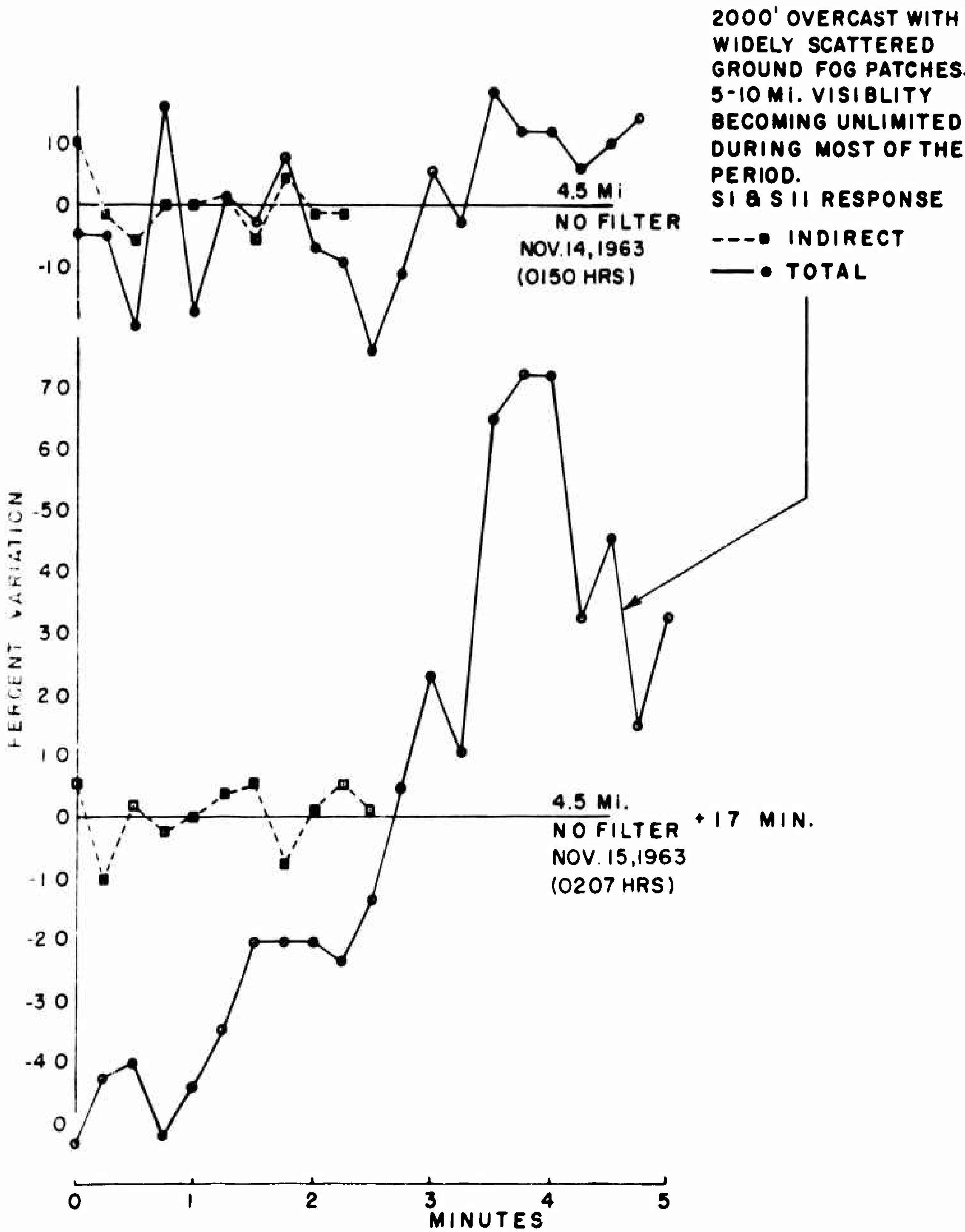


FIG. 42 (a) SIGNAL VARIATIONS VS TIME

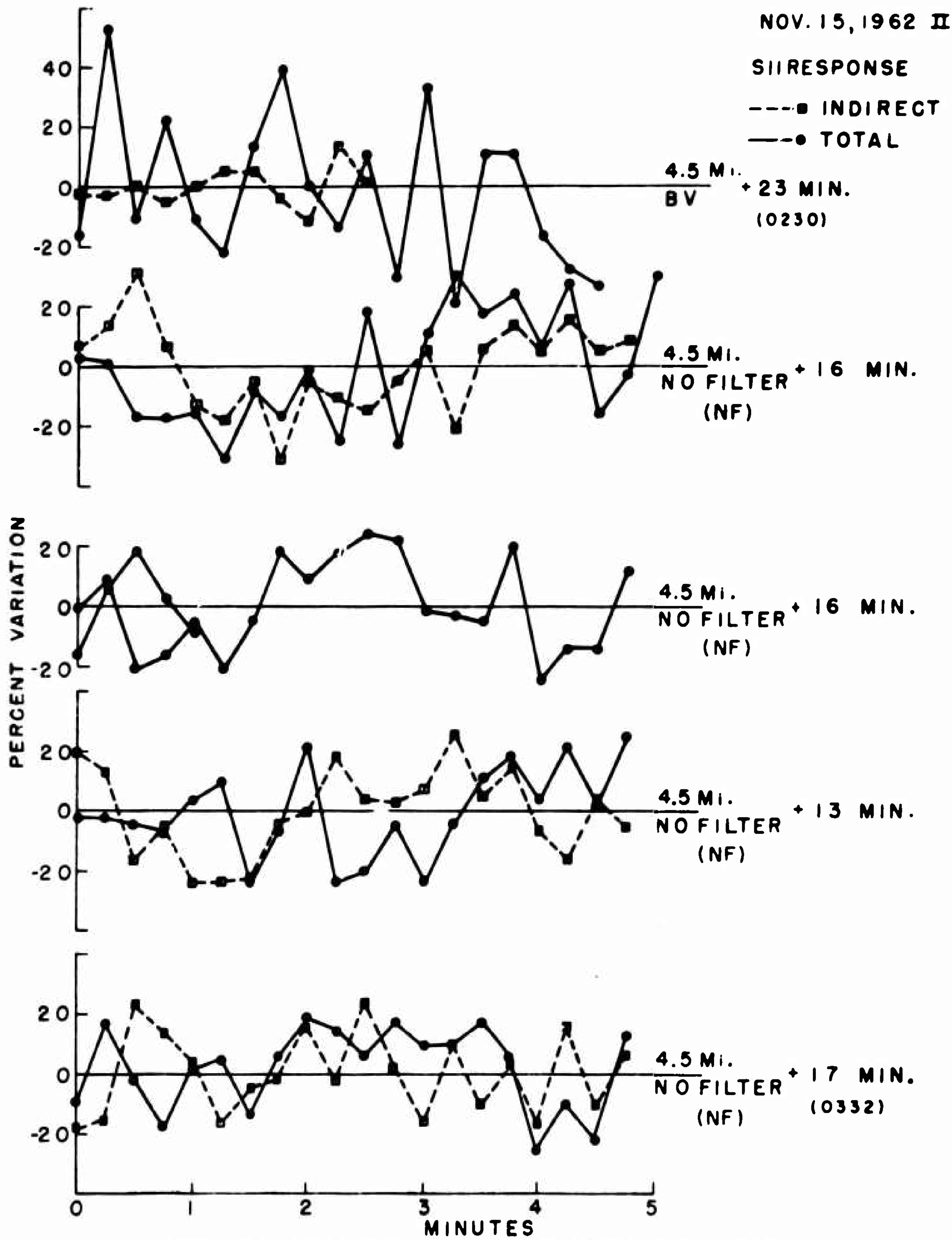


FIG. 42 (b) SIGNAL VARIATIONS vs TIME

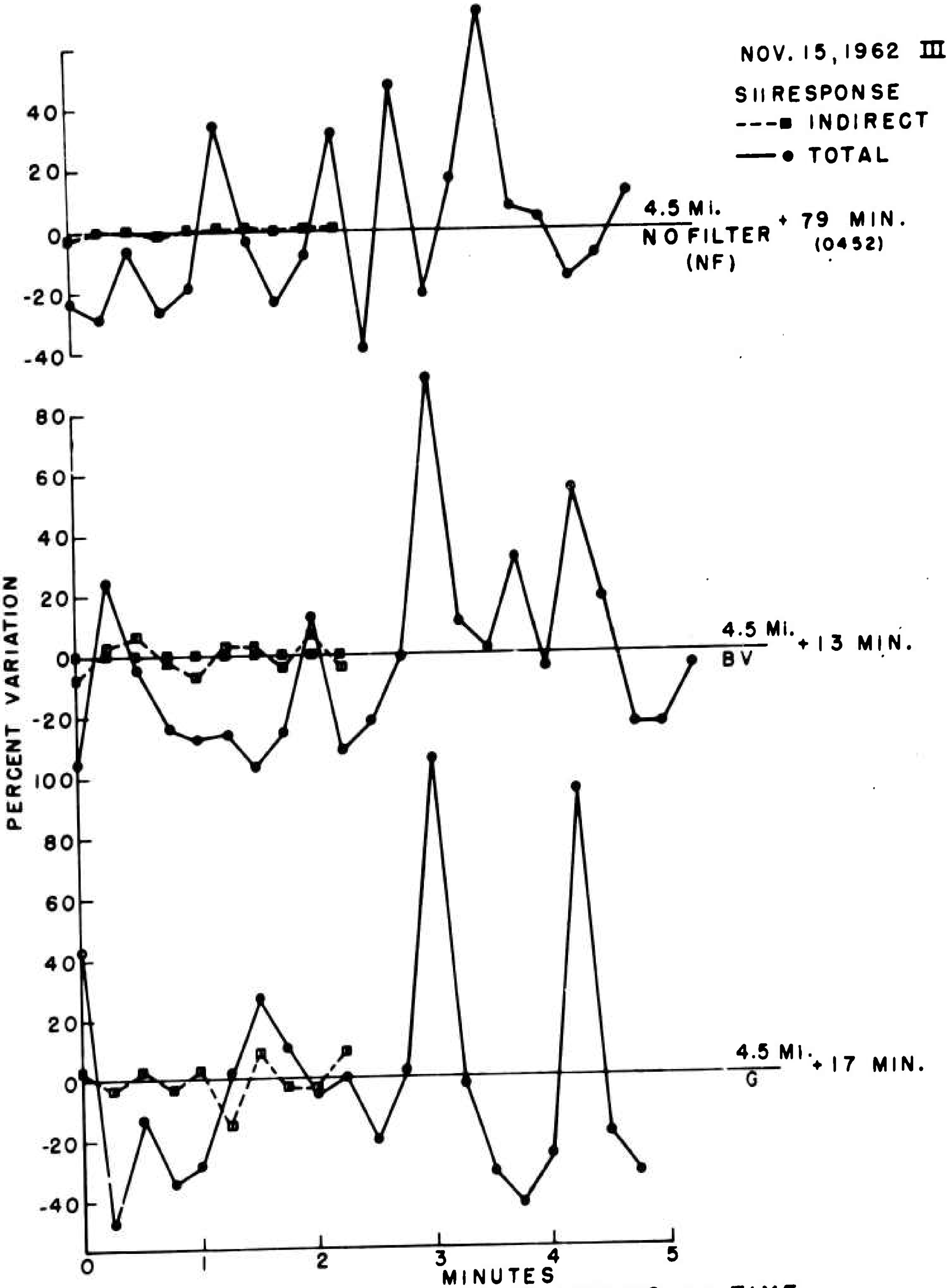


FIG. 42 (c) SIGNAL VARIATIONS VS TIME

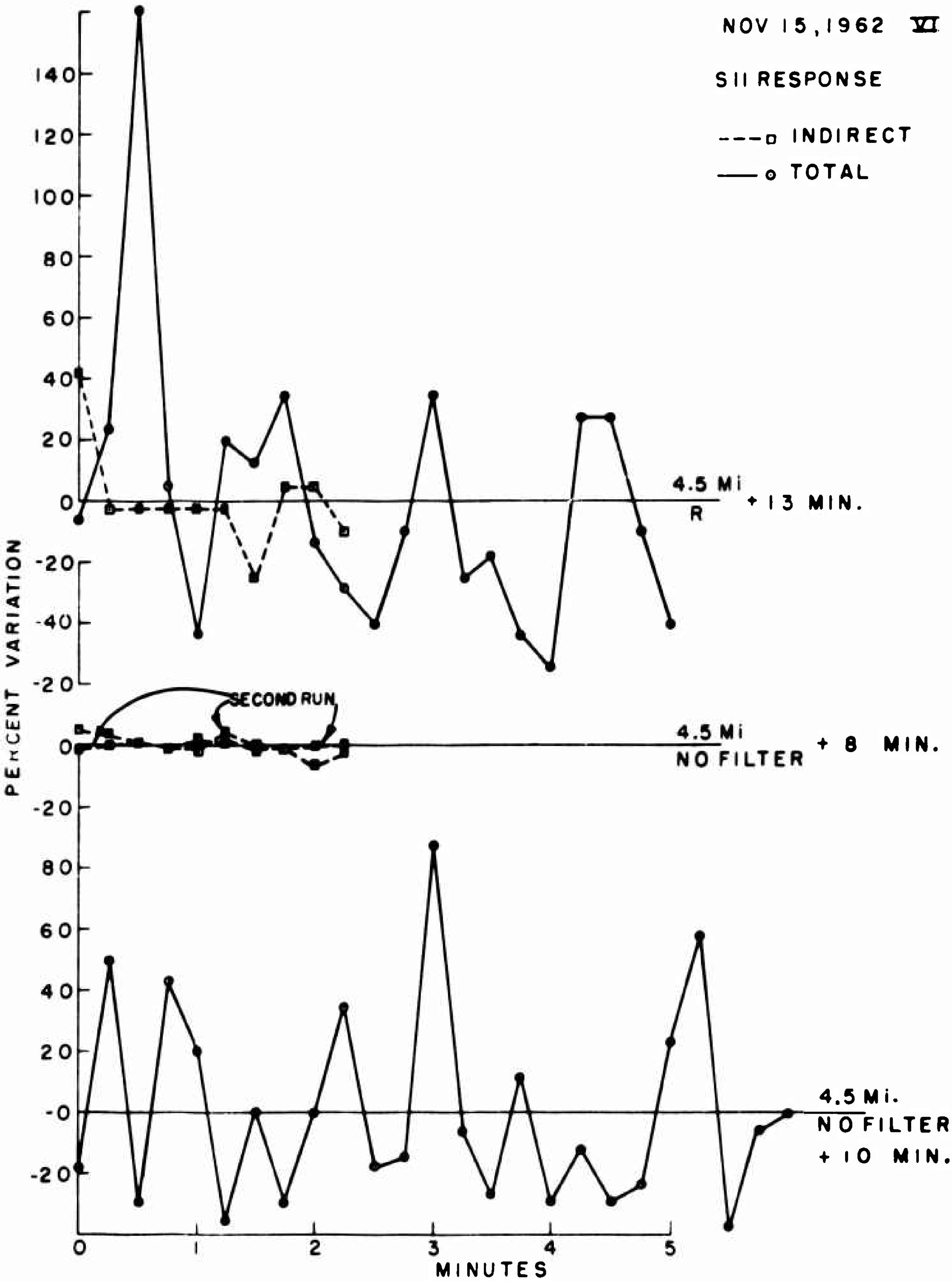


FIG. 42 (d) SIGNAL VARIATIONS VS TIME

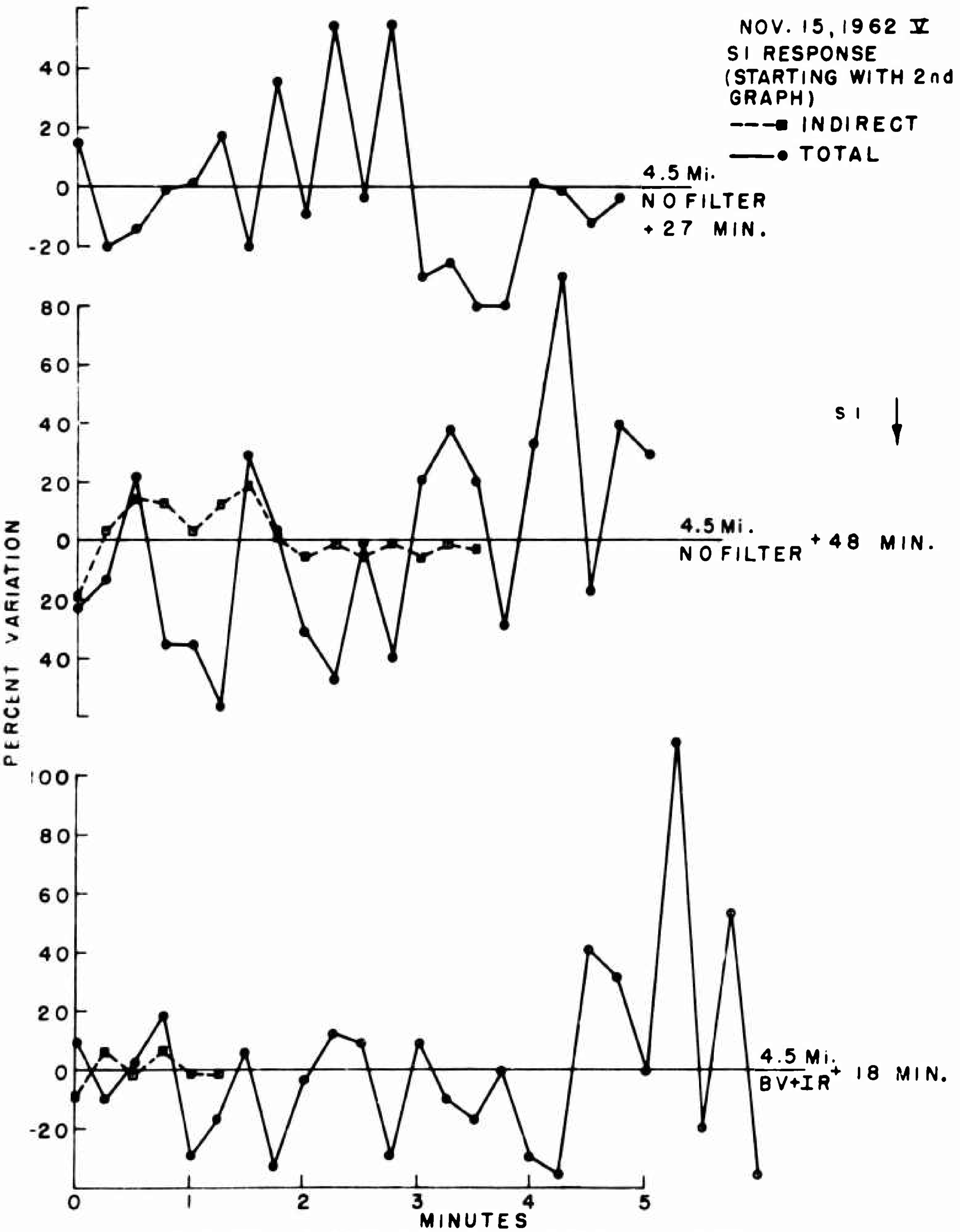


FIG. 42 (e) SIGNAL VARIATIONS VS TIME

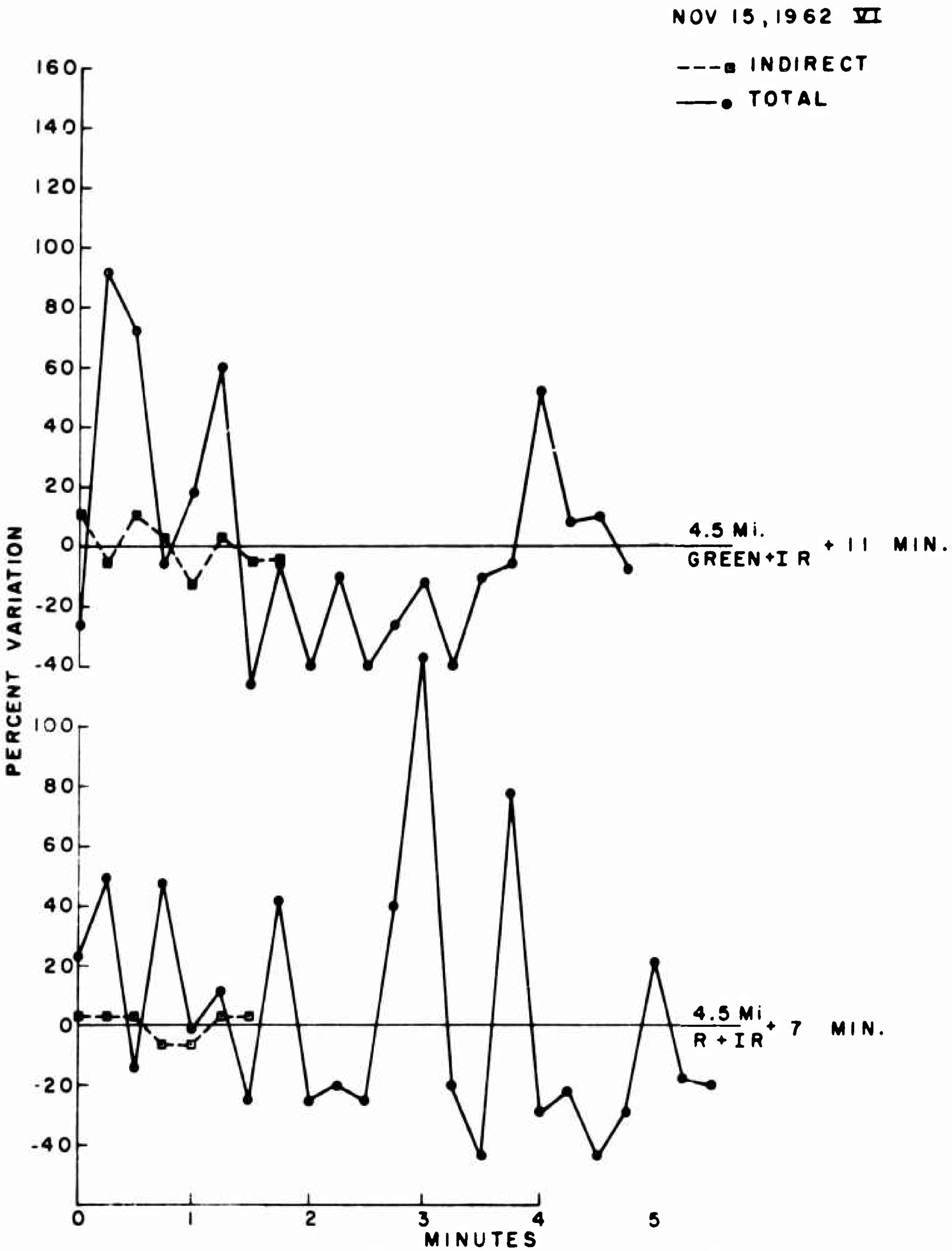


FIG. 42 (f) SIGNAL VARIATIONS VS TIME

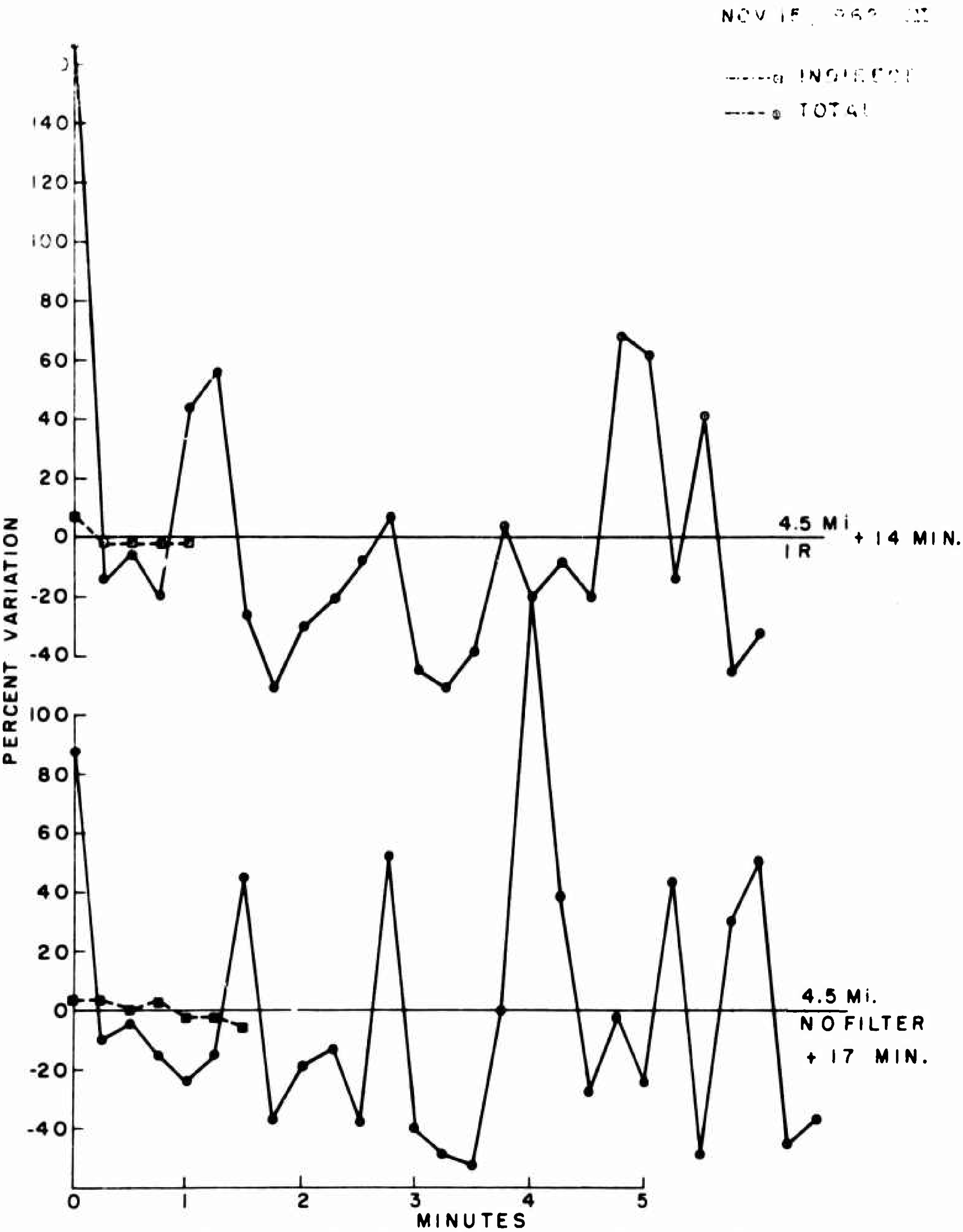


FIG. 42 (g) SIGNAL VARIATIONS VS TIME

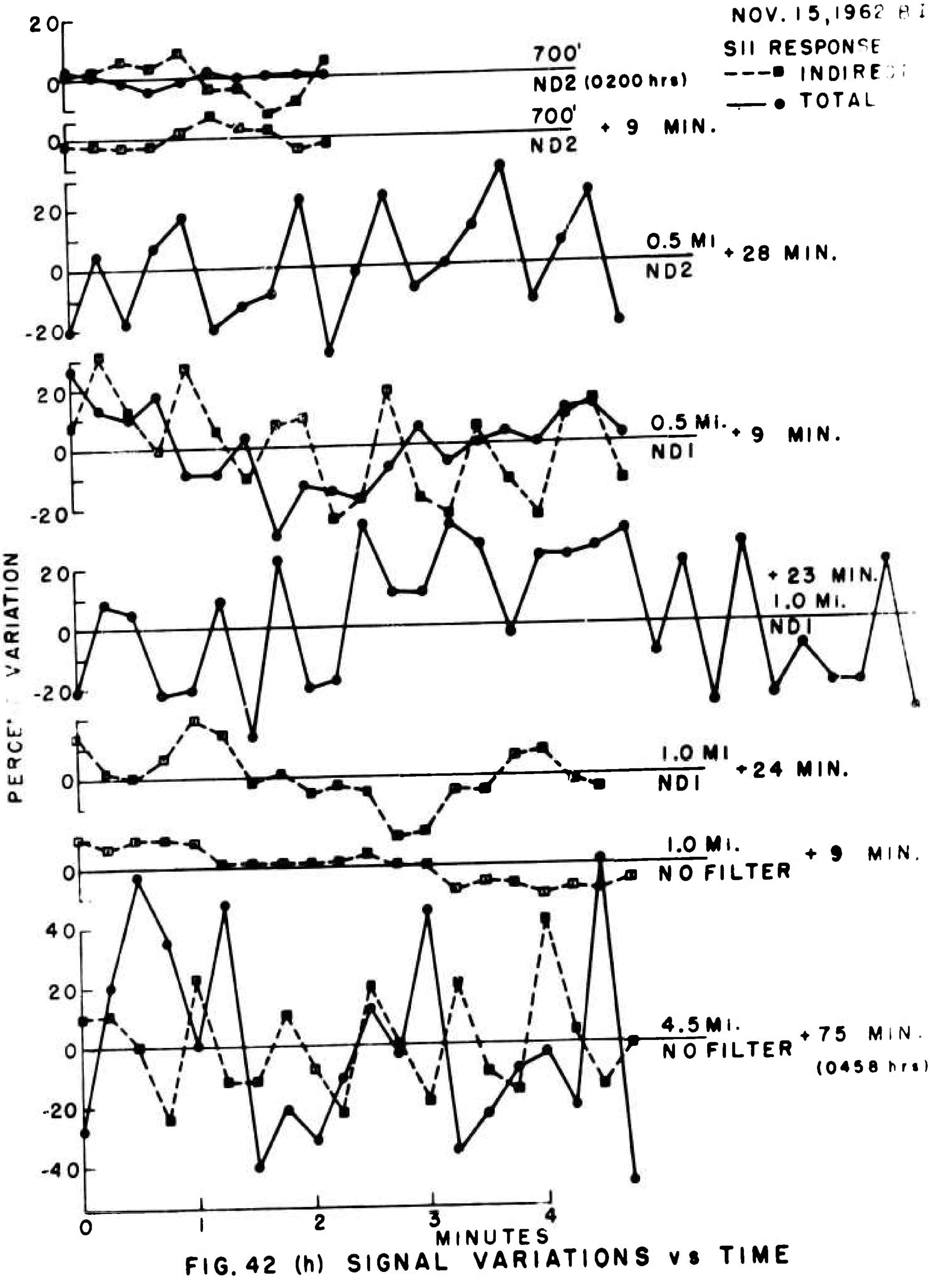


FIG. 42 (h) SIGNAL VARIATIONS vs TIME

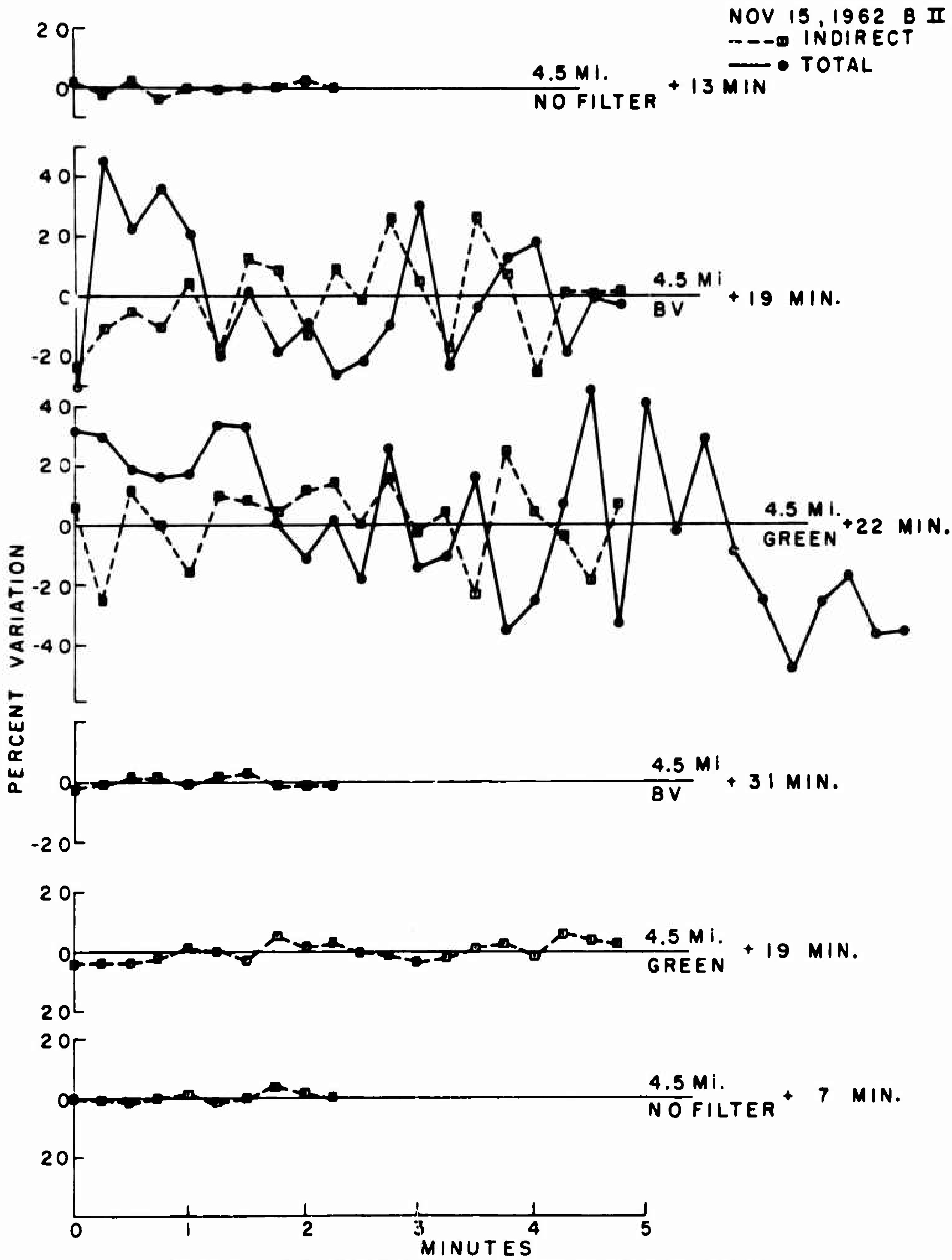


FIG. 42 (I) SIGNAL VARIATIONS VS TIME

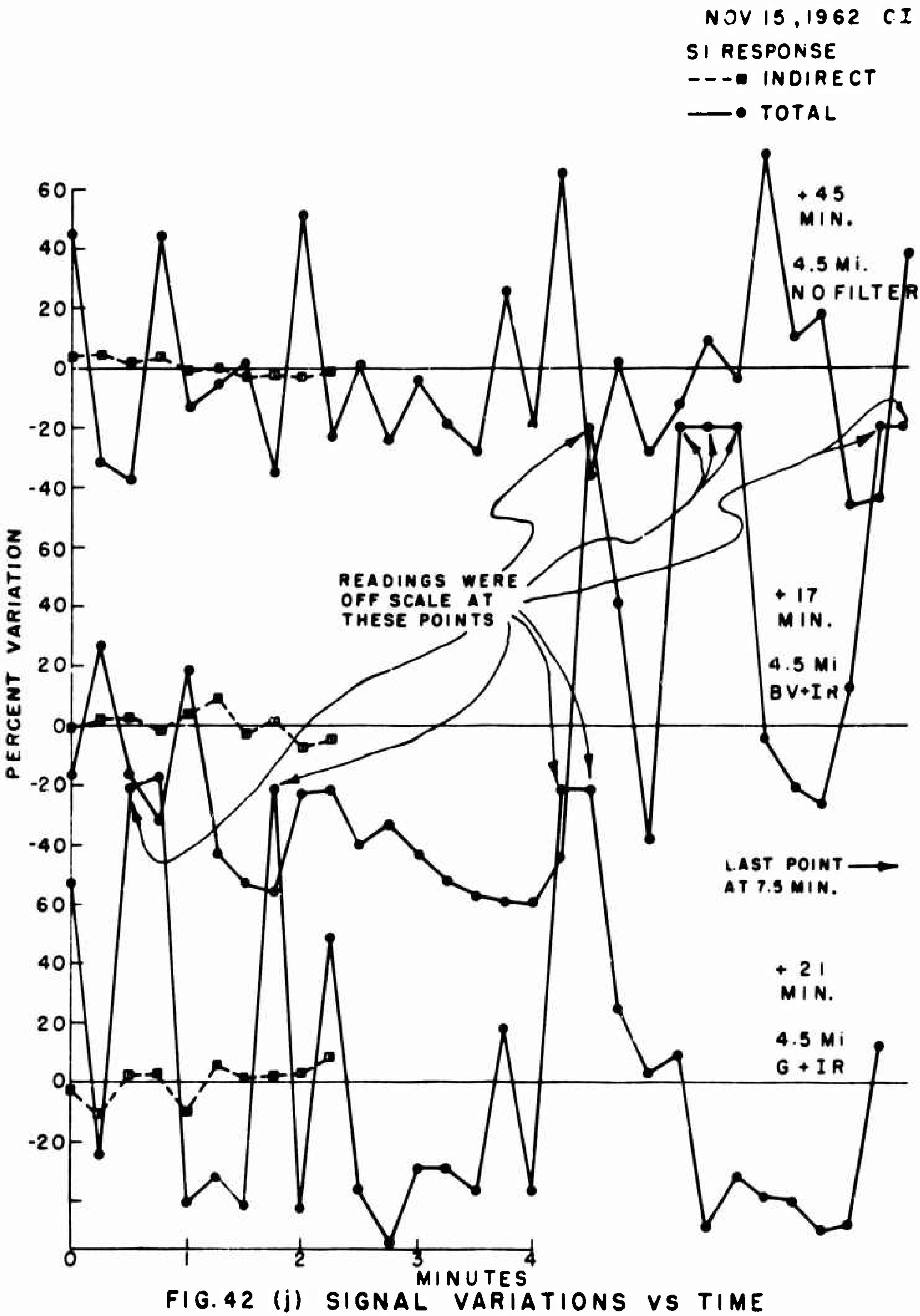


FIG. 42 (j) SIGNAL VARIATIONS VS TIME

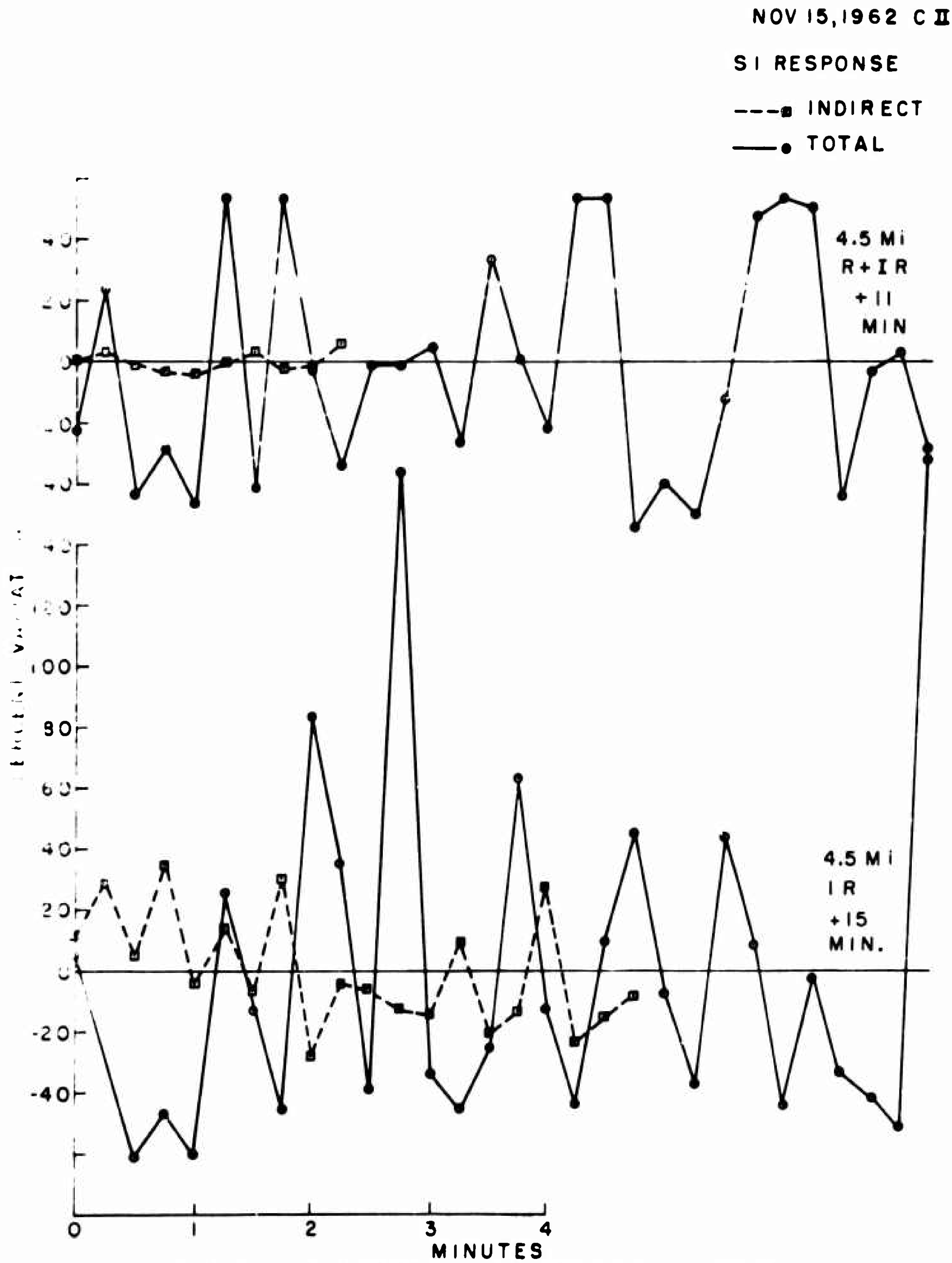


FIG. 42 (k) SIGNAL VARIATIONS VS TIME

be independent of wavelength. Figures 42-h and 42-i indicate an average deviation of about 30% from the norm, with a maximum of +60% and -50%. Figures 42-j and 42-k indicate greater fluctuations, with maximum peaks of greater than +165% and -60%. The vertical temperature gradient between +0.9°C and +3.3°C and +0.2°C and +2.1°C prevailed between the surface to 200 ft and 87 ft, respectively.

<u>16 Nov 62, 0,20-0529 hours, S-1 Response</u>

Weather conditions: partly cloudy skies at 2000 ft at 0100 hrs, becoming 9/10 broken between 1500 and 2000 ft at 0200 hours, with thinly scattered, near ground level, fog patches, followed by overcast between 1500 and 2000 ft by 0400 hours, with low-level fog patches

widely varying visibility conditions from about $1\frac{1}{2}$ miles to unlimited

E winds, 8 to 10 knots

Some Personal Weather Observations: At 0120 hours, at 0.13 mile, a 9-diameter halo was noted about a 2/3 full moon at an elevation angle of about 30 degrees to the SE. The sky appeared partly cloudy, with a slight fog halo at the 100-ft and 200-ft tower lights. At 0152 hours, at 0.5 mile, a weak halo was observed around the ground lights as well as the tower lights. At 0215 hours, most of the halo disappeared from the ground lights. Between 0223 and 0305 hours, at 4.5 miles, a thin layer of fog appeared at about 200 ft. All the lights became invisible to the eye, with only the diffuse light from the flash evident in low-level clouds. The 200-ft tower lights and flash were faintly visible in the 8-power telescope, with the moon becoming more obscured by broken clouds. By 0328 hours the tower lights were invisible in the telescope. By 0420 hours at 7.6 miles the moon was completely obscured by overcast skies, with no lights or flash effect visible.

Results:
1. $H_{NF/0.13\ mi} = 0.46$ at 0122 to 0125 hrs; $\sigma D = 0.29$
2. $H_{NF}/0.5\ mi = 0.62$, $\sigma_{0.13 - 0.5} = 2.20$/mi at 0137-0149 hrs; $\sigma D = 1.1$
3. $H_{NF}/1.0\ mi = 0.39$, $\sigma_{0.5 - 1.0}$ = negative at 0211-0218 hrs
4. $H_{NF}/4.5\ mi = 150$, $\sigma_{1.0 - 4.5} = 1.41$/mi; $\sigma D = 6.3$ at 0223-0305 hrs
5. All indirect at 7.6 and 10.3 mi

Analysis: The very high value of H at 4.5 miles is undoubtedly due to the predominance of multiple scattering in the presence of a high surface albedo with low overcast sky and limited visibility conditions.

Figure 43 indicates a somewhat more rapid indirect intensity drop until at least one mile beyond where the total intensity drop is greater, so that

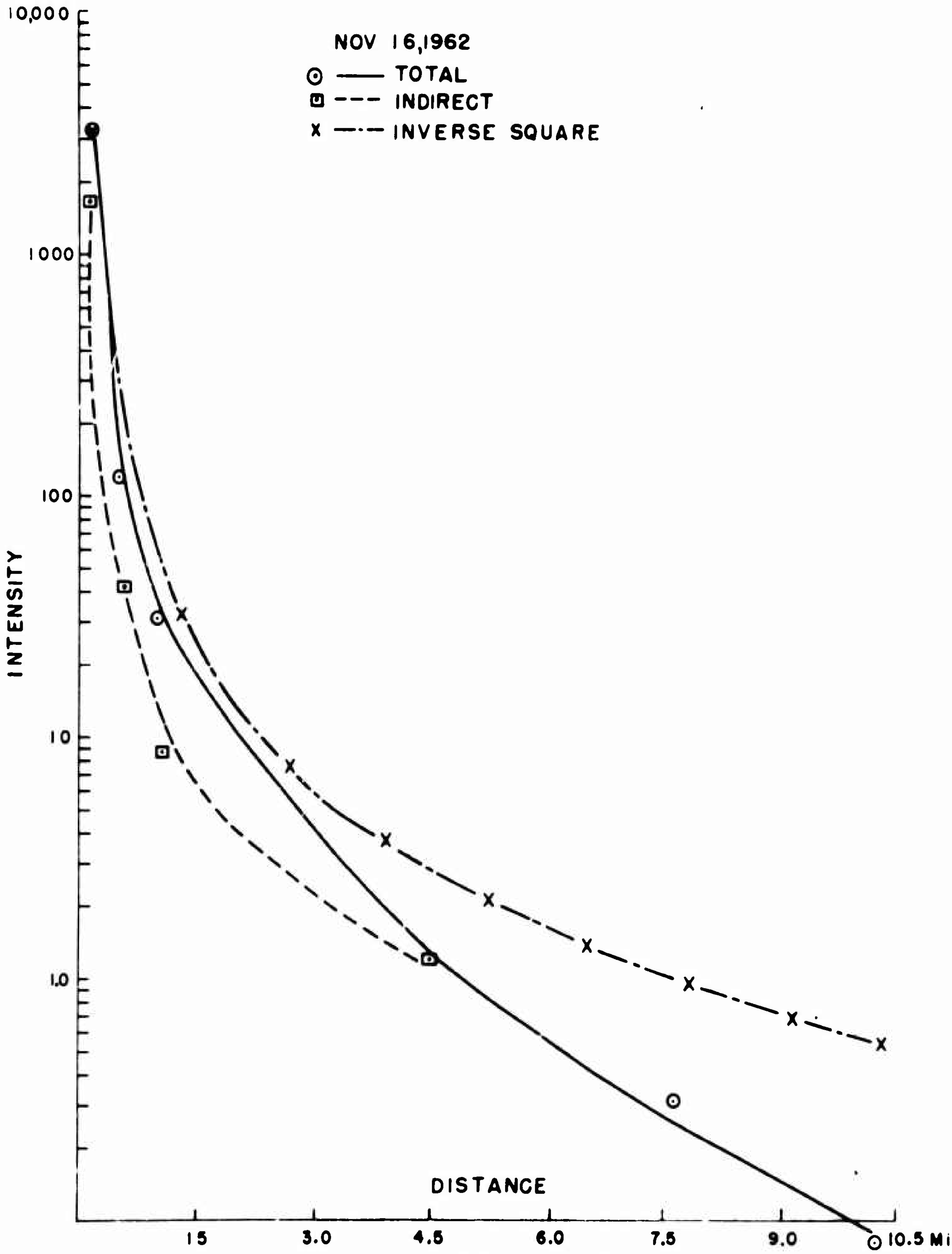


FIG.43 INTENSITY VS DISTANCE

almost all is indirect by about 4.5 miles. The inverse square/total intensity increases gradually with distance, reaching about 5 at seven miles and beyond.

Figure 44 indicates the usual indirect transmittance as varying less rapidly than the total to at least 4.5 miles, and then running almost parallel to at least 10.5 miles.

Fog conditions in the vicinity of the 100-ft tower level throughout the test period complicated analysis. The variability of the fog may very well account for the greater indirect than the total fluctuations at 0.5 mile in Fig. 45-a. At 4.5 miles and beyond when no lights were visible and only the diffuse light at the 4.5-mile point was visible, the magnitude of the fluctuation in Fig. 45-b is not more than +18% and -23% from the norm.

<u>17 Nov 62, 0100-0259 hours, S-1 Response</u>

Weather conditions: sky obscured by about 8/10 stratocumulus at about 2000 ft, and 2/10 ground fog

estimated visibility $1\frac{1}{2}$ miles

SE winds, 12 to 14 knots

Other Weather Observations: At the beginning of the test, i.e., 0100 hours, conditions were 1/2 crescent moon in SE, about 7-diameter halo, some stars visible, weak halo around 100-ft and ground lights, and loss of a halo around the 200-ft tower light. At 0117 hours at the 0.5-mile point there was no observable change in the weather conditions. About 0122 hours at the 0.5-mile point, somewhat increased halos were observed around all the lights. At 0137 hours, at the 1-mile point, no observable change in weather conditions occurred. At 0150 hours at 1 mile, all lights were still visible with halos, but the halo about the 200-ft light appeared somewhat weaker. At 0240 hours at the 4.5-mile point, no lights nor flash was visible, but the moon could still be seen. At 0255 hours a clearing trend was noted so that only the diffuse light of the flash signal became visible.

Results:
1. $H_{NF}/0.13\ mi = 0.43$ (0100-0102 hrs); σ D = 0.31
2. $H_{NF}/0.5\ mi = 3.4$ (0115-0122 hrs); σ D = 1.2
   ($\sigma_{0.13\ -\ 0.5} = 2.4$/mi, (0101-0122 hrs))
3. $H_{NF}/1.0\ mi = 8.8$ at 0135-0143 hrs; σ D = 2.3
   ($\sigma_{0.5\ -\ 1.0} = 2.3$/mi)
4. $H_G + IR/1.0\ mi = 4.1$ at 0146 to 0147 hrs
5. $H_{IR}/1.0\ mi = 5.8$ at 0150 to 0151 hrs
6. $H_{NF}/4.5\ mi = 120$ at 0240 hrs; σ D = 9.0

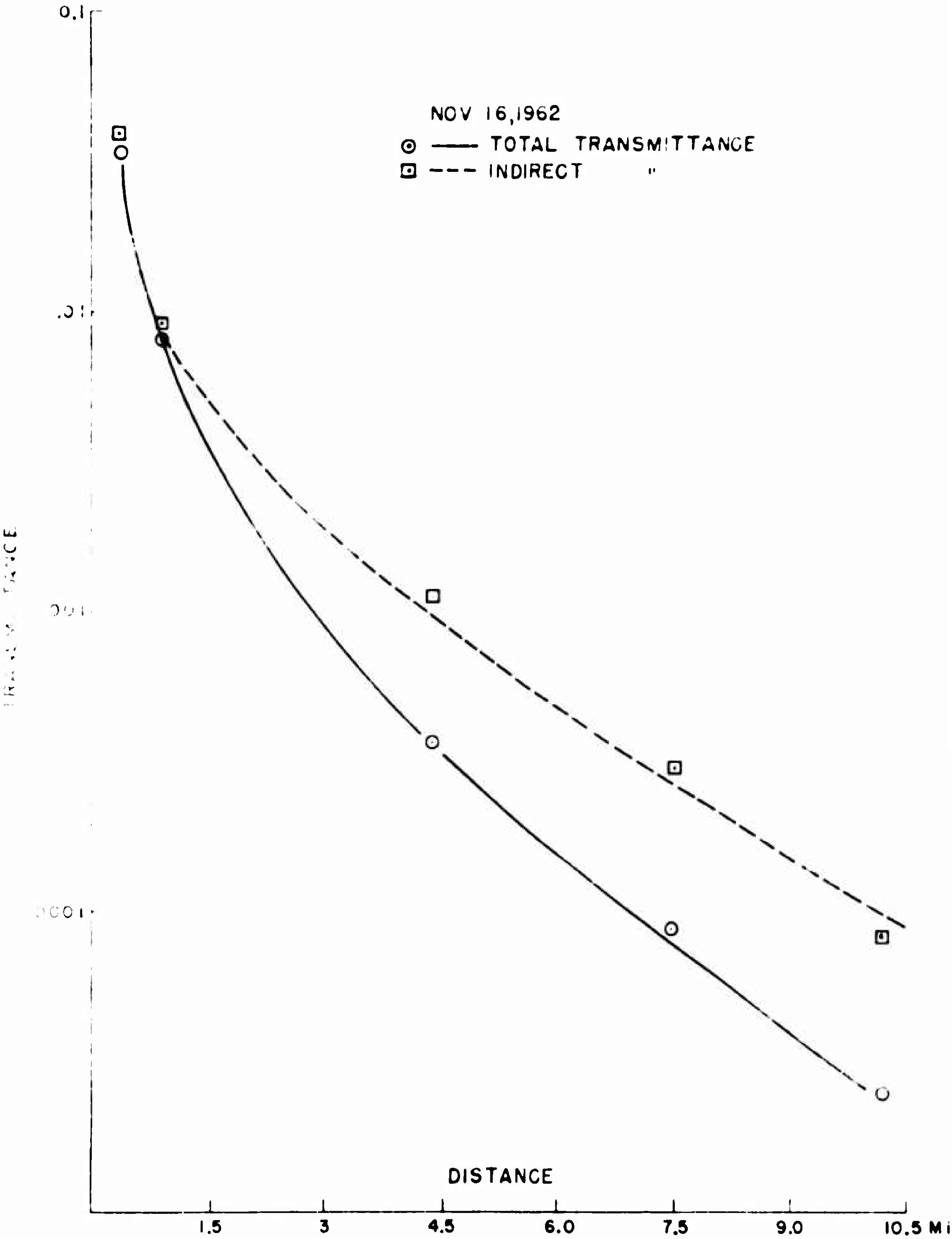


FIG. 44 TRANSMITTANCE VS DISTANCE

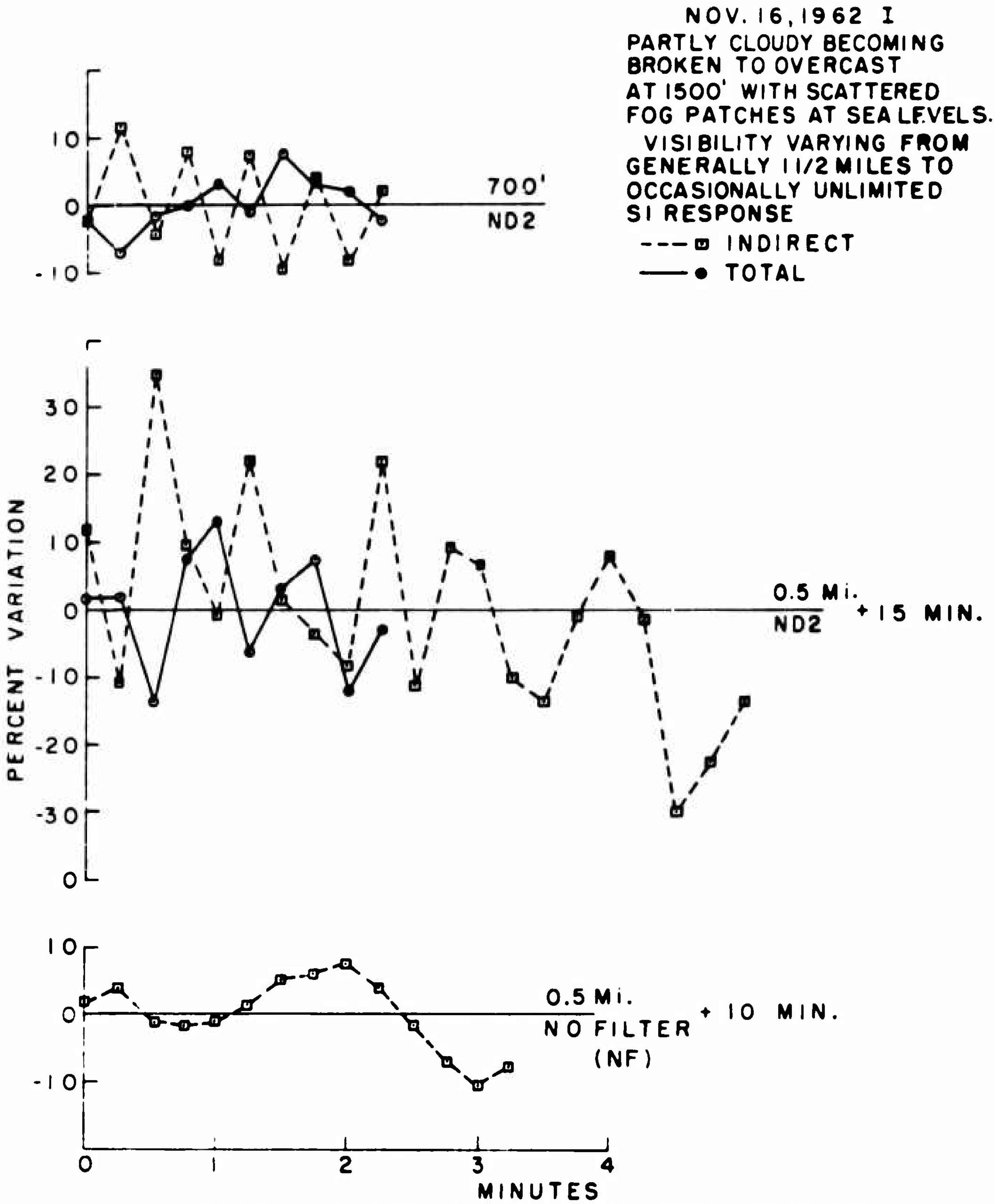


FIG. 45 (a) SIGNAL VARIATIONS VS TIME

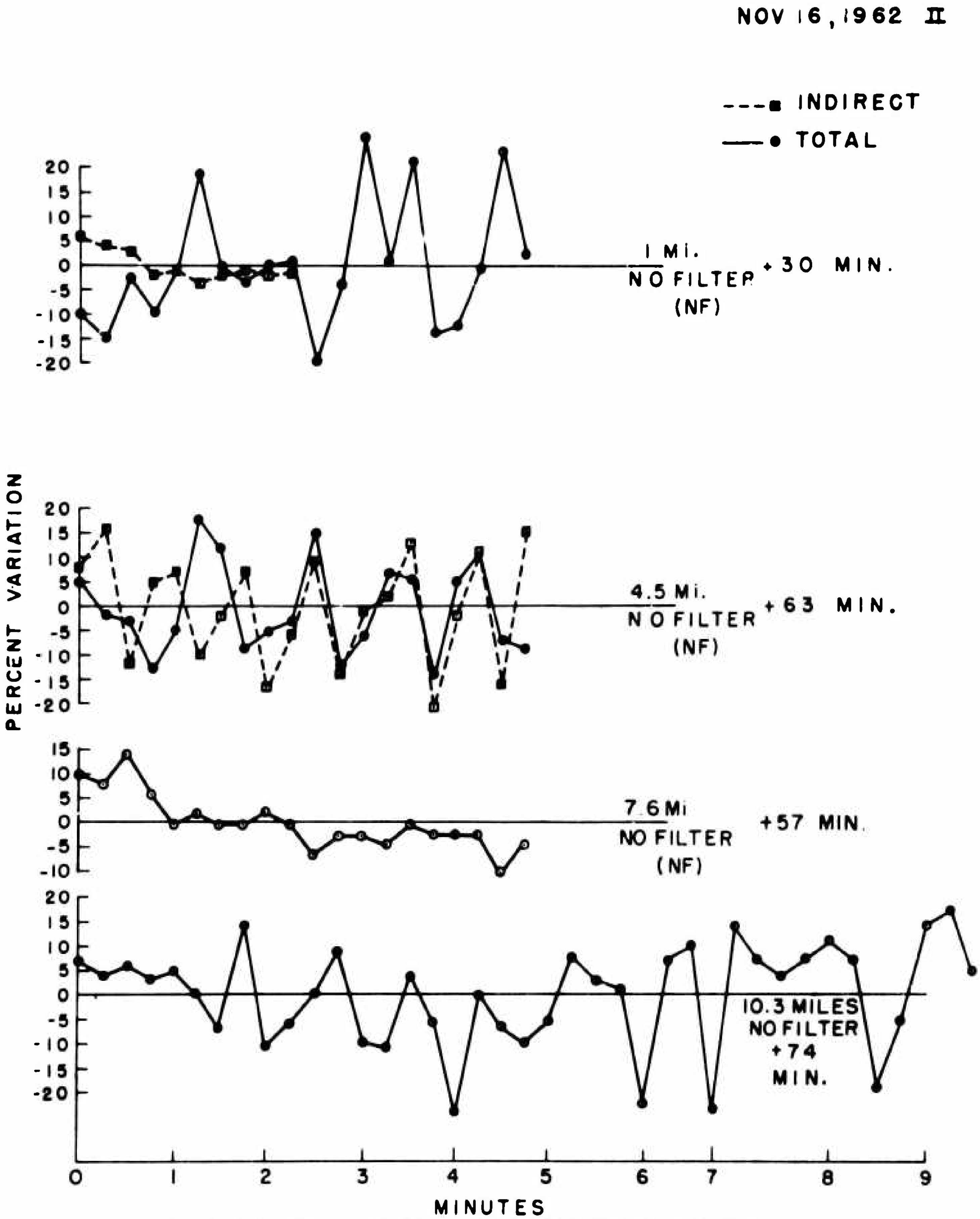


FIG. 45 (b) SIGNAL VARIATIONS VS TIME

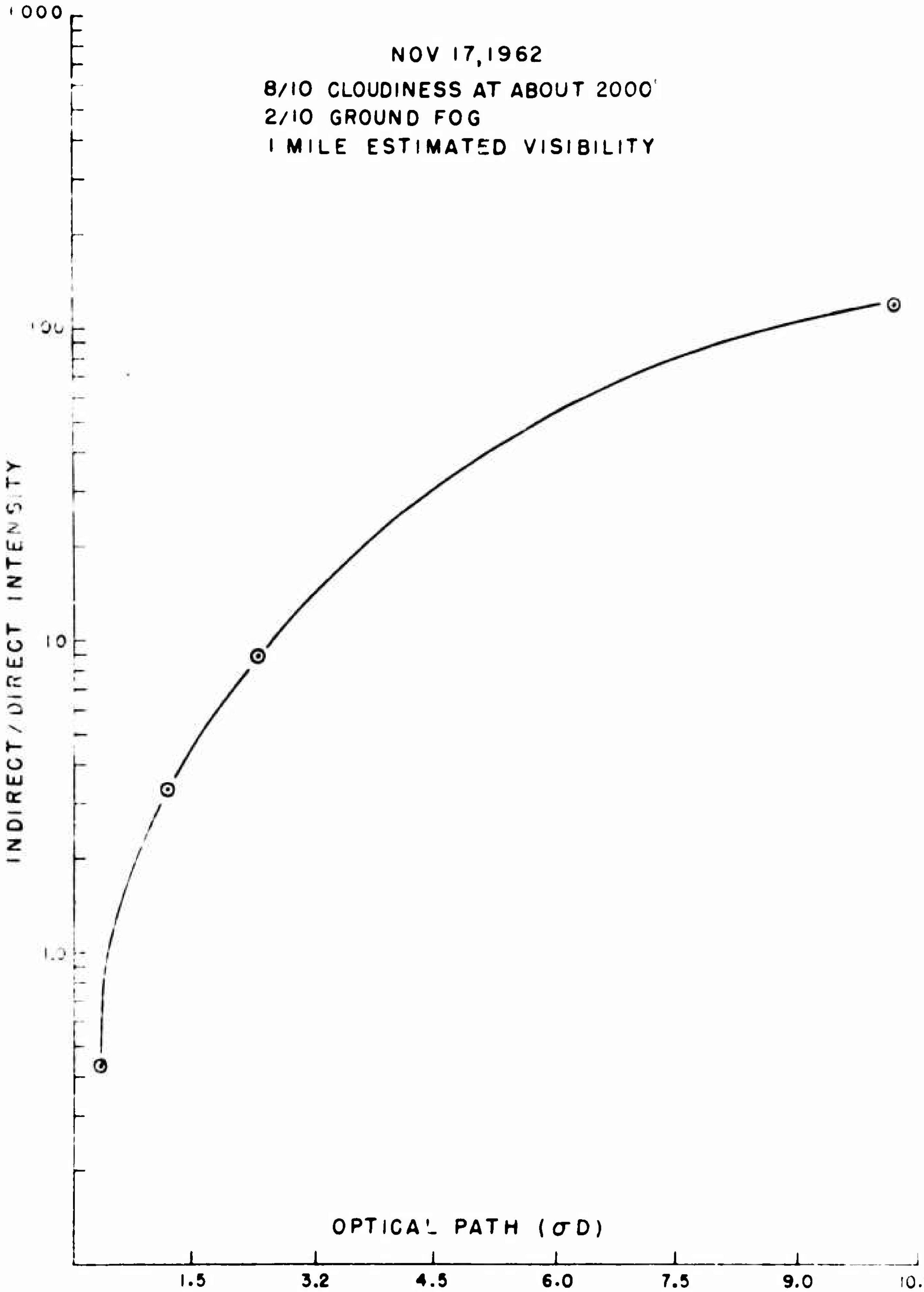
Analysis: The values for $H_{NF}/0.13\ mi = 0.43$ for $\sigma D = 0.31$, for $H_{NF}/0.5 = 3.4$ for $\sigma D = 1.2$, $H_{NF}/1.0\ mi = 8.8$ for $\sigma D = 2.3$, and $H_{NF}/4.5\ mi = 120$ were plotted in Fig. 46, as their measurements were made under relatively stable conditions. Comparisons with the locally obtained curve under the same optical paths and similar visibility conditions, but with surface albedo of about 0.2, indicate that an increase of more than 400% can occur for H in the presence of a low overcast and surface albedo of unity at relatively small optical depths, i.e., one mile. A "duct type," or light-energy-trapping effect, seems comparatively evident here. The S-1 response photomultiplier employed under the above-noted arctic conditions compared to the S-11 response photomultiplier employed locally would normally emphasize a greater increase should it have been an S-11 response photomultiplier, since one would normally expect a smaller H factor in the near infrared region of the S-1, i.e., 0.74 to 1.2 microns as compared to the spectral region of the S-11-type response, i.e., 0.32 to 0.65 micron.

The value of H obtained using the Wratten 58 (green) filter, however, is about 30% less than H obtained while employing the Wratten 87C (near infrared) filter. This effect in this case should be considered in the light of the somewhat greater absorption effect of water vapor for the near infrared than the green spectral region as well as the relatively much smaller direct component than indirect involved. The value for $H_{NF}/4.5\ mi \approx 120$ was obtained by the relationship $H_{4.5\ mi} \approx \left(\frac{\text{total transmittance}}{\text{direct transmittance}}\right)_{4.5\ mi} (1 + H_{0.13\ mi})$ where visibility $<$ 4.5 miles. NOTE: Derivation on page 8.

The intensity-vs-distance curve of Fig. 47 shows the indirect intensity to be equivalent to the total in the vicinity of one mile in the no-filter case. It is, however, interesting to note that the total intensity-vs-distance curves run parallel for the green plus near infrared and the near infrared case. This would seem to indicate that the addition of the relatively small green spectral region to the near infrared (note the spectral system response curves) produces a negligible effect on their respective total transmittances. The inverse square/total intensity increases gradually with distance so that it is about four at 4.5 miles.

The transmittance-vs-distance curve of Fig. 48 for the no-filter case indicates a high degree of parallelism so that one may surmise a negligible difference between the total and scattered transmittances over the paths involved.

Typically small fluctuation magnitude changes in Fig. 49 occurred under poor visibility conditions of about one mile, with about 8/10 cloud coverage at 2000 feet, and 2/10 ground fog. The fluctuation magnitudes of +14% and -12% from the norm were not exceeded up to and including the 4.5-mile distance.



1000
100
10
1.0
NOV 17, 1962
8/10 CLOUDINESS AT ABOUT 2000'
2/10 GROUND FOG
1 MILE ESTIMATED VISIBILITY
INDIRECT/DIRECT INTENSITY
OPTICAL PATH (σD)
1.5
3.2
4.5
6.0
7.5
9.0
10.5

FIG. 46 H VS σ D

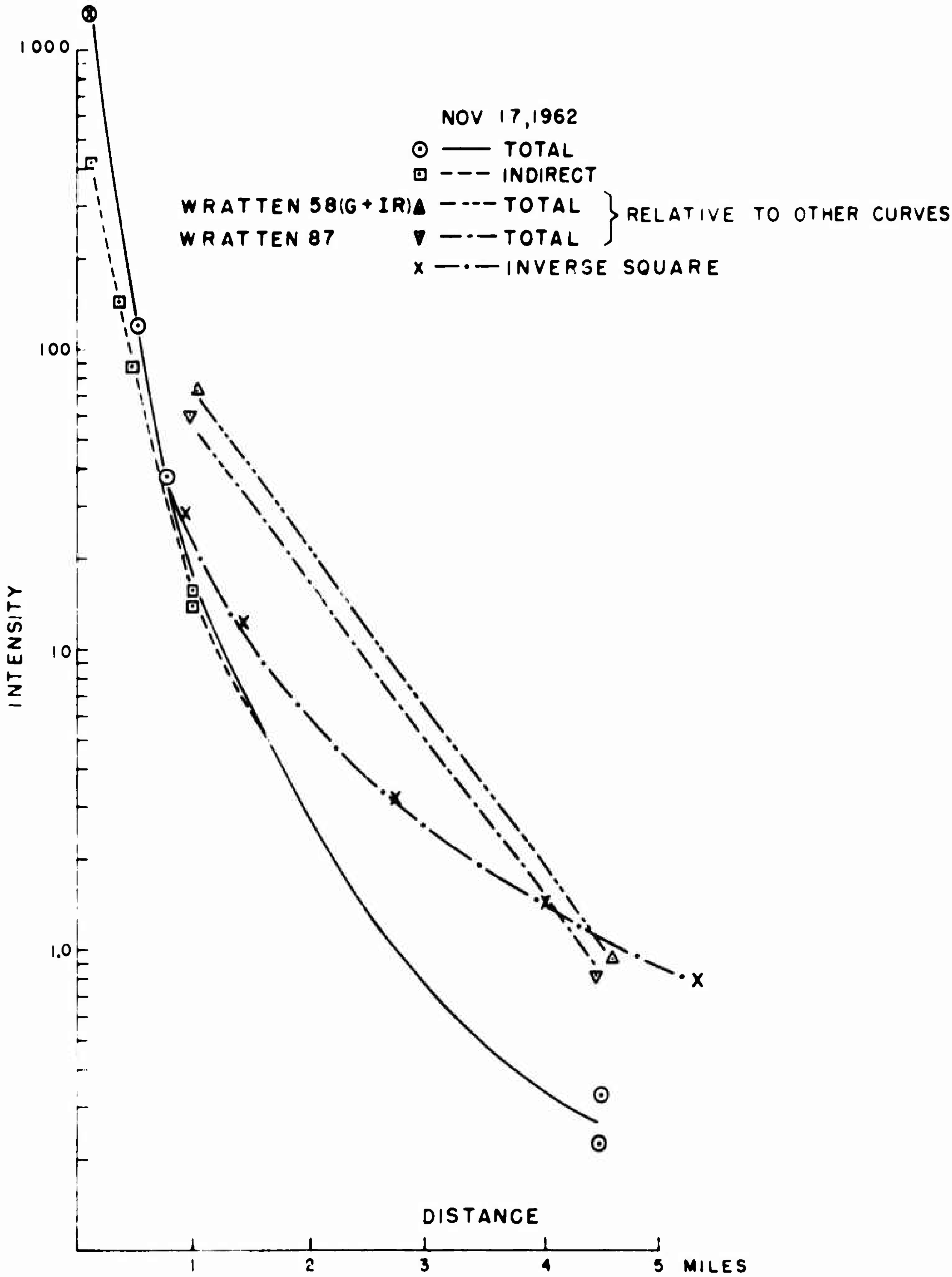


FIG.47 INTENSITY VS DISTANCE

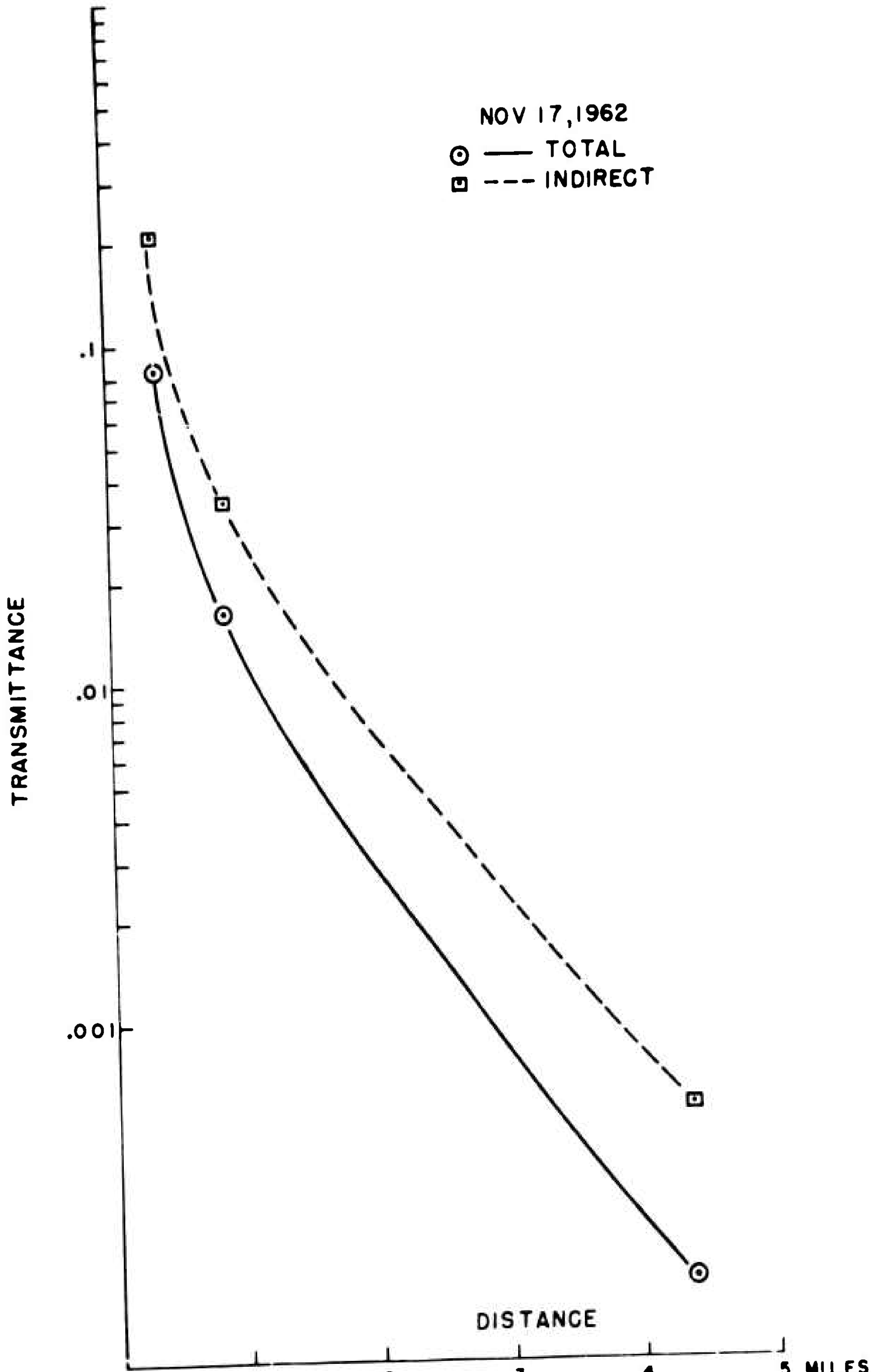


FIG. 48 TRANSMITTANCE VS DISTANCE

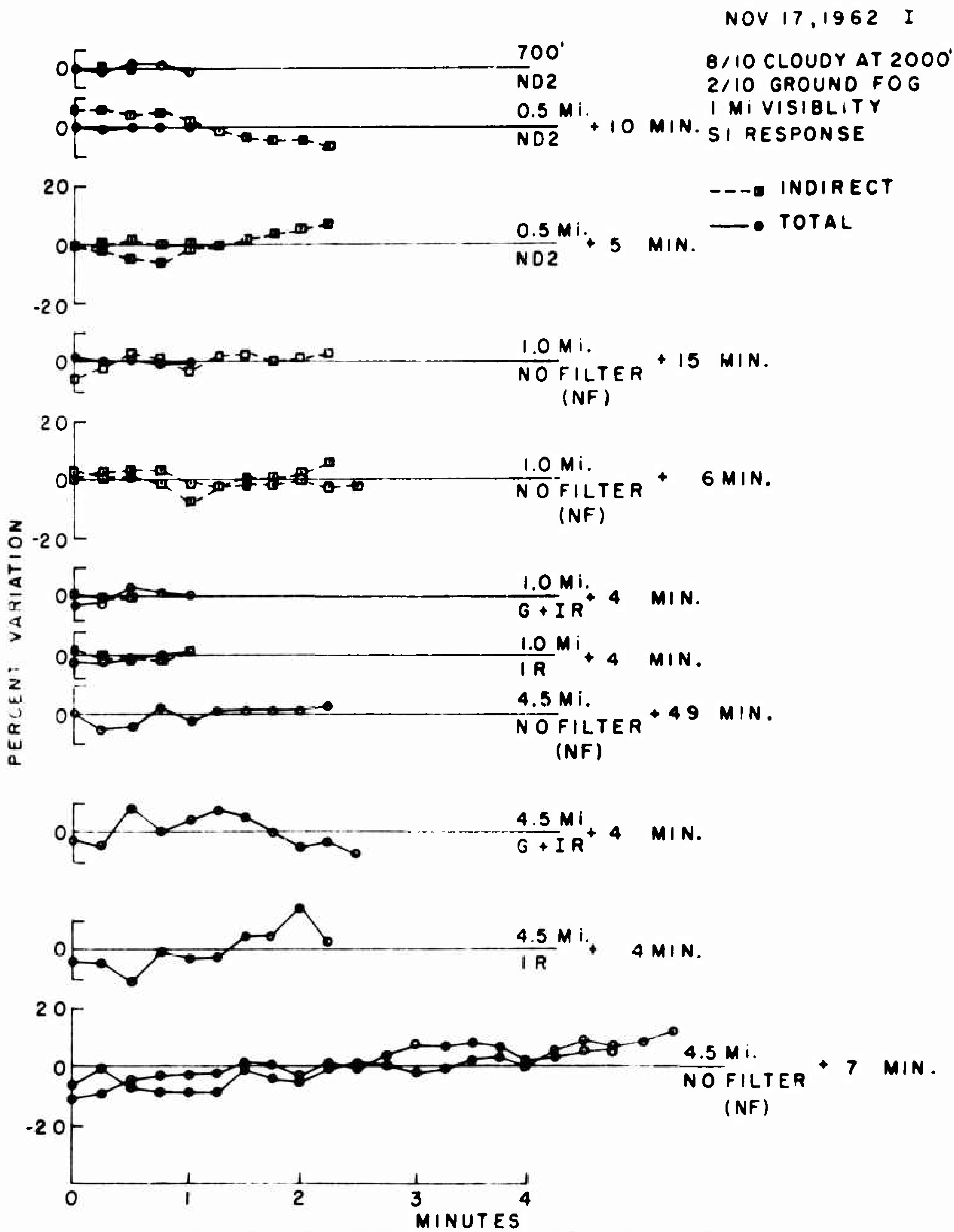


FIG. 49 SIGNAL VARIATIONS VS TIME

21 Nov 62, 2144-2150 hours, S-1 Response

Weather conditions: no moon nor stars visible, 9/10 to 10/10 fog

estimated visibility about 1/2 mile, +1.0°C gradient

SSE winds, 15 to 16 knots

blowing snow

Results: $H_{NF}/0.13\text{ mi} = 1.31$, $\sigma D = 0.78$, assuming $\sigma = \frac{3.0}{\text{visibility}}$

Analysis: Measurements were taken only for the no-filter case at 0.13 mile, at which distance weak halos could be observed around the surface lights and the lights at the 100-ft and 200-ft levels. A plot of H on Fig.12 would place the point about midway between the curve representing cloudy skies (at 2000 ft), one mile visibility in fog, ground albedo of unity, and the curve representing clear skies with ground albedo of unity.

The fluctuation magnitudes at 700 ft in Fig. 50 are within the ±10% range from the norm; 8/10 fog with 1/2-mile visibility, blowing snow, and a vertical temperature gradient of +1.0°C and -0.5°C between the surface to 200 ft and 87 ft, respectively, were present.

23 Nov 62, 1950-2032 hours, S-1 Response

Weather conditions: sky obscured in about 6/10 fog coverage and about 4/10 stratocumulus at 1500 ft

estimated visibility of 1 mile
+2.2°C gradient (vertical)
ENE winds, 18 knots, with blowing snow

Other Weather Observations: No moon nor stars were visible. Halos were noted around all the surface and tower lights at 0.13 mile; while no lights, including the flash, were visible during the test at the 4.5-mile station.

Results:

1. $$\left[\frac{\text{Total}_{NF}/\text{Nov } 23}{\text{Total}_{NF}/\text{Nov } 21}\right]_{0.13\text{ mi}} = 0.92$$

2. $$\left[\frac{\text{Total}_{NF}/\text{Nov } 23}{\text{Total}_{NF}/\text{Nov } 17}\right]_{0.13\text{ mi}} = 0.98$$

3. $H_{NF}/4.5\text{ mi} = 60$, assuming $\sigma = \frac{3.0}{\text{visibility}}$; $\sigma D = 13.5$

Analysis: Measurements were carried out only for the total and indirect at 0.13 and at 4.5 mi, which were indistinguishable in each case. Although results 1 and 2, above, are almost equal, it is interesting to note the great difference in the H values on 17 and 21 Nov, i.e., more than 200% at a distance of only about 0.13 mile from the source. This would indicate the near equality of total radiation at distances relatively close to the source, although the indirect or direct radiation may vary widely.

The value for $H_{IIF}/4.5$ mi ≈ 60 was obtained by calculating

$$\left(\frac{\text{total transmittance}}{\text{direct transmittance}}\right)_{4.5\ mi} \times H_{0.13\ mi})$$ where visibility < 4.5 miles and assuming $H_{0.13} \approx 0.5$. The latter value was selected since it was felt that this weather situation most closely resembled that of 17 Nov.

Figure 51 indicates the relatively small variations for the total intensity not exceeding ±18% from the norm at 4.5 miles. The same maximum variation for the indirect intensity can be attributed to the fog variability between the source and receiver. Six-tenths fog with 4/10 cloud at 1500 ft, 1-mile visibility, blowing snow and a vertical gradient of +2.2°C and +1.8°C between the surface and 200 ft and 87 ft, respectively, prevailed.

<u>25 Nov 62, 0209-0518 Hours, S-1 Response</u>

Weather conditions: sky obscured by fog followed by ground fog. There was 10/10 sky coverage initially, becoming 3/10 to 4/10 variable ground fog, with smaller amounts towards later part of test period, i.e., after 0430 hrs

estimated visibility, 1/2 to 1 mi in fog, and very light falling snow
+1.3°C to +1.7°C gradient (vertical)
SSE winds, 9 to 11 knots

Other Weather Observations: At 0209 hours at 0.13 mile, no moon nor stars were visible; very light snow was falling. Weak halos were around all the ground and tower lights, but somewhat less at the 100-ft red tower light than at the 200-ft white tower light. At about the same time, no lights on the tower or ground were visible from 4.5 miles. Only the diffuse light of the flash was visible in a horizontal plane in what appeared as thin clouds.

At 0223 hours at 0.5 mile, weak halos were observed around all the lights, while some stars appeared visible overhead after 0220 hours at the fixed 4.5-mile wanigan site. At 0246 hours at one mile, strong halos appeared around the 100-ft and ground lights, but with the top of the 200-ft tower appearing clearer. No weather change was apparent from 0246 hours at one mile until the end of the test at 0518 hours at 4.5 miles. However, from the fixed wanigan site at 4.5 miles, more stars seemed visible overhead by 0430 hours, but no lights nor stars, looking toward Camp Century, were present. The diffuse light of the flasher was still visible at 4.5 miles at the end of the test period. From the tower at about 0600 hours, the 750W tower white light at the 200-ft level could just begin to be observed at about 1-1/4 mile distance, while the 150W tower red light at the 100-ft level could be observed faintly at about one mile away.

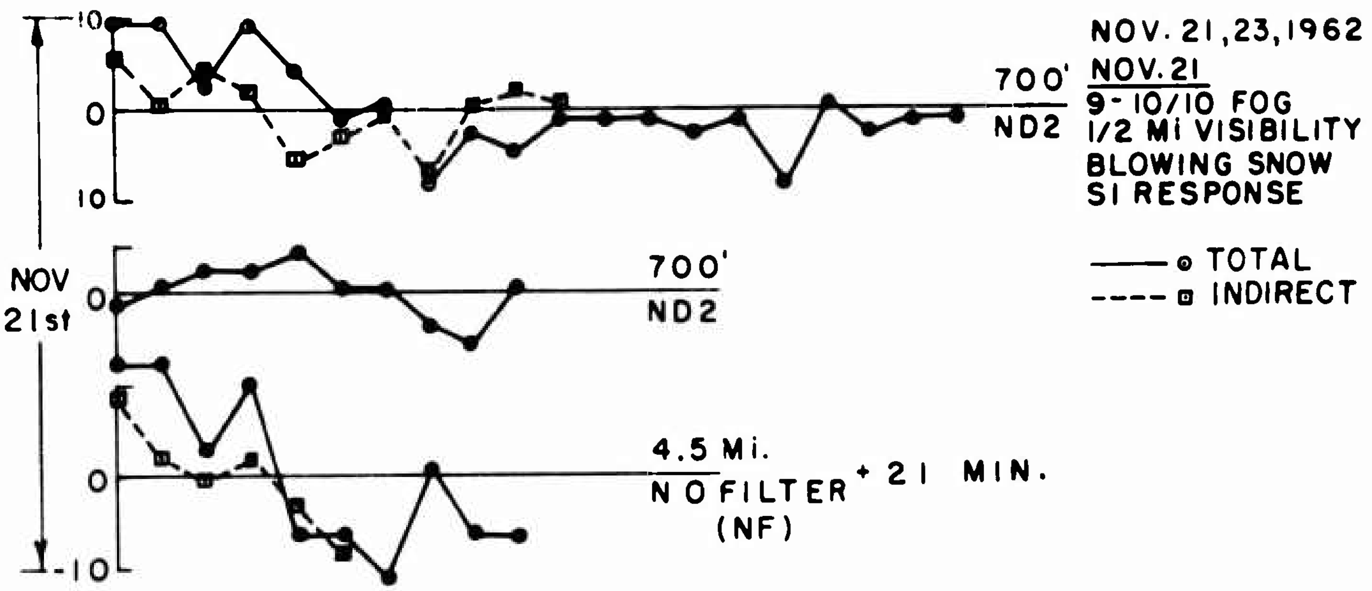


FIG. 50 SIGNAL VARIATIONS VS TIME

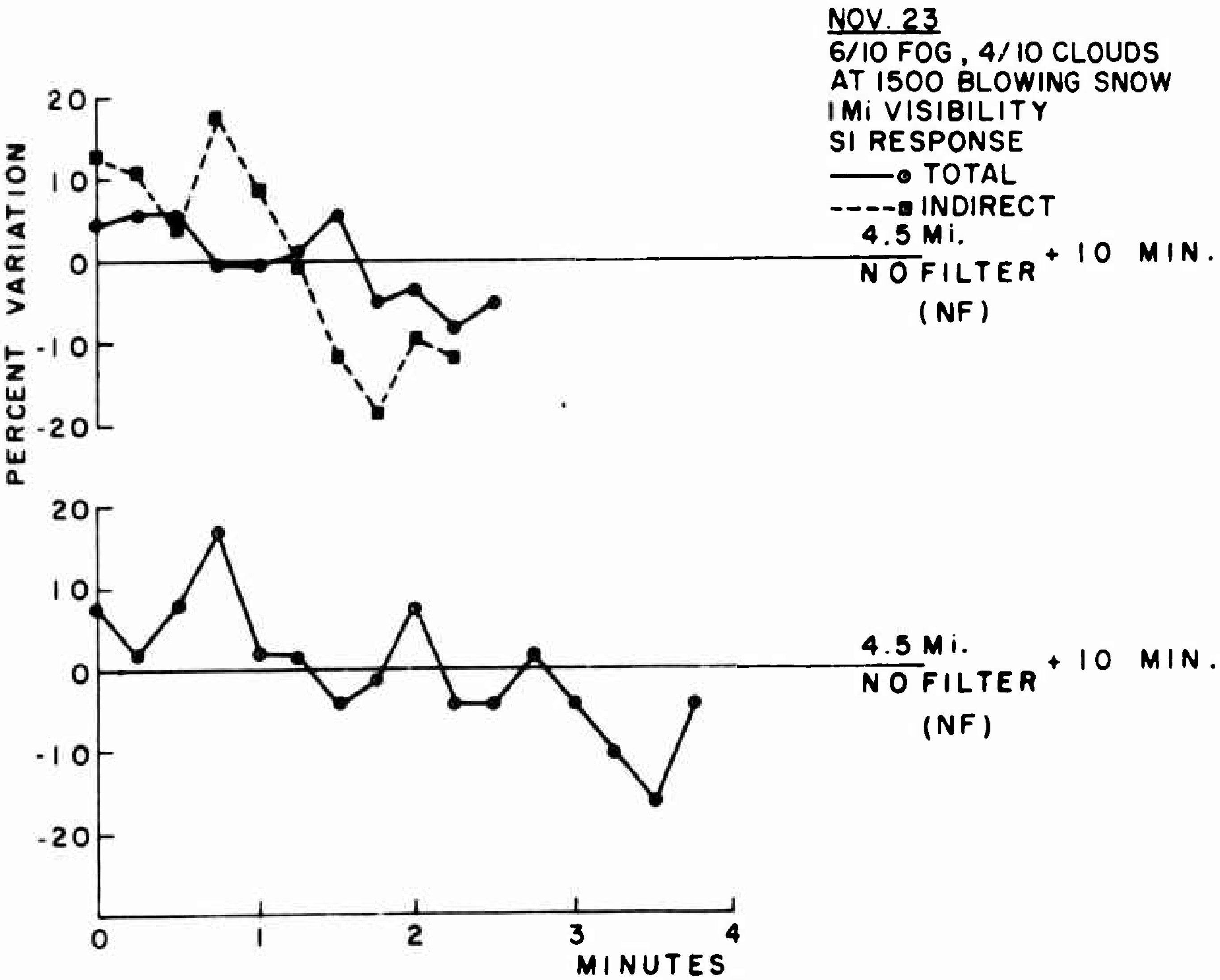


FIG. 51 SIGNAL VARIATIONS VS TIME

Results:

1. $H_{NF/0.13} = 0.49$ (0210 hrs) — weak halos around all lights at Camp Century
2. $H_{NF/0.5} = 1.77$ (0224 hrs) → 2.89 (0228 hrs) — weak halos around all lights at Camp Century

   $\sigma D = 3.4$

3. $H_{NF/1} = 42.1$ (0247 hrs), $\sigma D = 6.8$, strong halos around all lights

   $H_{G+IR/1} = 3.5$ (0250 hrs) — no noticeable weather change

   $H_{IR/1} = 8.0$ (0256 hrs) — no noticeable weather change

   $H_{NF/1} = 1.14$ (0301 hrs) → 3.7 (0305 hrs) — no noticeable weather change

   ($\sigma_{NF/9.5-1.0} = 6.8$/mi (0228-0247 hrs))

Analysis: The greatest weather change occurred between about 0200 and 0300 hours, with 10/10 fog becoming about 4/10 ground fog in this period. This could well account for the relatively rapid increase in H from 1.77 at 0.5 mile to 42.1 at one mile. The increase in H at 0.5 mile from 1.77 to 2.89 in about four minutes also indicates the rapid drop of the fog level toward the surface in becoming ground fog. Ground fog of smaller amounts could bring about an increase in H compared to fog, assuming even the same visibilities in each case, should the ground fog be in the close vicinity of the light source while the fog is not. In addition, one must also consider the possible changes in water content drop-size distribution as the fog changes to ground fog.

The greater value of H_{IR} than H_{G+IR} or H_{NF} at one mile would appear to indicate the effects of a rapidly changing weather pattern plus, perhaps, the effects of very light falling snowflakes in causing greater scattering for the near infrared than for the visible.

The following relationship applies in Fig. 52:

$$\frac{\left[\frac{\text{inverse square}}{\text{total}}\right]_{D_1}}{\left[\frac{\text{inverse square}}{\text{total}}\right]_{D_2}} = 1.7 \pm 10\% \quad (D_1 < D_2) .$$

It is interesting to note in Fig. 52 the same slopes for the near infrared as the near infrared and green regions in the curves showing total intensity vs distance. These measurements were made during a period when relatively very small weather changes were occurring, so one may safely conclude that the total attenuation effects for the near infrared are about the same as for the near infrared plus green in this ground fog plus light falling snow weather. One may surmise that this independence of wavelength effect is suggested in comparing the visible to the near infrared total attenuation effects in this type of weather.

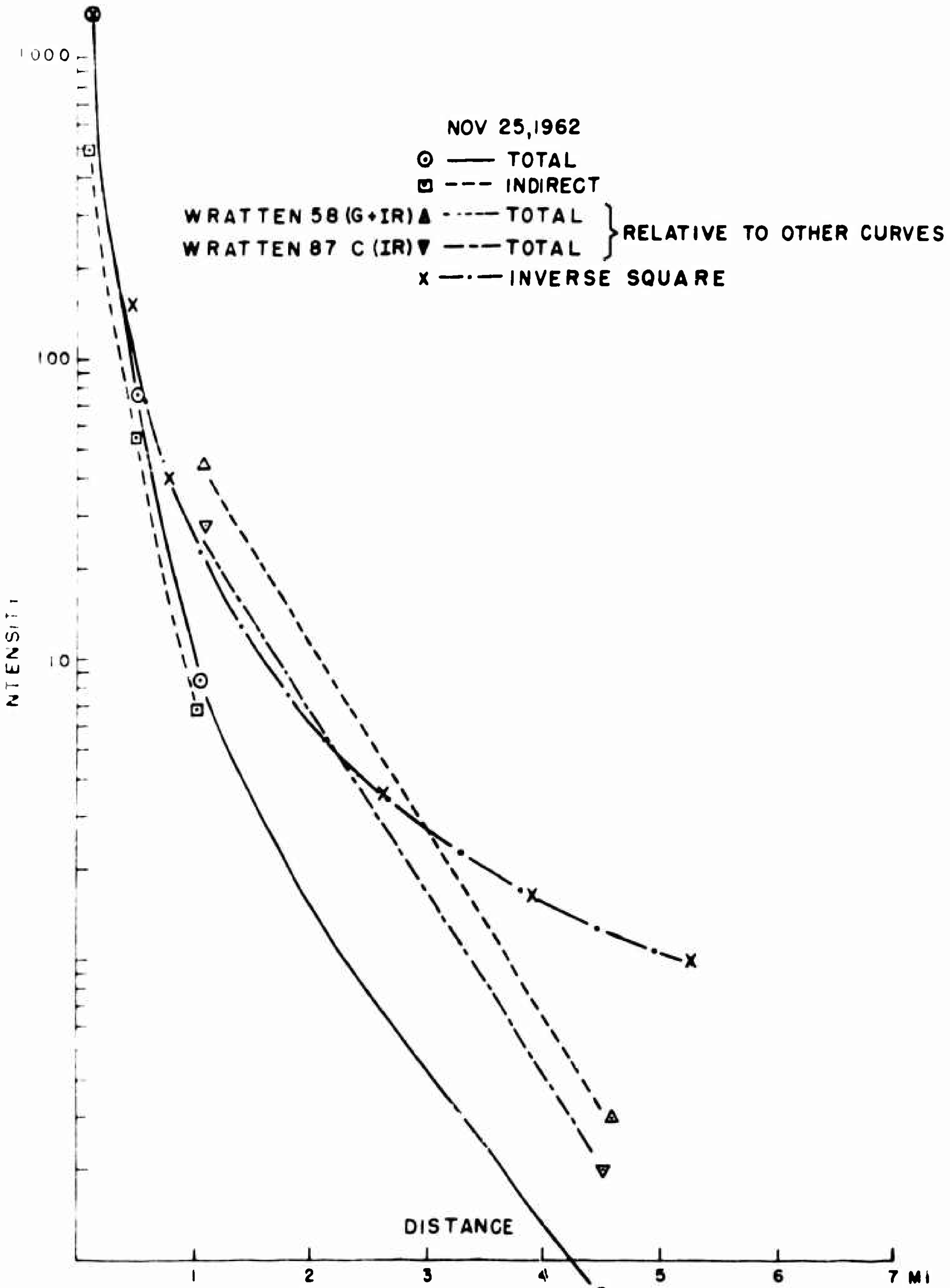


FIG.52 INTENSITY VS DISTANCE

The indirect and total transmittance slopes of Fig. 53 for the no-filter case are almost identical, with perhaps a somewhat steeper slope in the indirect transmittance for the first 0.5 mile.

Analysis was complicated by the presence of fog in the vicinity of the 100-ft tower level plus the presence of very light falling snow. However, the general small variational trend, typical of poor visibility situations, prevailed (Figs. 54-a - 54-e). The maximum spread of +32% and -22% from the norm occurred at 4.5 miles for the R + IR case, and almost the same for the B + IR case at 4.5 miles. The indirect intensity fluctuation pattern at 1.0 mile for the no-filter case in Fig. 51-d is discounted, since it is likely due to some prevailing factor other than the index of refraction fluctuations of the air molecules. The vertical temperature gradient in this period varied from +1.7°C to +3.3°C and +1.3°C to 1.9°C from the surface to 200 ft and 87 ft, respectively.

26 Nov 62, 0224-0335 hours, S-1 Response

Weather conditions: sky partly obscured by scattered ground ice fog extending up to at least 200 ft

visibility 1/2 to 1 mile

SE winds, 11 to 12 knots, becoming 19 knots from the SSE towards end of test period

blowing snow after about 0300 hours
+2.0°C to +0.5°C gradient (vertical)

temperature: -27 to -33°C

Other Weather Observations: Many stars were visible in the overhead position at the 4.5-mile point between 0215 and about 0305 hours. The diffuse light in the horizontal plane appeared visible from the flash at this distance during this time period. At 0224 hours, at 0.13 mile, weak halos were observed around the tower lights and airport runway lights, and the stars were visible overhead. At the 0.5-mile point the halos around the lights were more intense. Very strong halos were observed around all the lights at 1.0 mile at 0302 hours, and the lights could be faintly discerned. However, the top of the tower appeared somewhat clearer. At about 0330 hours at one mile, the lights were almost invisible, while the stars were no longer visible in the blowing snow.

Results:

1. $H_{NF}/0.13 = 0.68$ (0209-0212 hrs); $\sigma D = 0.71$

2. $H_{NF}/0.5 = 5.0$ (0223-0229 hrs), ($\sigma_{0.13 - 0.5 \text{ mi}} = 5.5/\text{mi}$); $\sigma D = 2.7$

3. $H_{NF}/1.0 = 14.6$ (0246-0248 hrs) ($\sigma_{0.5 - 1.0 \text{ mi}} = 3.1/\text{mi}$); $\sigma D = 3.1$

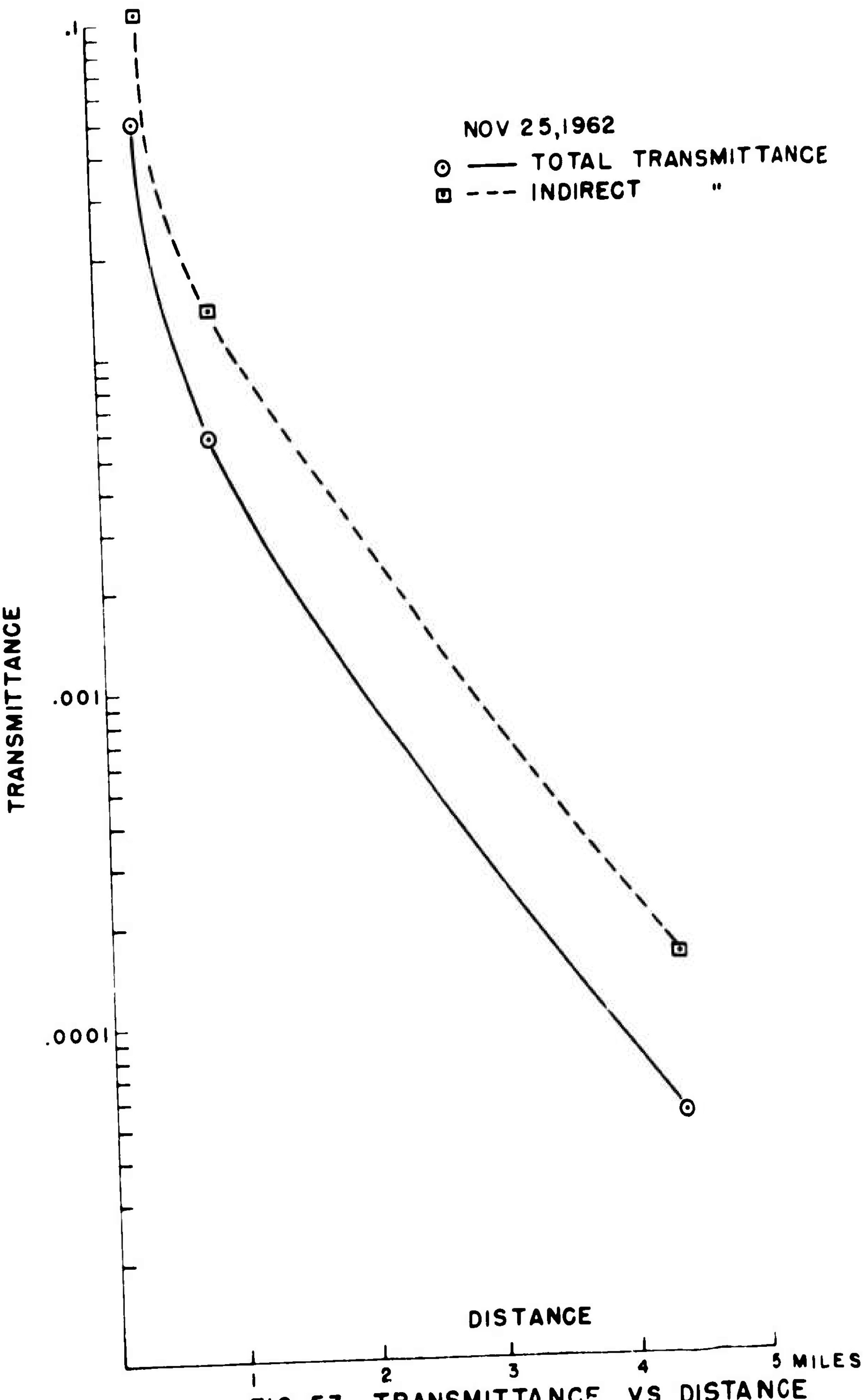


FIG. 53 TRANSMITTANCE VS DISTANCE

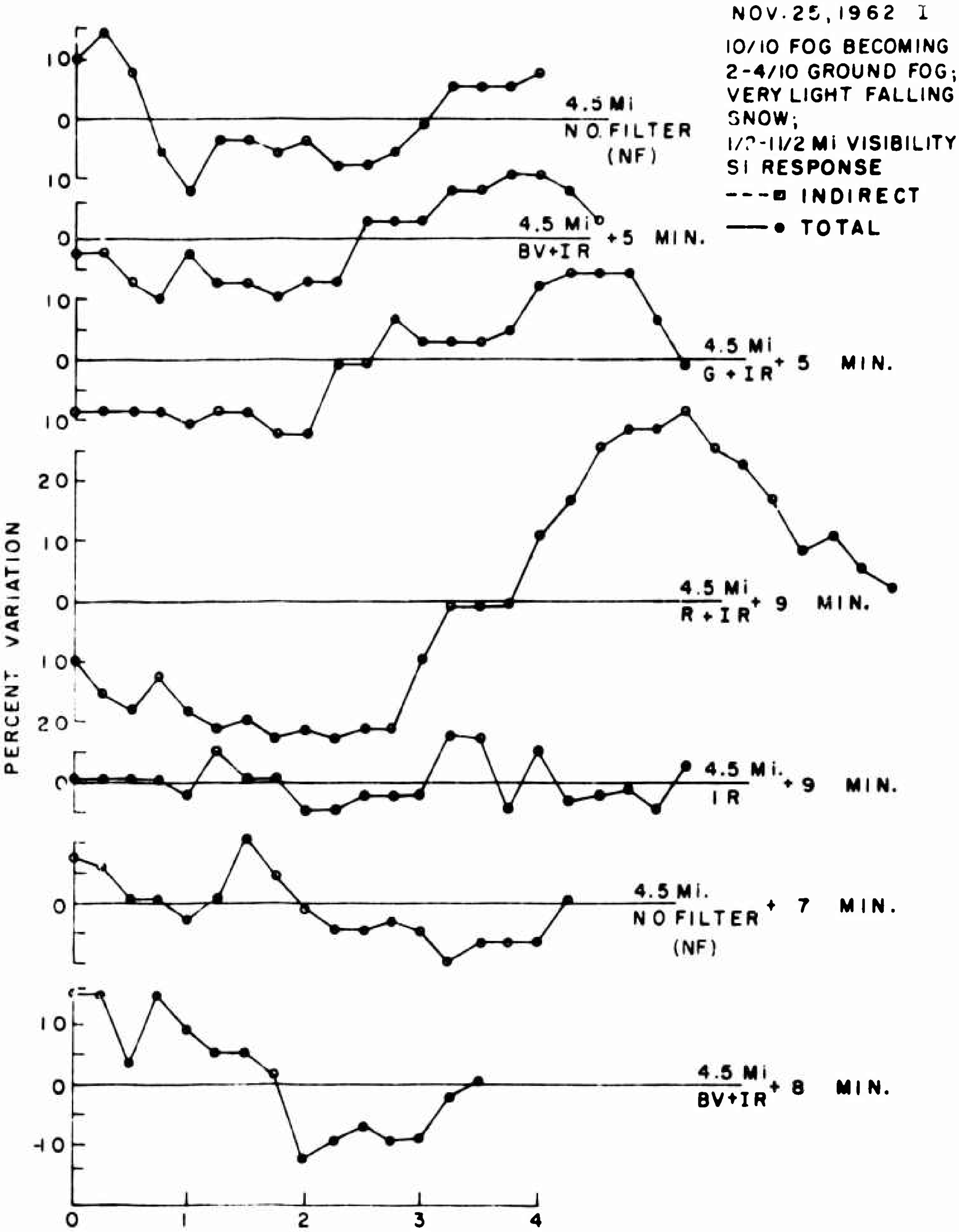


FIG. 54 (a) SIGNAL VARIATIONS VS TIME

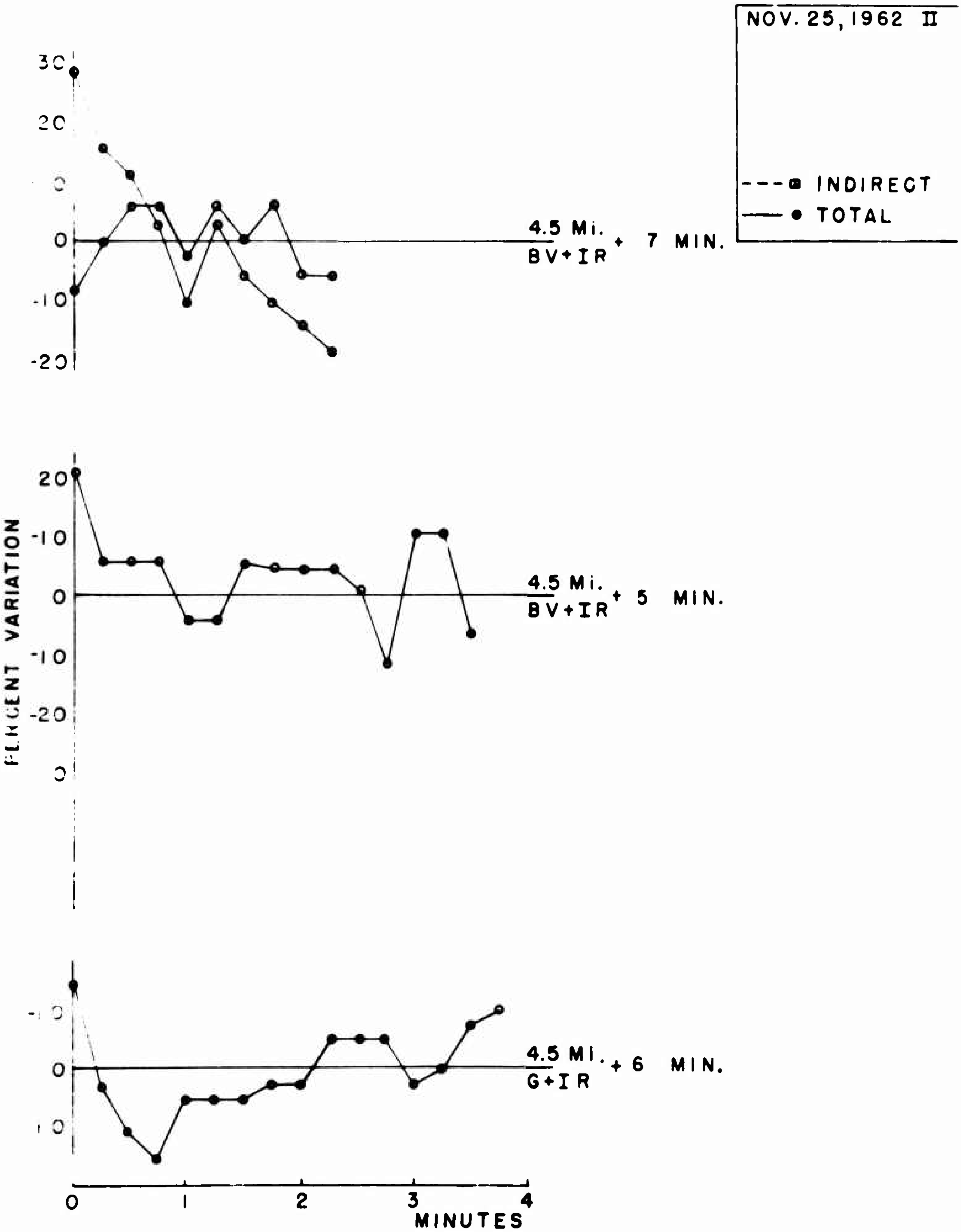


FIG. 54 (b) SIGNAL VARIATIONS VS TIME

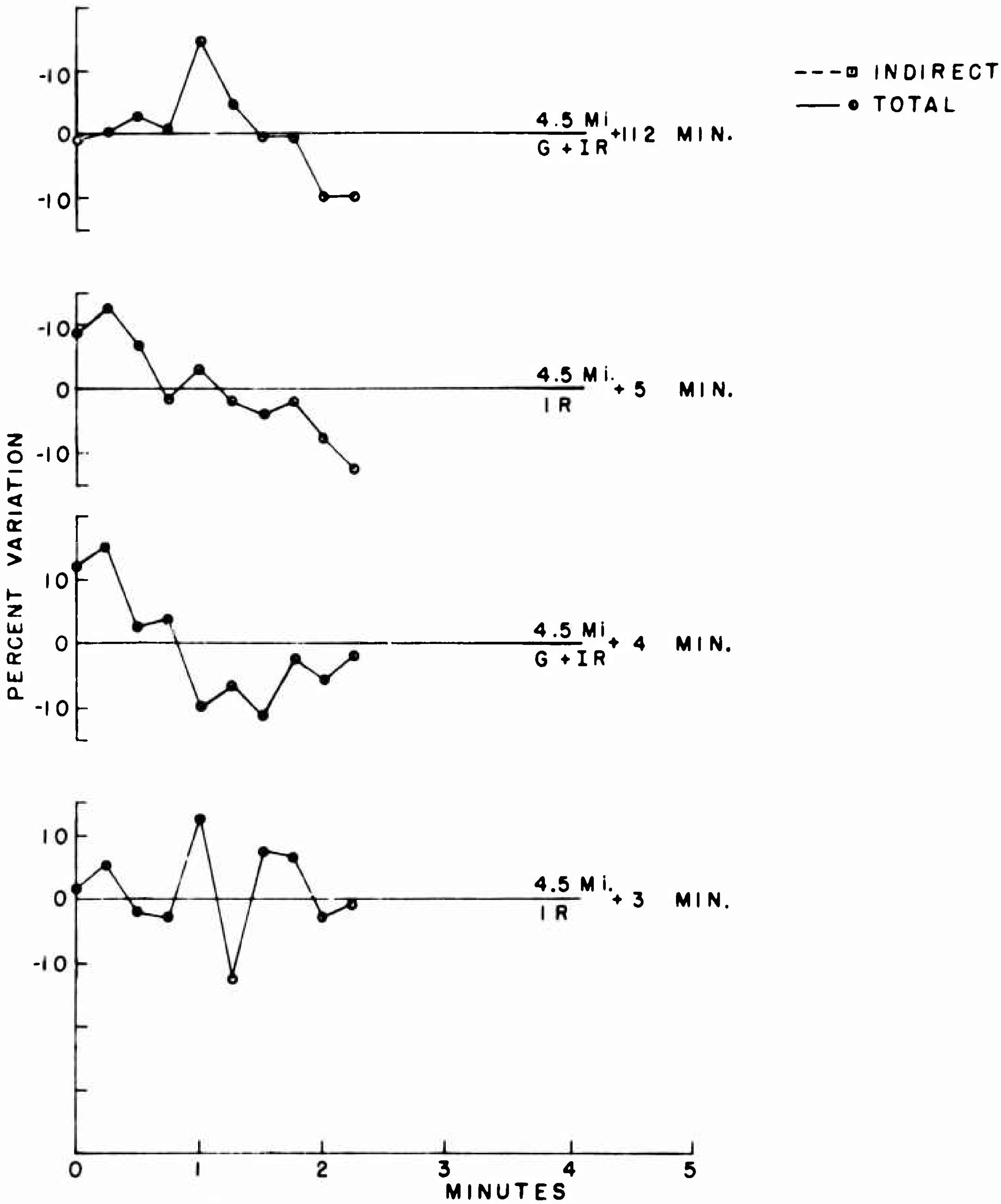


FIG. 54 (c) SIGNAL VARIATIONS VS TIME

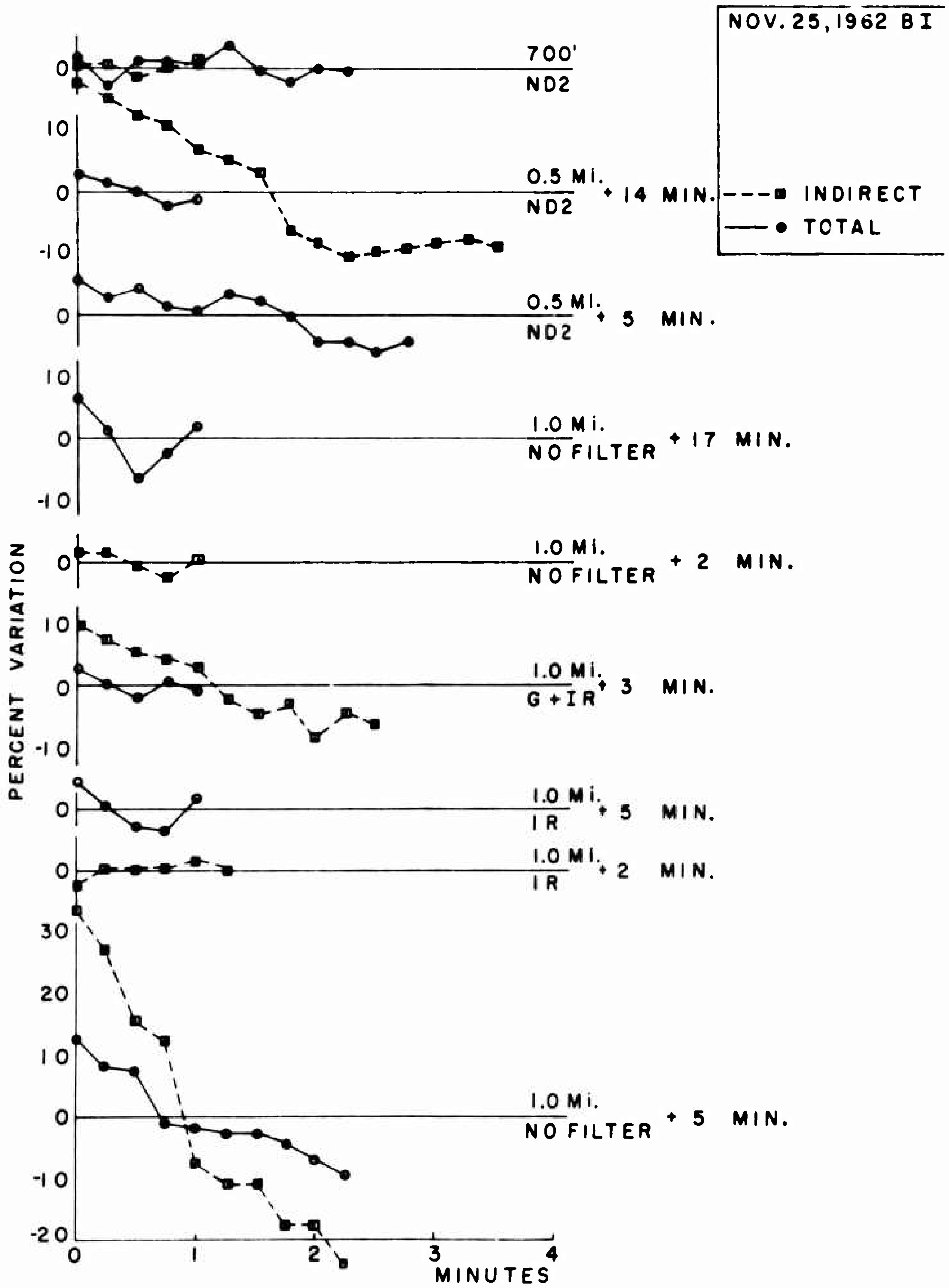


FIG. 54 (d) SIGNAL VARIATIONS VS TIME

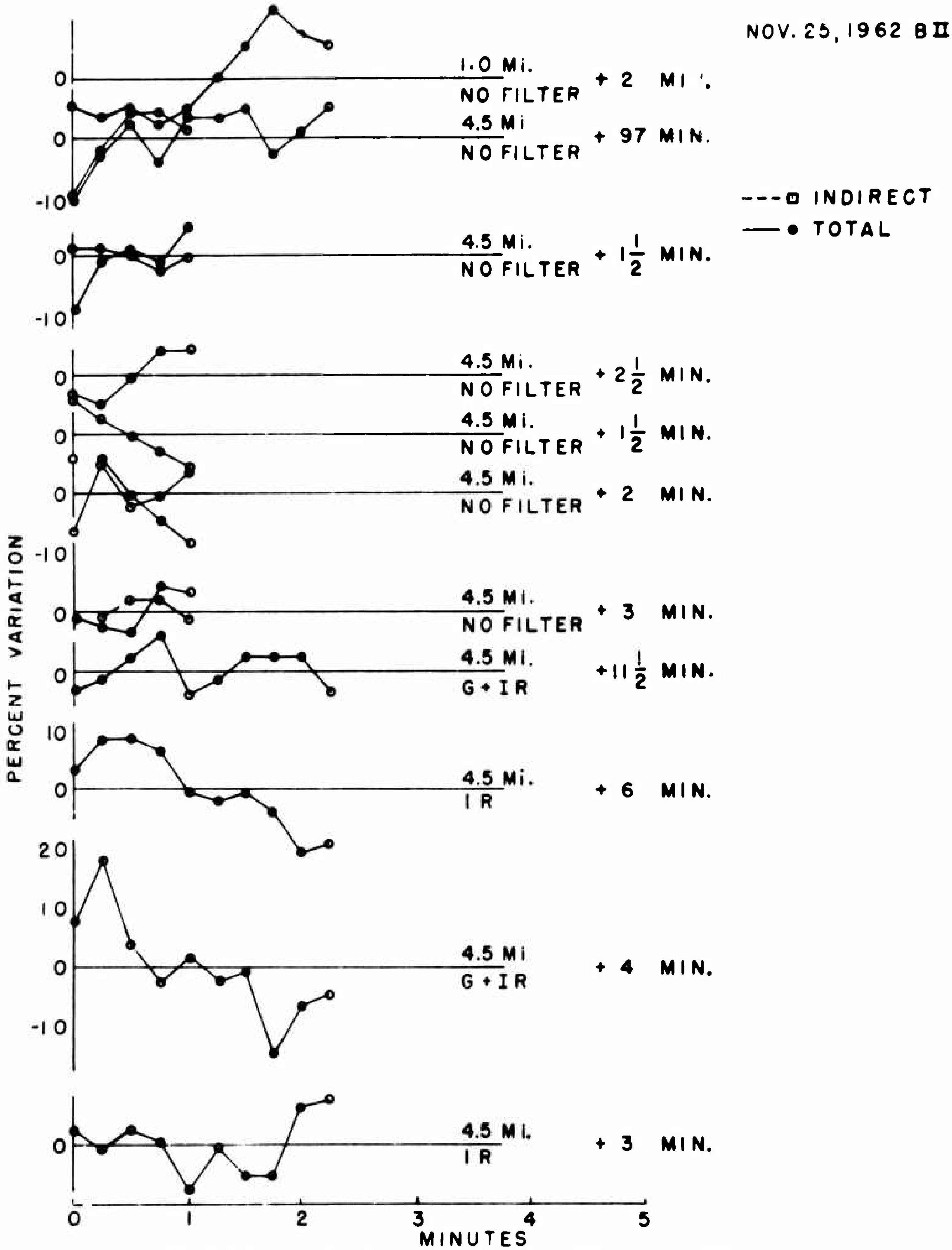


FIG. 54 (e) SIGNAL VARIATIONS VS TIME

4. $H_{G+IR/1}$ = 37.5 (0314-0317 hrs) -- infinite (0317-0320 hrs)

5. $H_{IR/1}$ = 4.1 (0320-0328 hrs)

6. $H_{NF/1.0}$ is infinite (0330-0335 hrs)

7. $\left[\frac{\text{total } 4.5 \text{ mi}}{\text{total } 1.0 \text{ mi}}\right]_{IR} \approx 0.005$ (0307-0309 hrs)

Analysis: Results 1, 2, and 3 are included in Fig.12. The upper regions of the curve could very well be less steep, since the smaller values for σ between 0.5 and 1.0 mile as compared to 0.13 and 0.5 mile indicate an improvement in visibility at the 0.5-mile point while measurements were being carried out at the one-mile point. A greater σ at 1.0 mile would therefore follow should a somewhat greater direct component be considered at the 0.5-mile point.

The greater value for $H_{(G+IR)}$ than H_{IR} indicates the greater scattering effect in the green and the greater absorption effect in the near infrared in the presence of ice crystals and perhaps water droplets. The infinite value for H at one mile with no filter is due to the predominance of the visible wavelength and perhaps to some extent to the added effects of blowing snow as a result of the increased winds at about 0330 hours.

Result 7 includes the limited data obtained at the 4.5-mile point until the generator broke down.

Figure 55 indicates the intensity vs distance relationship up to 1.0 mile such that the inverse distance square/total intensity increases rapidly with distance.

Figure 56 shows the almost unchanged values of the ratios of the indirect to the total transmittances over the short pathlength of about one mile.

Ice fog in the vicinity of the 100-ft tower level complicated analysis (Figs. 57-a and 57-b). The variation of the indirect intensity at one mile for the no-filter case in Fig. 54-a is due, in large measure, to the fog-clearing effect near the top of the tower at that time. The maximum variation from the norm is +30%, and -12% at one mile under visibility conditions between 1/2 and 1 mile. The vertical temperature gradient varied from +2.0°C to +0.5°C and +0.6°C and +0.3°C between the surface and 200 ft and 87 ft. respectively.

30 Nov 62, 0146-0527 hours, S-1 Response

Weather conditions: sky partly obscured by scattered ground ice fog extending up to about 200 ft

visibility of 1 to 2 miles

temperature: -35 to -46°C
-6.0°C to -2.5°C gradient (vertical)

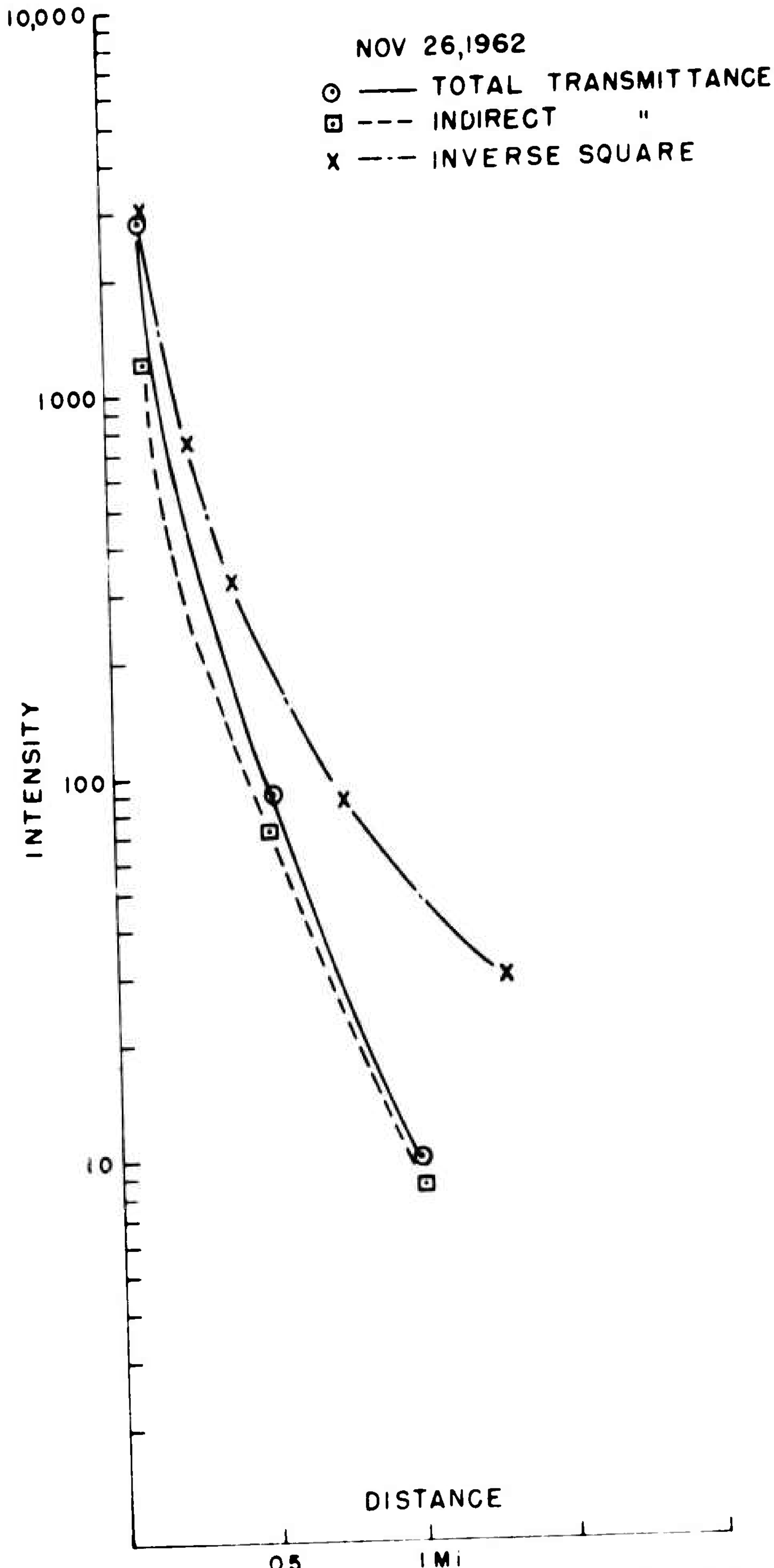


FIG.55 INTENSITY VS DISTANCE

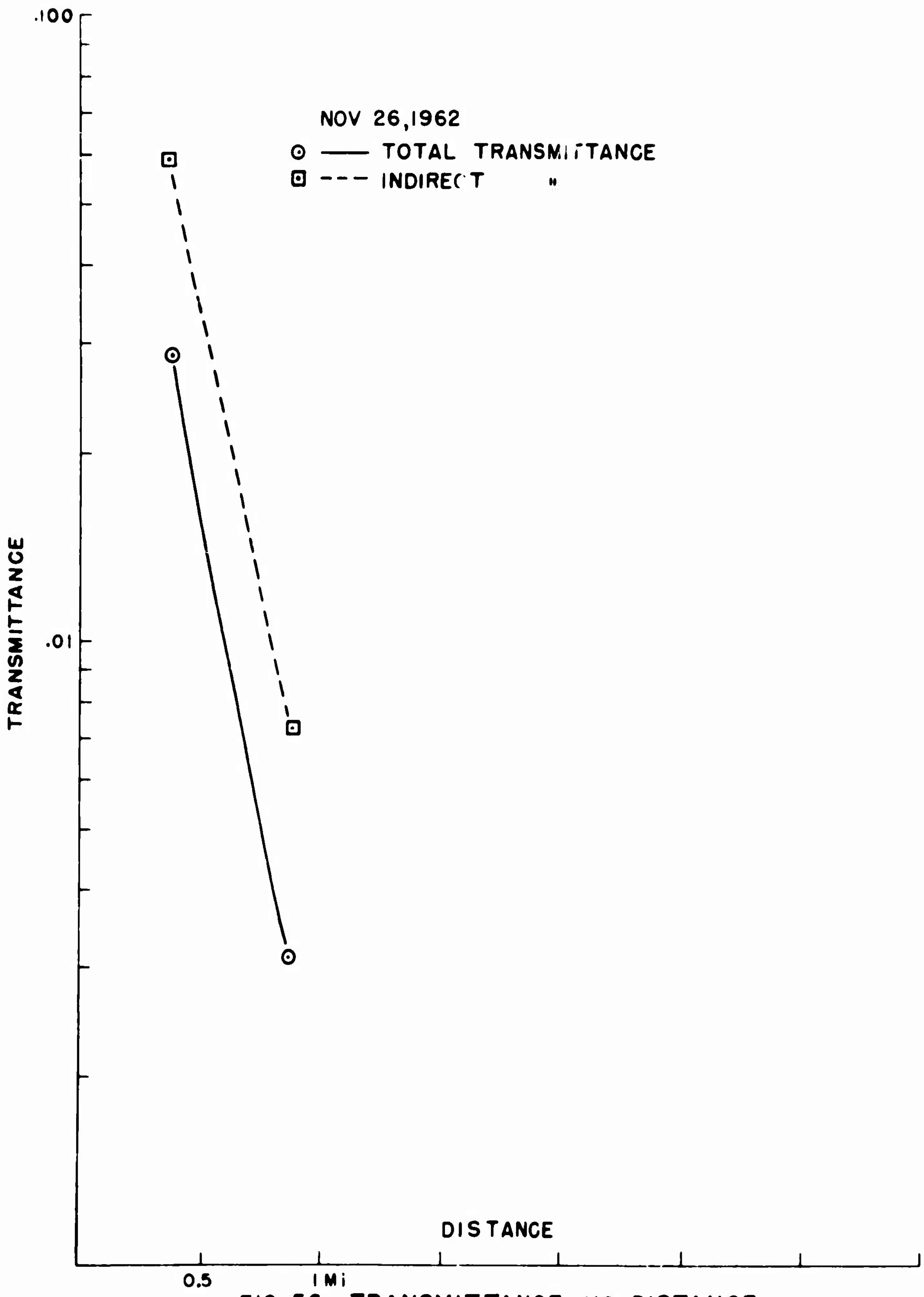


FIG. 56 TRANSMITTANCE VS DISTANCE

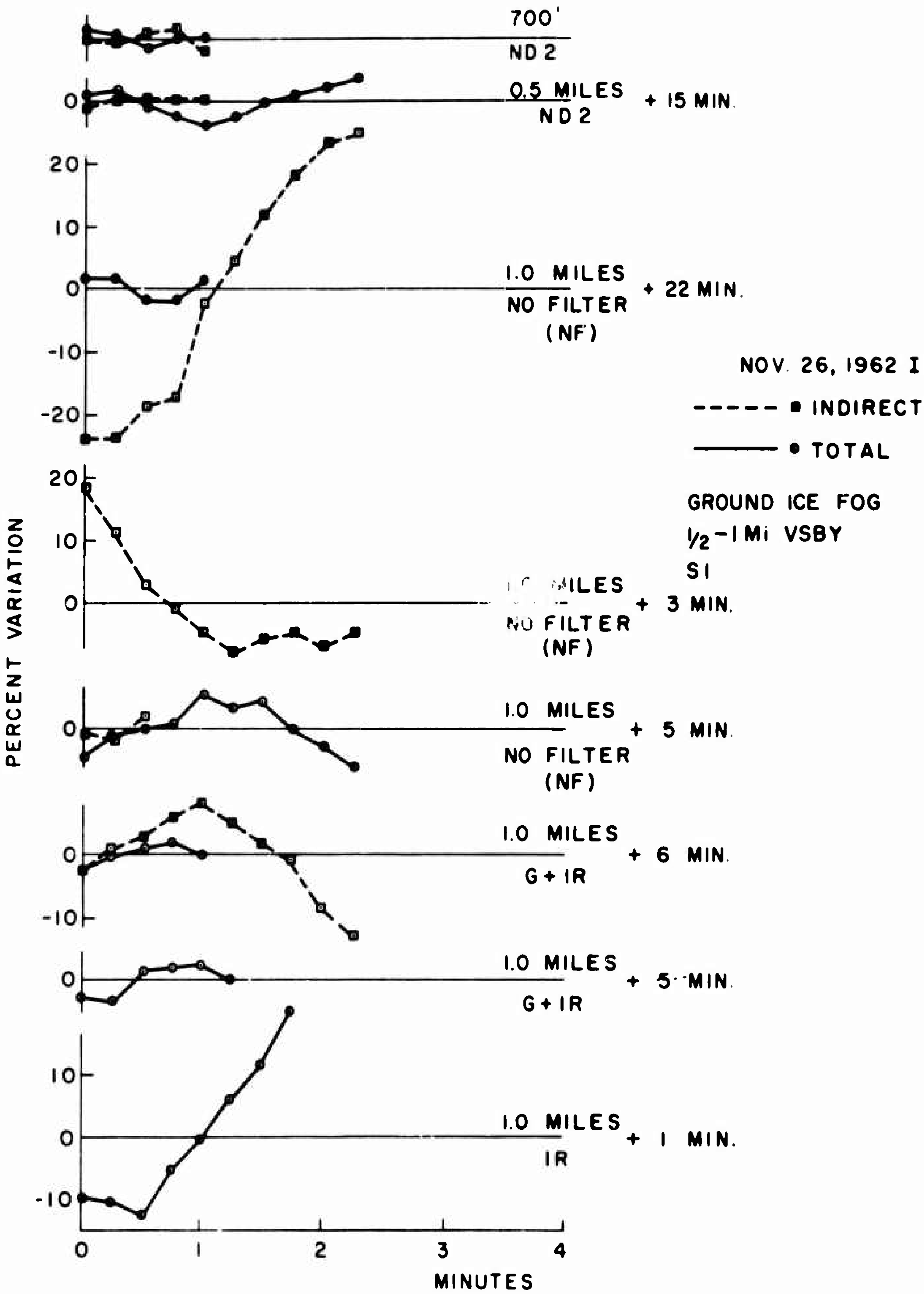


FIG. 57 (a) SIGNAL VARIATIONS vs TIME

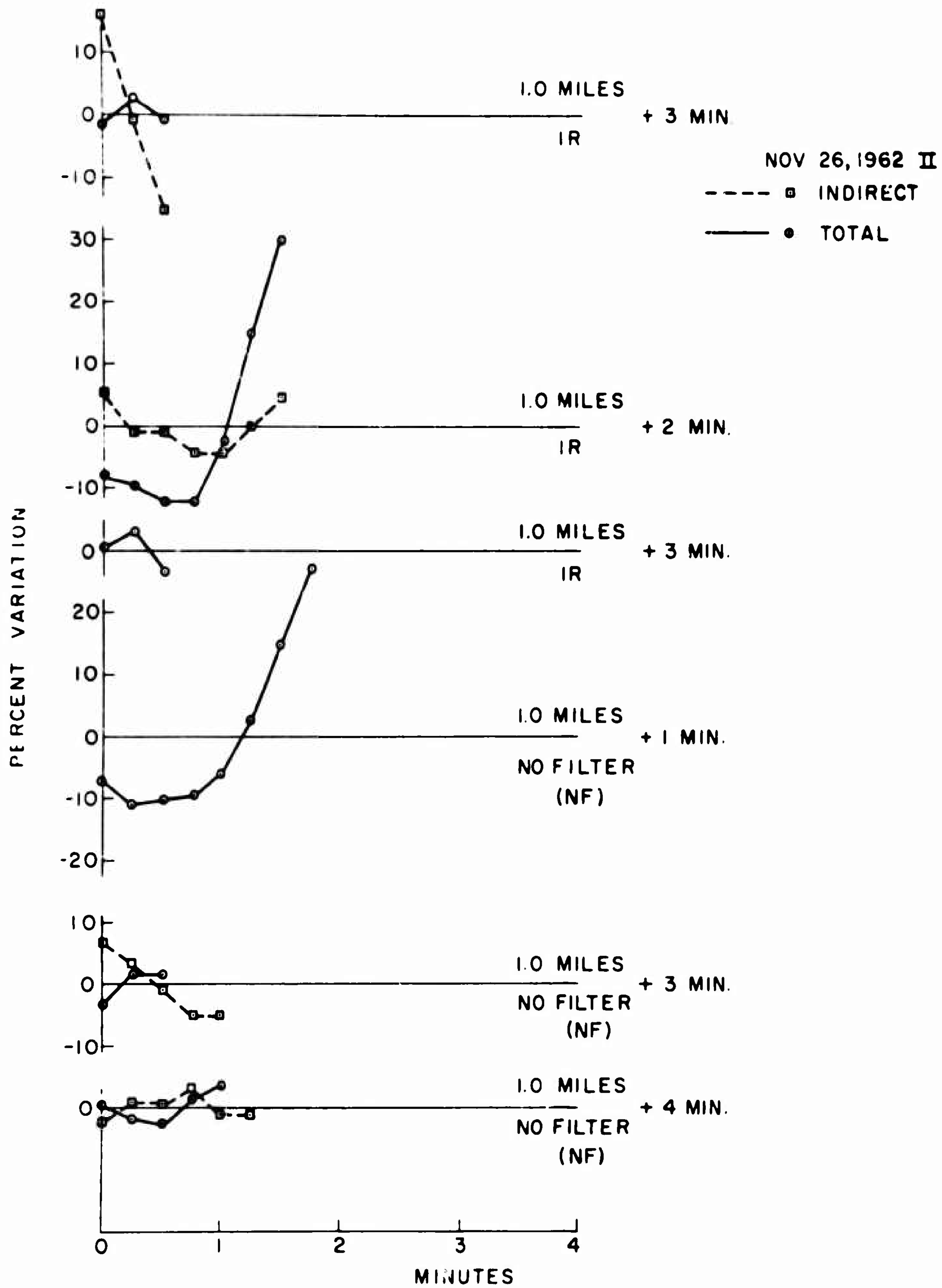


FIG. 57 b. SIGNAL VARIATIONS VS TIME

ENE winds, 8 to 10 knots, becoming E in later period

Other Weather Observations: At 0.13 mile between 0146 and 0300 hours, light ice fog was observed around surface and tower lights, seemingly less intense at 100 ft than at 200 ft. Some stars were faintly visible, and no noticeable halos were around the tower lights. At 0.5 mile, between 0312 and 0315 hours, light halos were observed around the surface lights. At 1.0 mile between 0331 and 0400 hours, light halos were observed around the surface lights, while none appeared around the 200-ft level. At 4.5 miles between 0509 and 0527 hours, only the diffuse or indirect light of the flash appeared visible, while the 200-ft tower light appeared visible in an 8-power telescope.

Results:

1. $H_{NF/0.13} = 0.39$ (0146-0149 hrs), $\rightarrow$ 0.31 at 0300-0302 hrs; $\sigma D = 0.30$ (-40°C)

2. $H_{NF/0.5} = 0.47$ (0312-0315 hrs), $\sigma_{0.13 - 0.5} = 2.3$/mi (0300-0315 hrs) $\sigma D = 1.2$ (-40°C)

3. $H_{NF/1.0} = 0.54$ (0335 hrs), $\sigma D = 1.4 \rightarrow 0.63$ $\sigma D = 1.6$ (0400 hrs); $\sigma_{0.5 - 1.0} = 1.4$/mi (0314-0335) $\rightarrow$ 1.6/mi, (0314-0400 (-40 5o -42°C)

4. $H_{G+IR/1.0} = 0.53$ (0343) (-42°C)

5. $H_{IR/1.0} = 0.64$ (0353) (-42°C)

Analysis: It is interesting to note that $H_{IR/1.0}$ is about 20% greater than $H_{G+IR/1.0}$ during a short time when the weather appeared unchanged. This may prove indicative of ice fog conditions with no or negligible water vapor present, with temperatures of -35 to -44°C, since water droplets spontaneously freeze below about -33°C.[a]

From Fig. 58 one notes that at about 1/4 mile the total intensity remains about the same as if there were no atmospheric attenuation, i.e., with zero surface albedo. At 1.0 mile the total intensity drops to about 1/3 that of a nonattenuating atmosphere with negligible surface albedo with a nonlinear increase of $\frac{\text{inverse distance square intensity}}{\text{total intensity}}$ versus distance being present.

The parallelism of the infrared plus green versus the infrared total intensity curves suggests an independence of wavelength versus total transmittance in this type of ice fog. The total transmittance of the infrared plus green as well as the infrared in the 1 to 4.5 mile range is approximately 50% that of a nonattenuating atmosphere with negligible surface albedo.

The ratio of the indirect transmittance to the total transmittance, derived from Fig. 59, increases nonlinearly with distance.

The presence of fog around the ground and tower lights and the obscuring of the tower lights, particularly at the 100-ft tower level, at 4.5 miles,

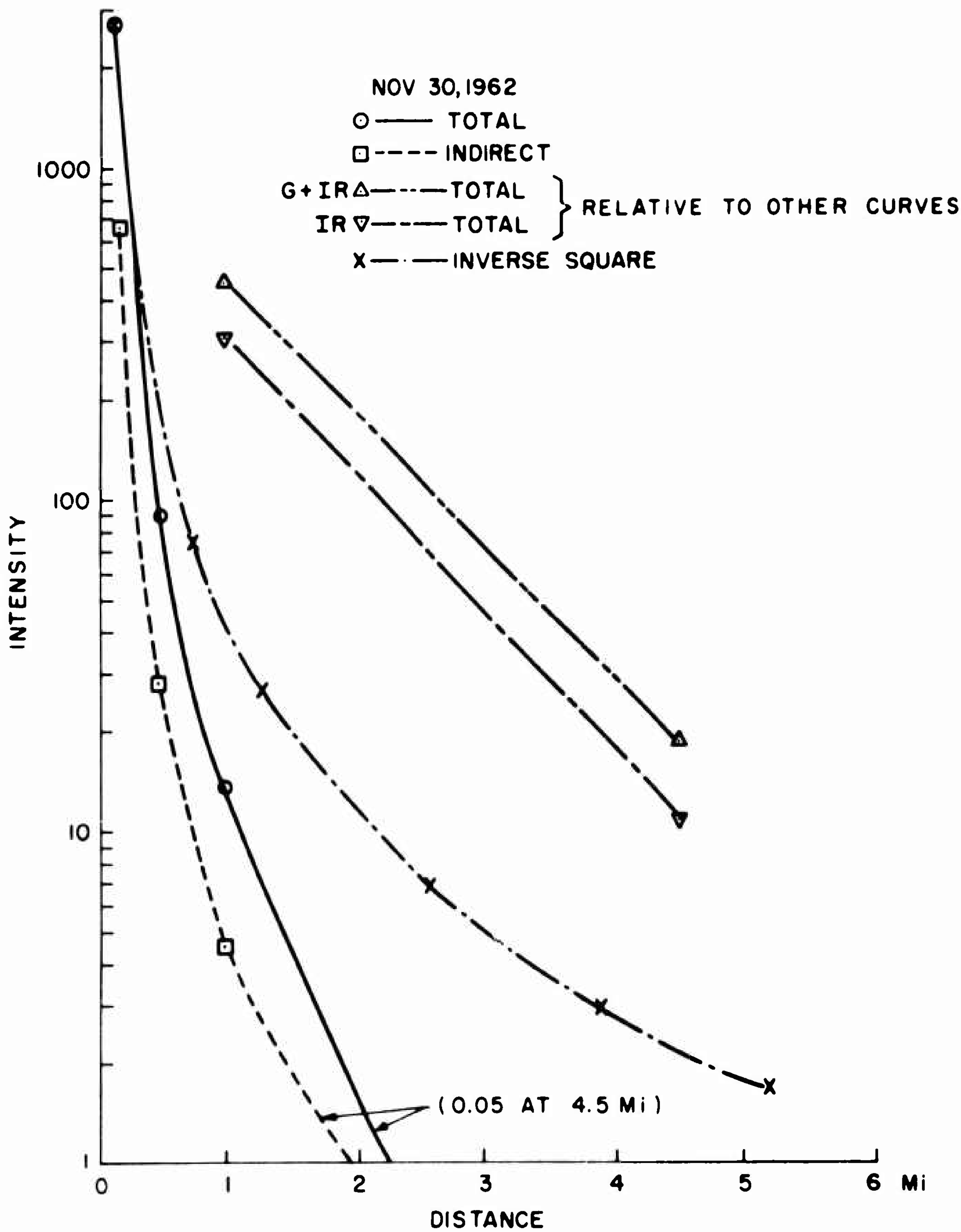


FIG. 58 INTENSITY VS DISTANCE

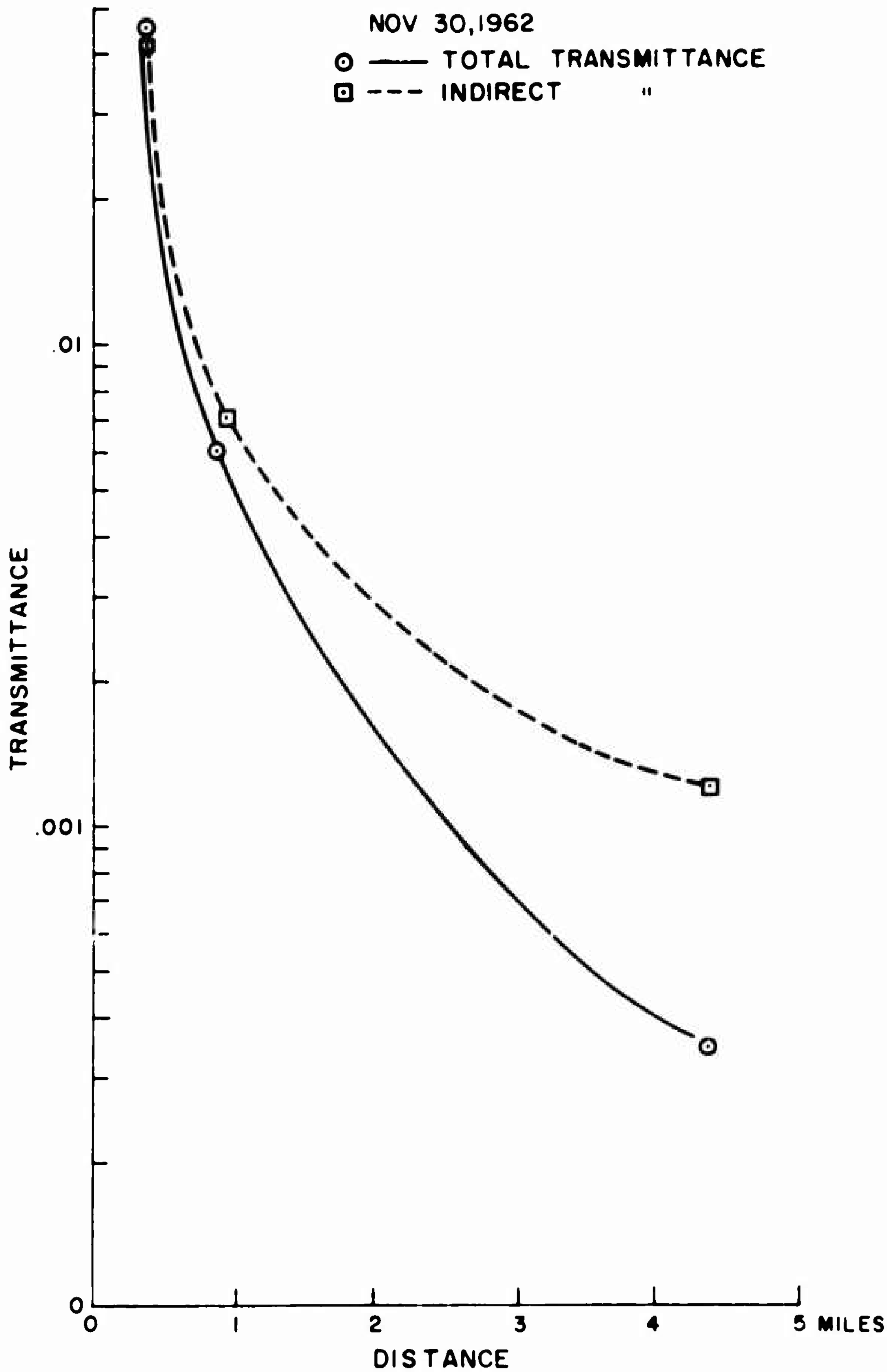


FIG. 59 TRANSMITTANCE VS DISTANCE

complicated analysis. The latter effect sharply limited the fluctuation spread at the 4.5-mile point so that at no point did the maximum fluctuation from the total average exceed +14% and -15% deviation from the norm (Figs. 60a and b). One- to 2-mile visibilities prevailed under ground ice fog conditions throughout the test period. The vertical temperature gradient varied from -6.0°C to -2.5°C, -8.1°C to -6.6°C, -9.8°C to -13.3°C from the surface to 200 ft, 87 ft, and 15 ft, respectively.

CONCLUSIONS AND RECOMMENDATIONS

In the summation graph of indirect/direct intensity vs optical depth (Fig. 12), which includes some results obtained in the local New Jersey area, one can note the greater value of the ratio in the arctic environment than locally, except for curves 5 and 7. Curve 5 involves a 1/2 to 1 mile visibility in variable fog with very light falling snow, while curve 7 takes into account a 1- to 2-mile visibility situation in the presence of ground ice fog comprised almost entirely of ice crystals. There is no evident explanation for these deviations; however, the remaining graphs emphasize the much greater indirect/direct ratio for a given optical path in the presence of a surface albedo of unity with and without a cloud cover, particularly for the situation involving a low overcast and very good visibilities.

A "duct type" effect seems also to be highly evident for the 27 Oct and 17 Nov cases, as shown in Fig. 12, by comparison with the local New Jersey effects at a much lower surface albedo. For example, an increase of more than 300% occurs for H at an optical depth of 1 in the presence of a 2000-ft extensive cloud deck on 17 Nov, with a surface albedo of near unity, as compared to the local curve 9 of Fig. 12 under clear skies and approximately 0.2 surface albedo.

Figure 34 for 13 Nov, comparing total vs inverse distance square intensity vs distance, shows a trapping, or "duct" effect, of light energy beyond about the 1-mile point with a homogeneous snow surface and an estimated 3000-ft ceiling, plus scattered fog patches with prevailing good visibilities. This duct effect reaches a maximum between 4.5 and 5.5 miles, with an increase of about 350% evident in this range. Figure 40 for 15 Nov is another similar example of this duct effect, with the boundaries being the snow surface and a broken to overcast 2000-ft ceiling under prevailing good visibility conditions and scattered fog. This effect becomes noticeable beyond about 1/2 mile from ground zero, with an increase of 700 to 1600% beyond 3 miles. The presence of fog patches in both cases, however, complicates a fully reliable evaluation of the results. A duct effect also appears on 29 Oct, with presence of fog patches, with a maximum increase to about 350% beyond one mile.

It is also noteworthy that very large variations in the received light intensity can occur from one flash to the next or over very short time intervals of less than 30 seconds. This variation assumes maximum magnitudes of 160% in the presence of excellent visibilities and steep temperature inversions and of somewhat less magnitudes in the presence of excellent visibilities and smaller temperature inversions for a given distance. Such variations, moreover, show a marked distance dependency, but no wavelength dependency. This would indicate that, in general, such a variation can occur for any effective point light pulse type radiation source under similar meteorological conditions.

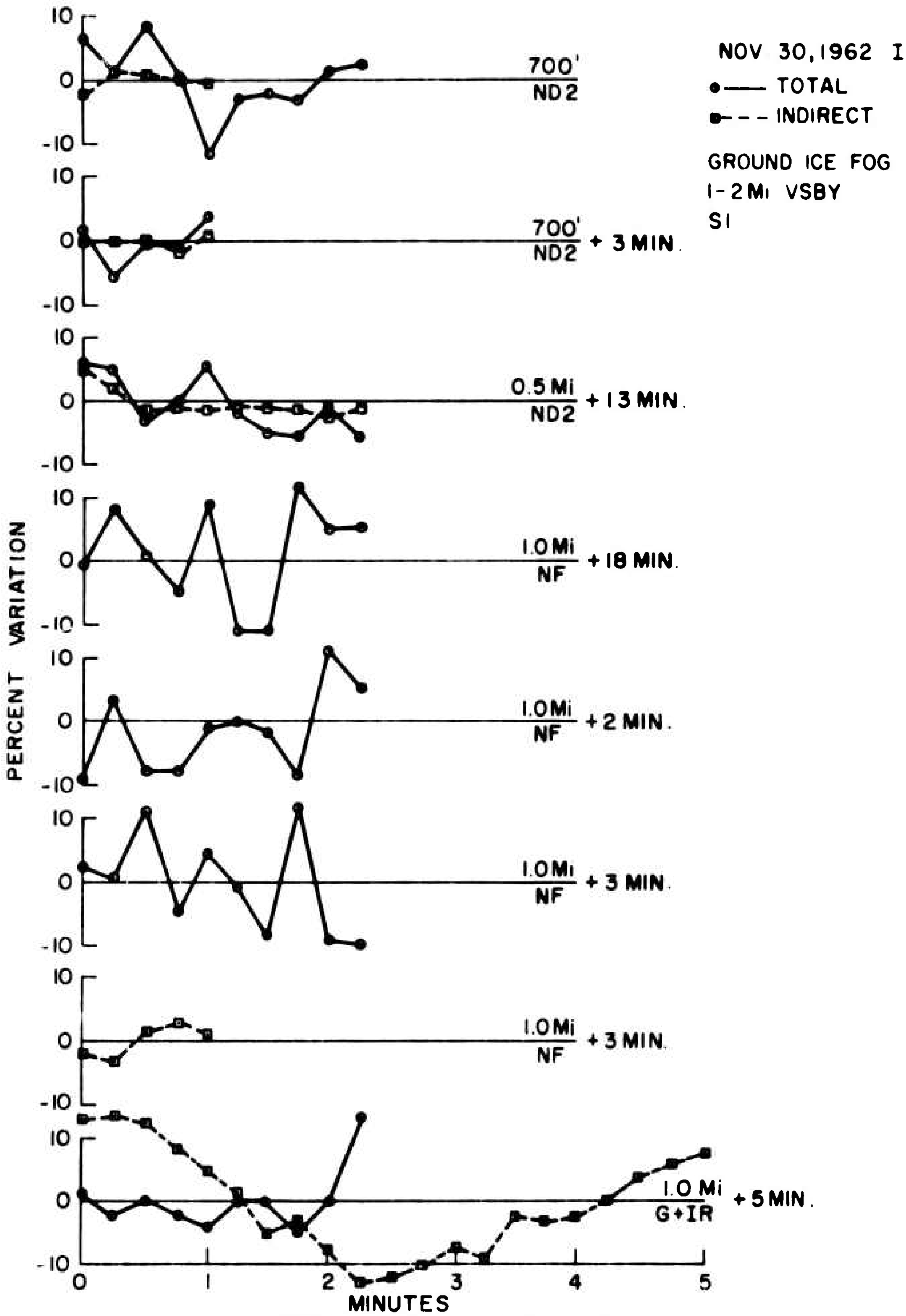


FIG. 60a SIGNAL VARIATION VS TIME

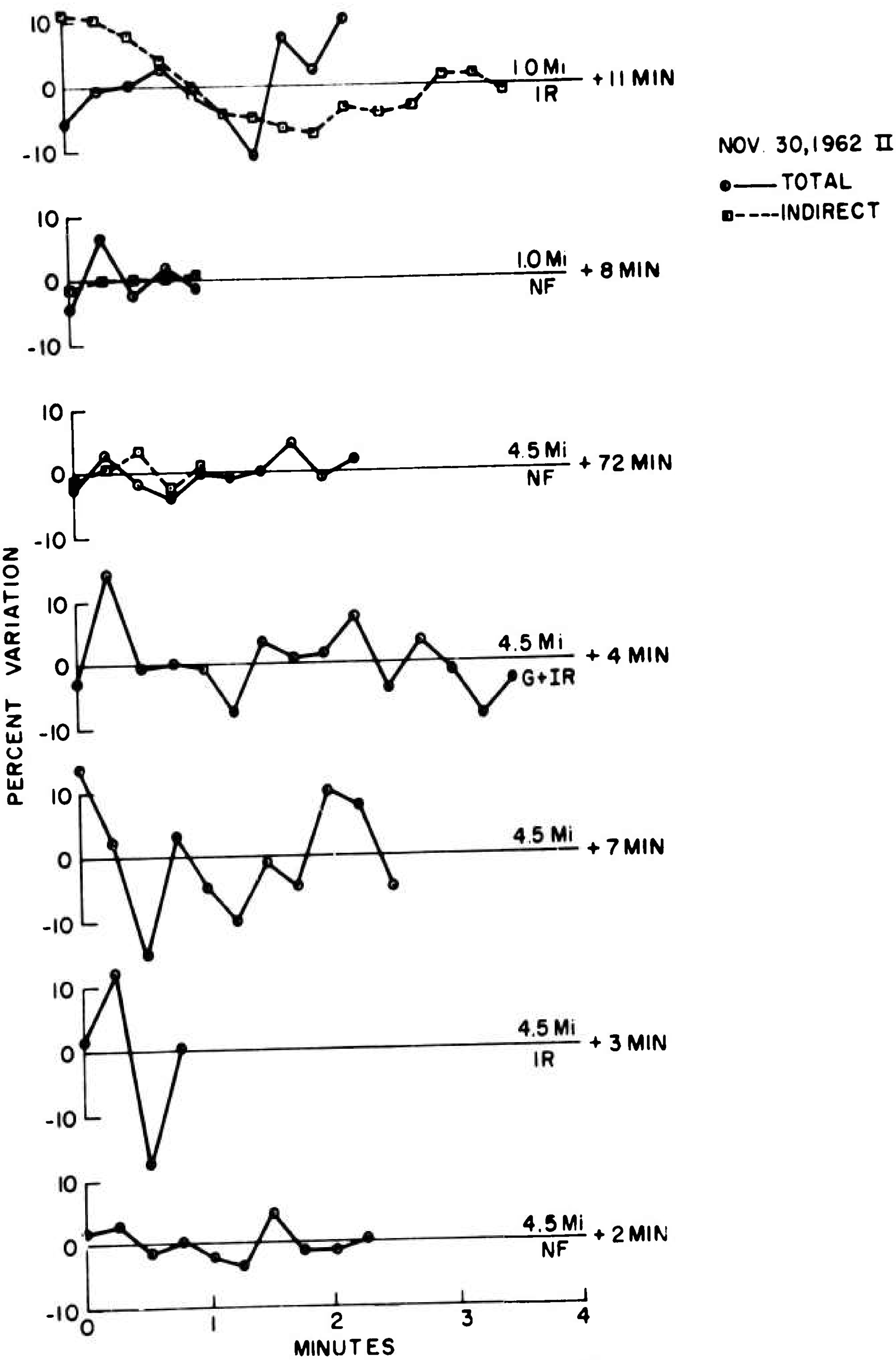


FIG. 60b SIGNAL VARIATIONS VS TIME

It is recommended that a statistical type of empirical effort be made in order to obtain substantial quantitative relationships for a maximum variety of specific and measurable atmospheric conditions in different climates.

ACKNOWLEDGMENTS

We wish to thank Dr. Helmut Weickmann for providing us the opportunity and encouragement to expose ourselves to the challenging environment of the Greenland Icecap. Acknowledgment is also made of the logistic support given by the Engineer Corps of Fort Belvoir, and some of the weather data provided by the Fort Monmouth Army Meteorological Team and the Fort Huachuca Meteorological Team. Appreciation is expressed to Mr. L. Budney for computing and plotting the signal percentage variation from the norm graphs and the combined spectral response curves.

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2. Middleton, W. K., Vision Through the Atmosphere, U. of Toronto Press p. 44, 1952, Fig. 3.11, p 44.

3. Mason, B. J., Clouds, Rain, and Rainmaking, Cambridge University Press, 1962.

APPENDIX - SUMMARY CHART

Date and Time	General Weather Conditions	Results*	Further Comments
14 Mar 62 2130 - 2330 hrs	Clear skies. Estimated visibility >40 miles. +10°C gradient (between surface and 200 ft, which applies to all cases indicated in this chart). 9-knot surface winds.	(1) $H_{NF} = 0.33$, estimated optical depth < 0.34. (2) $\left[\frac{\text{Indirect}}{\text{Total}}\right]_{NF} = 0.25$	About a 50% increase in H_{NF} compared to local New Jersey area. 70% maximum deviation from total intensity average, no filter (NF), over a 2-1/4 minute interval (at a 5/minute flash rate, which applies to all cases listed in this chart). S-10 PM (photomultiplier).
15-16 Mar 62 2300 - 0100 hrs	Clear skies. Estimated visibility of 7-10 miles. +16°C gradient. 7-knot surface winds.	(1) $H_{NF} = 3.0$, estimated optical depth 1.5. (2) $\left[\frac{\text{Indirect}}{\text{Total}}\right]_{NF} = 0.75$	About a 100% increase in H_{NF} compared to local New Jersey area. 40% maximum deviation, no filter, for total intensity average over a 2-1/2 minute interval. Total radiation at 4.5 miles equal to about 25% of total of 14 Mar. S-10 PM.
24 Mar 62 0100 - 0300 hrs	Light ground fog extending to at least 200 ft. Estimated visibility of 3-4 miles. +12°C to +13°C gradient. 14-knot surface winds.	(1) H_{NF}, B,G,R = 47, ∞, 64, 64, respectively. Estimated optical depth (NF) of 4.5 (2) $\left[\frac{\text{Indirect}}{\text{Total}}\right]_{NF,\ B,G,R} = 0.98 - 1.0$ (3) $\left[\frac{\text{Indirect (vertical)}}{\text{Total}}\right]_{NF} = 0.36$	The indirect radiation equalled the total, with the receiver pointing towards the light source. However, where the receiver is pointing vertically overhead, the indirect radiation was 36% of the total with the receiver pointing directly at the source. 20% maximum deviation, NF and B (blue filter) from total and indirect intensity average over a 2-1/4 minute interval. No wavelength dependence evident for $\left[\frac{\text{Indirect}}{\text{Total}}\right]$. Total or indirect radiation at 4.5 miles equal to about 1/3 the total on 15-16 Mar 62, S-10 PM.

*Results - The period of 14-27 Mar 62 applies to a fixed distance of 4.5 miles at all times.

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Date and Time	General Weather Conditions	Results	Further Comments
25 Mar 62 0100 - 0300 hrs	Light mist with light blowing snow; estimated visibility of 10-15 miles. +8°C to +9°C gradient. 17-knot, ENE surface winds.	(1) H_{NF} B,G,R = 1.4, 2.4, 1.0, 0.95, respectively; estimated optical depth (NF) of 1.1. (2) $\left[\frac{\text{Indirect (vertical)}}{\text{Total}}\right]_{NF}$ = 0.14. (3) $\left[\frac{\text{Indirect (vertical)}}{\text{Direct}}\right]_{NF}$ = 0.33.	The ratio of the $\frac{\text{Indirect}}{\text{Direct}}$ decreased with increasing wavelength so that $\left[\frac{H_B}{H_G}\right] \approx \left[\frac{\lambda_B}{\lambda_G}\right]^{-4}$ and $\left[\frac{H_G}{H_R}\right] \approx \left[\frac{\lambda_G}{\lambda_R}\right]^{-0.4}$ About a 33% increase in H_{NF} compared to local New Jersey area. With receiver pointing vertically overhead, the indirect radiation was 14% of the total with the receiver pointing directly at the source. About 70% maximum deviation, green and red filters, from total intensity average over 2-1/4 and 4-1/4 minute intervals, respectively. Total radiation at 4.5 miles equal to about 33% of total on 24 Mar, 8-10 PM.
27 Mar 62 0000 - 0300 hrs	Ground ice fog at -38°C near surface. Estimated visibility of 1-1/2 miles. 12-knot surface winds.	(1) H_{NF} B,G,R = 26, 20, ∞, 12, respectively; estimated optical depth (NF) of 9.0. (2) $\left[\frac{\text{Indirect}}{\text{Total}}\right]_{NF\ B,G,R}$ = 92 - 100%	It is noteworthy that almost 50% of the total radiation on 25 Mar, i.e., good visibility night of 10-15 miles (although in the presence of some light mist plus light blowing snow) can reach a 4.5-mile distant target as indirect radiation under relatively poor visibility conditions of 1-1/2 miles on the night of 27 Mar. 40% maximum deviation, green filter, from total and indirect intensity average over a 5-minute interval. 8-10 PM.

Date and Time	General Weather Conditions	Results	Further Comments
27 Oct 62 0135 - 0305 hrs	Fog with 300-500 ft ceiling; 1/2 to 3/4 mile estimated visibility. 10-13 knot, SE surface winds.	(1) H_{NF}/0.2 mi = 5.8; optical depth 0.84. (2) H_{NF}/0.5 mi = 46; optical depth 2.1.	Direct radiation is a negligible portion of the total at 0.5 mile; however, rapid fluctuations are expected to be present. Maximum NF deviation of about 3% for total and indirect over a 3/4-minute interval. S-11 PM.
29 Oct 62 0145 - 0545 hrs	2-3/10 ground fog becoming 6-8/10 towards end of period; visibility varying between 3 to 10 miles, becoming greater than 50 miles briefly. -0.2°C to +3°C gradient. 8-10 knot, SE surface winds.	(1) H_{NF}/0.5 mi = 0.061; optical depth = 0.02. (2) H_{NF}/1.0 mi = 0.080; optical depth = 0.44. (3) H_{NF}/4.5 mi = 2.3; optical depth = 1.80. (4) H_B/4.5 mi = 1.9; optical depth = 1.71. (5) H_G/4.5 mi = 1.0; optical depth = 1.26. (6) H_R/4.5 mi = 0.88; optical depth = 1.26. (7) H_{IR}/1.0 mi = 0.70; optical depth = 1.1. (8) H_{B+IR}/1.0 mi = 0.99; optical depth = 1.1.	At 4.5 miles, H_{IR} is about 40% greater than H_B + IR, whereas at 1 mile, H_B + IR is about 40% greater than H_{IR}. This effect can be attributed to the greater ratio of the indirect to absorption effects for the near IR over greater distances. Presence of "duct effect" reaching a maximum of over 300% at 4.5 miles for total radiation between 1 and 4.5 miles. Total and indirect transmittances in the blue, green, and red independent of wavelength. Maximum deviation of 38% for total red, 33% for total green, and 28% for total blue at 1 mile. S-11 and S-1 PM.

Date and Time	General Weather Conditions	Results	Further Comments
29 Oct 62 0145 - 0545 hrs (contd)		(9) $H_{B+IR/4.5\ mi} = 16.4$; optical depth = 4.95. (10) $H_{IR/4.5\ mi} = 22.2$; optical depth = 6.75.	
2 Nov 62 0125 - 0325 hrs	8/10 fog with very light falling snow. 3/4 - 1 mile estimated visibility. -0.3°C gradient. 9 - 10 knot, S surface winds.	(1) $H_{NF/4.5\ mi} = 12$ (0125 hrs) → 24 (0135 hrs) optical depth = 13.5 (2) $H_{G+IR/4.5\ mi} = 10$ (0155 hrs) = 19 (0310 hrs) (3) $H_{B+IR/4.5\ mi} = 20$ (0218 hrs) (4) $Total_{R+IR/4.5\ mi} = 91\%$ $indirect_{R+IR/4.5\ mi}$ (0238 hrs) (5) $H_{R+IR/4.5\ mi} = 20$ (0243 hrs) (6) $Total_{NF/4.5\ mi} = 90\%$ $indirect_{NF/4.5\ mi}$ (0245 hrs) (7) $Total_{IR/4.5\ mi} =$ $indirect_{IR/4.5\ mi}$ (0255 hrs) (8) $Total_{B/4.5\ mi} = 95\%$ $indirect_{B/4.5\ mi}$ (0300 hrs) (9) $H_{NF/4.5\ mi} = 13$ (0321 hrs) optical depth = 13.5	This is a good example of the rapid and wide variations occurring in fog plus very light falling snow. Maximum deviation of 33% IR filter, from the indirect intensity average over a 2-1/2 minute interval at 4.5 miles. S-1 PM.

Date and Time	General Weather Conditions	Results	Further Comments
7 Nov 62 0015 - 0135 hrs	10/10 sky observed in rapidly varying scattered ground fog, with 8/10 to 9/10 clouds at about 1200 ft. 1/2 mile visibility; +3.2°C gradient. 10 - 13 knot SE surface winds.	(1) $H_{NF}/0.2\ mi = 0.98$ (0015 - 0022 hrs) optical depth = 1.13 (2) $H_{NF}/0.5\ mi = 1.02$ (0125 - 0135 hrs) optical depth = 3.2	There is little difference between the H values for an optical depth of 1.3 or greater within 1/2 mile from the source, seemingly due to the presence of some ground fog and a low cloud deck. Maximum deviation of 22%, NF, from the total intensity average over a 2-minute interval. S-1 PM.
8 Nov 62 0000 - 0145 hrs	Scattered ground fog with 10/10 thin, high clouds at beginning of test up to 1-mile measurements, and becoming clear afterwards. Two-mile visibility at 1/2-mile point improving to >50 miles between the 1- and 4.5-mile distances. +12°C to +13.5°C gradient. 4 - 6 knot ESE surface winds.	(1) $H_{NF}/0.13\ mi = 0.42$ optical depth = 0.21 (2) $H_{NF}/0.5\ mi = 0.38$ optical depth = 0.80 → 0.23 (10 min later) optical depth = 0.84 → 0.04 (10 min later) optical depth = 0.77 (3) $H_{NF}/1 = 0.54$ optical depth = 1.5 (4) $H_{NF}/4.5\ mi = 0.31$ optical depth = 0.12	Scattered ground fog resulted in relatively high H values at the 0.13-mile and initially at the 0.5-mile points. σ changed slightly during a 25-minute interval at 0.5 mile, yet H dropped rapidly in that time by about one order of magnitude. This can perhaps best be explained by the deterioration of the ground fog above the light source at the 100-ft tower level. The indirect intensity begins to decrease at a more rapid rate than the total at about 1 mile and continues to do so until at least the 4.5-mile point. Maximum deviation of +350% at +13.5°C gradient and 50 miles visibility from the total intensity over a 4-3/4 minute interval at 4.5 miles. S-1 PM.

Date and Time	General Weather Conditions	Results	Further Comments
9 Nov 62 0000 - 0200 hrs	Sky obscured by 10/10 fog with about a 700-ft ceiling and scattered patches in the vicinity of the 200-ft tower level. Visibility varying from 3 to 50 miles. -1.4 to -1.6°C gradient. 3 - 5 knot S surface winds.	(1) H_{NF}/0.13 mi = 0.42; σ D = .0065 (2) H_{NF}/0.5 mi = 1.02; σ D = .025 (3) H_{NF}/1.0 mi = 1.55; σ D = 1.1 (4) H_{NF}/4.5 mi = 0.36; σ D = 0.54	The large variations of σ and H would seem to indicate the presence of scattered fog between the ground and light source at the 100-ft tower level, which complicates analysis. The H variations could also be due, in part, to the fog ceiling variation. The indirect intensity drops more rapidly with distance than the total so that the total transmittance exceeds the indirect transmittance at distances beyond about 2-1/4 miles. A "duct effect" occurs up to about 2 miles. Maximum deviation of 55% NF from the total intensity average over a 2-1/4 minute interval. S-1 PM.
11 Nov 62 0200 - 0300 hrs	Five-mile surface; estimated visibility in ice fog (-33 to -37°C) 10/10; thin, high clouds; low-level fog patches. 5 - 6 knot SSE surface winds.	No signal nor flash observed at the fixed 4.5-mile station.	The indirect light flash was observed about 3/4 mile away. Light source embedded in drifting fog patches. S-11 PM.
13 Nov 62 0118 - 0548 hrs	3000-ft estimated overcast, varying scattered fog patches between Camp Century tower and the 7.6-mile point. 3/5 mile to unlimited visibility. +0.3°C to -0.4°C gradient. 8-knot SSW surface winds.	(1) H_{NF}/0.13 mi = 0.60; σ D = .078 (2) H_{NF}/0.5 mi = 4.0; σ D = 2.4 (3) H_{NF}/0.5 = 1.68; σ D = 0.74 (4) H_{NF}/1.0 mi = 0.97; σ 0.5 - 1 negative	This is an example of the wide variability in H and σ as a result of the relatively rapid fog patch variations in the vicinity of the light source. A "duct effect" occurs between 1 and 7 miles. Maximum deviation of 20%, NF, from the indirect intensity average

Date and Time	General Weather Conditions	Results	Further Comments
13 Nov 62 (contd)		(5) $H_{NF}/4.5$ mi = 12.8; σ D = 1.62	over a 2-1/2 minute interval. Fog patches near light source complicated analysis. S-11 PM.
14 Nov 62 0355 - 0757 hrs	Partly cloudy at about 2000 ft, with scattered fog patches at about 200 ft and some variable high cloudiness (3-7/10 cirrostratus) becoming 8-9/10 stratocumulus at about 2500 ft with 1-2/10 low-level fog and ice fog towards end of test at the 4.5-mile point. 1-1/2 to 4 miles estimated visibility. -20°C in ice fog. +1.6°C to +3.5°C gradient. 4 to 9 knots SE surface winds.	(1) $H_{NF}/0.13$ mi = 0.19; σ D = σ D = 0.42 (2) $H_{NF}/0.5$ mi = 0.97; σ D = 1.1 (3) $H_{NF}/1.0$ = 1.07; σ D = 0.68 (4) 60% total intensity, NF, increase towards end of test at 4.5-mile point.	The presence of scattered fog patches complicates analysis, but it is particularly noteworthy that a 60% total intensity, NF, occurred while the overall visibility was deteriorating and a low overcast had appeared at the 4.5-mile point. Maximum deviation of about 15%, NF, from the total and indirect intensity average over a 2-1/2 interval at 1 mile and 17% from total intensity average, G spectral region, over a 1-minute interval at 4.5 miles.
15 Nov 62 0147 - 0826	Broken to overcast cloudiness at about 2000 ft with scattered varying ground fog. Visibility varying from about 3 miles to unlimited. +0.9°C to +3.3°C gradient. Two to 6 knots, E - ESE surface winds.	(1) $H_{NF}/0.5$ mi = 0.95; σ D = 0.09 (2) $H_{NF}/4.5$ mi = 8.0; σ D = 0.81 (3) $H_{NF}/1.0$ mi = 0.35) negative (4) $H_{NF}/4.5$ mi = 1.45) negative *(5) $H_{NF}/4.5$ mi = 1.02 *(6) $H_B/4.5$ mi = 1.05 *(7) $H_N/4.5$ mi = 0.86 *(8) $H_R/4.5$ mi = 1.1	Analysis complicated during initial period by presence of fog in vicinity of light source. 165% maximum deviation from total intensity average, IR filter, over a 7-minute interval, at 4.5 miles under excellent visibility conditions. No significant % change of deviation magnitudes due to wavelength. Improved visibilities gave rise to greater deviations. S-1 and S-11 PM.

*Taken during a 45-minute interval when prevailing visibility was excellent. S-11 PM.

Date and Time	General Weather Conditions	Results	Further Comments
15 Nov 62 (contd)		*(9) $H_{NF}/4.5$ mi = 0.83 *(10) $H_{B+IR}/4.5$ mi = 0.97 *(11) $H_{G+IR}/4.5$ mi = 0.42 *(12) $H_{R+IR}/4.5$ mi = 0.80 *(13) $H_{IR}/4.5$ mi = 0.60 *(14) $H_{NF}/4.5$ mi = 0.77	
	*Taken during a 66-minute interval when prevailing visibility was excellent. S-1 PM		
16 Nov 62 0120 - 0529 hrs	Partly cloudy until about 0150 hrs, becoming broken to overcast at 1500 ft; scattered low-level, ground fog patches. Visibility varying from about 1-1/2 miles to unlimited. 8 to 10 knots, E surface winds.	(1) $H_{NF}/0.13$ mi = 0.46; σ D = 0.29 (2) $H_{NF}/0.5$ mi = 0.62; σ D = 1.1 (3) $H_{NF}/1.0$ mi = 0.39; σ negative broken sky (4) $H_{NF}/4.5$ mi = 150 σ D = 6.3 (overcast) (5) 100% indirect radiation at 7.6 and 10.3 miles.	Analysis complicated by presence of scattered fog patches in vicinity of light source. The extremely high value of $H_{NF}/4.5$ is due to the combined effects of low cloudiness, low visibility, and a surface albedo of 1. 23% maximum deviation from total intensity average, NF, over a 4-3/4 minute interval at 1 mile; greater variations were apparent for higher visibilities. S-1 PM.
17 Nov 62 0100 - 0259	Sky obscured by about 8/10 low cloudiness at about 2000 ft and 2/10 ground fog. Estimated visibility of 1-1/2 miles. 12-14-knot SE surface winds.	(1) $H_{NF}/0.13$ mi = 0.43; σ D = 0.31 (2) $H_{NF}/0.5$ mi = 3.4; σ D = 1.2 (3) $H_{NF}/1.0$ mi = 8.8; σ D = 2.3	Comparison of H_{NF}, in this case at optical depths of about one, with that in N. J. local shore area indicates a "duct type" effect, i.e., $>400\%$. This is another example of an extremely

Date and Time	General Weather Conditions	Results	Further Comments
17 Nov 62 (contd)		(4) $H_{G+IR}/1.0$ mi = 4.1; σ_{NF} D = 2.3 (5) $H_{IR}/1.0$ mi = 5.8; σ NF D = 2.3 (6) $H_{NF}/4.5$ mi = 120; σ D = 9.0	high value of H, i.e., $H_{NF}/4.5$ mi due to the combining effects of low clouds, low visibility, and a surface albedo of 1. 14% maximum deviation of total average, IR filter, over a 5-1/4 minute interval at 4.5 miles. S-1 PM.
21 Nov 62 2144 - 2150 hrs	9/10 to 10/10 fog with blowing snow. Estimated visibility of 1/2 mile. +1.0°C gradient. 15 - 16 knots SSE surface winds.	$H_{NF}/0.13$ mi = 1.31; estimated optical depth = 0.78	10% maximum deviation of total average, NF, over a 4-3/4 minute interval at 0.13 mile (the only distance involved). S-1 PM.
23 Nov 62 1950 - 2032 hrs	Sky obscured in about 6/10 fog, 4/10 clouds at 1500 ft and blowing snow. Estimated prevailing visibility of 1 mile. +2.2°C gradient. 18 knots, ENE surface winds.	(1) $\left[\frac{\text{Total NF/Nov 23}}{\text{Total NF/Nov 24}}\right]_{0.13\text{ mi}} = 0.92$ (2) $\left[\frac{\text{Total NF/Nov 23}}{\text{Total NF/Nov 17}}\right]_{0.13\text{ mi}} = 0.98$ (3) $H_{NF}/4.4$ mi = 60; σ D = 13.5 (assuming σ = 3/visibility) (4) Total and indirect intensities at 0.13 and 4.5 miles were indistinguishable at their respective distances.	It is interesting to note that comparisons of the total intensities at 0.13 mile for 3 cases where fog and blowing snow or low clouds prevailed were within 10% of each other although the visibilities varied between 1/2 to 1½ miles. 18% maximum deviation of total average, NF, over a 3-3/4 minute interval at 4.5 miles. S-1 PM.

Date and Time	General Weather Conditions	Results	Further Comments
25 Nov 62 0209 - 0518 hrs	Sky obscured by 10/10 fog becoming 3 to 4/10 ground fog and then less than 3/10 after 0430 hrs. Very light falling snow. Estimated visibility of 1/2 to 1 mile. +1.3°C to +1.7°C gradient. -27°C to -33°C near surface temperature. 11-12 knot SE surface winds becoming 19 knots, SSE after 0300 hrs.	(1) $H_{NF}/0.13$ mi = 0.49 (2) $H_{NF}/9.5$ mi = 1.77 → 2.89 4 minutes later; σ D = 3.4 (3) $H_{NF}/1$ mi = 42.1; σ D = 6.8 (4) $H_{G+IR}/1$ mi = 3.5 (5) $H_{IR}/1$ mi = 8.0 (6) $H_{NF}/1$ mi = 1.14 → 3.7 four minutes later	Rapidly changing fog conditions complicated analysis. $\sigma_{NF}/0.5\text{-}1$ = 6.8 was obtained during about a 20-minute period while the fog developed between the surface and 100 ft. The calculated σ value, however, corresponded closely to the estimated visibility of 1/2 mile during this period. Independence of wavelength vs transmittance surmised from the different wavelength measurements during a period of no significant weather change. 32% maximum deviation of total average for the R+IR region over a 7-minute interval at 4.5 miles. S-1 PM.
26 Nov 62 0224 - 0335 hrs	Sky partly obscured by scattered ground ice fog extending up to at least 200 ft. Visibility of 1/2 to 1 mile. Blowing snow after 0300 hrs, +2.0°C to 0.5°C gradient. -27°C to -33°C near surface temperature. 11-12 knot, SE surface winds becoming 19 knots, SSE after 0300 hrs.	(1) $H_{NF}/0.13$ mi = 0.68; σ D = 0.7 (0209-0213 hrs) (2) $H_{NF}/0.5$ mi = 5.0; σ D = 2.7 0223 - 0229 hrs (3) $H_{NF}/1.0$ mi = 14.6; σ D = 3.1 0246-0248 hrs (4) $H_{G+IR}/1$ mi = 37.5 0314 -0319 hrs; → infinite 0317 -0320 hrs (5) $H_{IR}/1$ mi = 4.1; 0320-0328 hrs (6) $H_{NF}/1$ mi infinite 0330 - 0335 hrs (7) $\left[\frac{\text{Total 4.5 mi}}{\text{Total 1.0 mi}}\right]_{NF}$ = 0.005 (0307-0309 hrs)	The presence of some scattered ice fog in the vicinity of the light source complicated analysis. Results (1) through (3) are more reliable since they occurred prior to the onset of blowing snow; however, a change of $\sigma_{0.13\text{-}0.5\ mi}$ = 5.5/mi at 0.5 mi to $\sigma_{0.5\text{-}1.0}$ = 3.1/mi at 1 mi indicated a drop in the ice fog concentration during about a 40-minute interval. 30% maximum deviation of total average for the IR region over a 1½ min interval at 1 mile. S-1 PM.

Date and Time	General Weather Conditions	Results	Further Comments
30 Nov 62 0146 - 0529 hrs	Sky partly obscured by scattered ground ice fog extending up to about 200 feet. Visibility of 1 to 2 miles. -6.0°C to -2.5°C gradient. -35°C to -46°C temperature near surface. 8 - 10 knot ENE winds becoming E surface winds.	(1) $H_{NF}/0.13$ mi = 0.31-0.39; σ D = 0.30 (2) $H_{NF}/0.5$ mi = 0.47; σ D = 1.2 (3) $H_{NF}/1.0$ mi = 0.54; σ D = 1.4 $H_{NF}/1.0$ mi = 0.63; σ D = 1.6 (4) $H_{G+IR}/1$ mi = 0.53 (5) $H_{IR}/1$ mi = 0.64	$H_{IR}/1$, being about 20% greater than $H_{G+IR}/1$ during an interval when the weather appeared unchanged, may be indicative of the predominance of ice crystals in ice fog. A wavelength independence is suggested for total transmittance resulting from the parallelism of the infrared and green and the infrared total intensity curves. 15% maximum deviation of total average for the IR region over a $2\frac{1}{2}$-minute interval at 4.5 miles. S-1 PM.

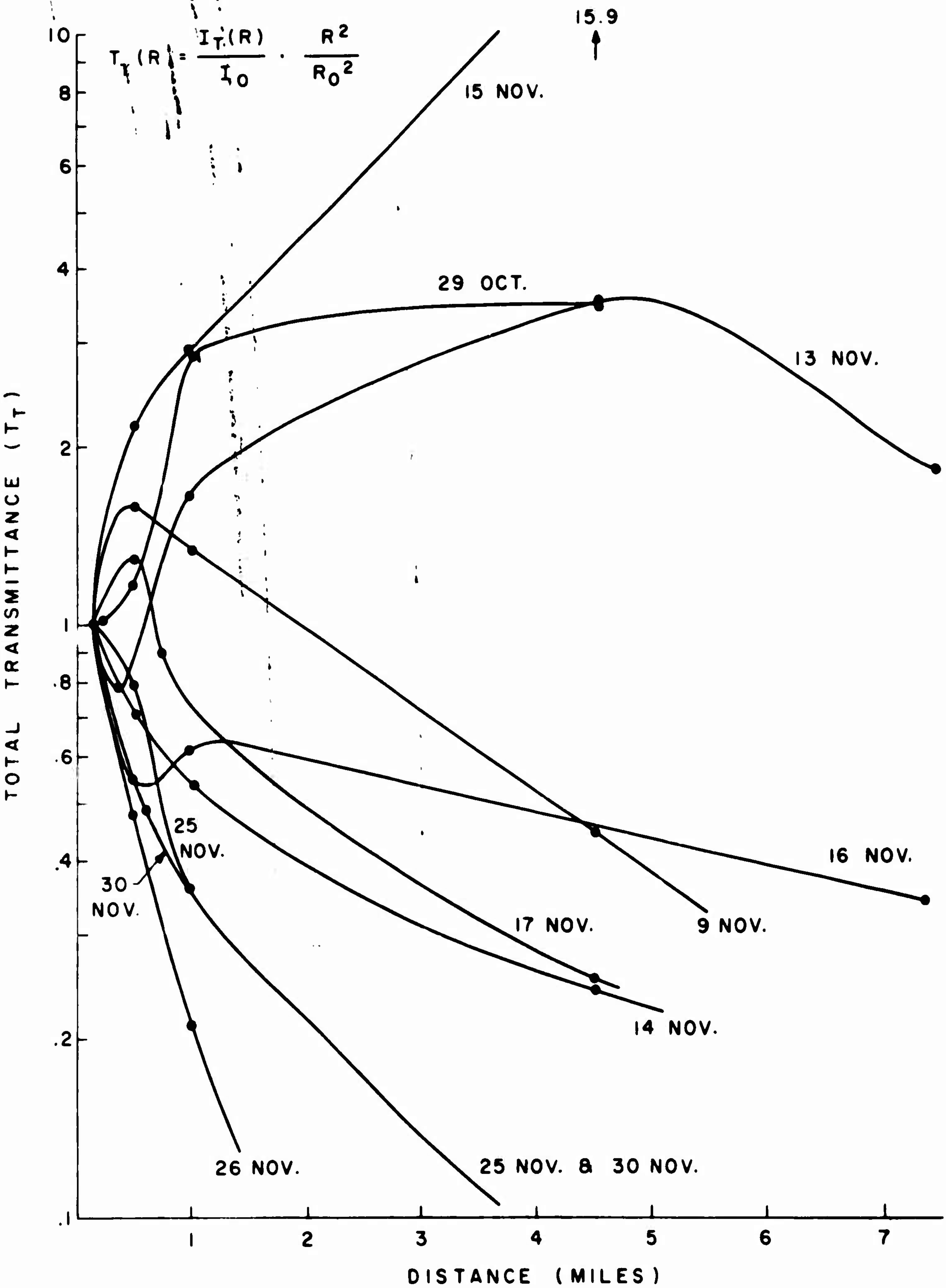

FIG. 61 GREENLAND TRANSMITTANCE CURVES

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13 ABSTRACT

Twenty-two nighttime measurements were made of the atmospheric effects on light attenuation from a point source during the spring and fall of 1962 at a site on the Greenland icecap (Camp Century), located at 77°10'N and 61°08'W at an elevation of 6800 feet above sea level.

The Arctic environment provided an ideal surface albedo of almost unity, while the additional presence of clouds provided "duct effect," or energy-trapping, situations. Graphs are included to show the total and indirect intensity fluctuations over 12-second intervals under various atmospheric conditions. Some comparison is also made of the ratio of indirect/direct intensity vs optical depth under some Arctic and New Jersey shore atmospheric conditions.

This is a DASA-sponsored project, under DASA NWER thermal subtask 12.017, Thermal Atmospheric Scattering Studies.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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It is highly desirable that the abstract of classifie[d re]ports be unclassified. Each paragraph of the abstract [shall] end with an indication of the military security cla[ssific]ation of the information in the paragraph, represented as *(TS)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. [How]ever, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningf[ul terms] or short phrases that characterize a report and may be [used as] index entries for cataloging the report. Key words mus[t be] selected so that no security classification is required. [Identi]fiers, such as equipment model designation, trade nam[e, mili]tary project code name, geographic location, may be u[sed as] key words but will be followed by an indication of tec[hnical] context. The assignment of links, rules, and weights [is] optional.

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