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Project Report
ETS-69 ✓

AD-A136120

Optical Detection Loss
Due to Air-Borne Salts
on Diego Garcia

R. Weber

28 October 1983

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

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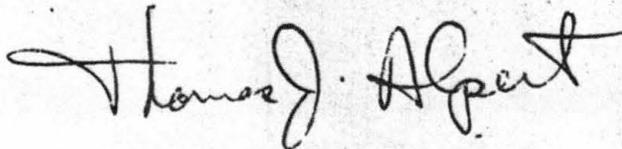
Thomas J. Alpert, Major, USAF
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

OPTICAL DETECTION LOSS
DUE TO AIR-BORNE SALTS
ON DIEGO GARCIA

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Group 94

PROJECT REPORT ETS-69

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Abstract

From 28 April to 8 May 1983, a survey team visited Diego Garcia to determine if the loss of optical transmission due to the deposition of air-borne sea salts on its optical components would preclude the installation of a GEODSS site on the southern part of the island. This report describes the objectives, the motivation, the planning, the experimental procedures, the laboratory measurements, the collection and interpretation of the data, the analysis of the data, the expected detection loss, and the selection of a specific location for a GEODSS site. Then, recommendations are offered.

Briefly, the results indicated that with the wind from the SE and under typical operating conditions--sky brightness greater than 19.5 magnitudes per square arcsecond and for an operational night of 12 hours--the expected detection loss due to the deposition of air-borne salts on the coverplate of a GEODSS telescope would be approximately one-tenth of a visual magnitude. The maximum loss under atypical conditions would be approximately three-tenths of a magnitude. Since it became apparent during the survey that the detection losses would not be great enough to preclude the installation of a GEODSS site on the southern part of Diego Garcia, an exact location for a site was pin-pointed by the survey team before its departure from the island.

CONTENTS

Symbols

T Optical transmission (percent)

$T°$ Temperature

t Exposure time (hours)

ϕ Angle of incidence of wind with respect to the glass surface. Here, $\phi = 90°$ corresponds to the case of perpendicular incidence.

SNR   Point source signal-to-noise ratio.

R.H.   Relative humidity (percent)

T_{DRY} Dry-bulb temperature

Figures

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I. OBJECTIVES OF THE SURVEY

On April 28th, a team consisting of representatives of SPACECOM (Capt. Dave Dyche and CMSgt. Mike Rice), ESD (Capt. Lou Soracco and Mr. Floyd Farnsworth), and Lincoln Laboratory (R. Weber), arrived on Diego Garcia to perform a limited site survey. The site survey was limited in that there were only two well-defined (and related) objectives:

1. To determine the impact on the detection capability of a GEODSS system, if located on the southern part of the island, due to the deposition of air-borne salts on the optical components.

2. To identify a specific location for a GEODSS site on the southern part of the island provided an "on the spot" determination can be made that the detection capability of the system would not be seriously degraded.[*]

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[*] "Seriously degraded" was agreed to be a detection loss in excess of 0.5 visual magnitudes over the course of an operational night.

II. BACKGROUND AND MOTIVATION

A few words are in order as to why this effort was to be confined to
the southern part of Diego Garcia. Figure 1 shows the locations of the five
sites (numbered 1-5) offered by the Navy to ESD in 1982. Late in that year,
it was agreed that Site 1, near the Charlie site, was the prime location for
a GEODSS installation. As a consequence of this agreement, a site survey was
conducted during December of 1982. The major conclusion of the survey was
that Site 1 would be acceptable if the levels of lighting in the area could
be reduced and controlled in the future. It was also noted in the survey
report (24 December 1982) that there appeared to be a salt deposition problem
at Sites 3, 4 and 5.

In March, the Navy officially withdrew its offer of Sites 1 and 2 on the
grounds that the location of a GEODSS site at either of those locations would
tend to restrict the growth and lighting to such an extent that vital opera-
tions would be hampered. At a joint AF/Navy meeting held at the PACNAV
facility at Pearl Harbor on 22 March, the Navy insisted that Diego Garcia be
revisited to explore the possibility that either of Sites 3, 4[*], or 5 may be
acceptable to the Air Force. It was here that the AF agreed to the present
survey to determine the effect on the optical performance of a GEODSS instal-
lation at each of the three mentioned sites due to the deposition of salts
from the atmosphere.

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[*]Site 4 was subsequently ruled out because of planned antenna construction
in the area.
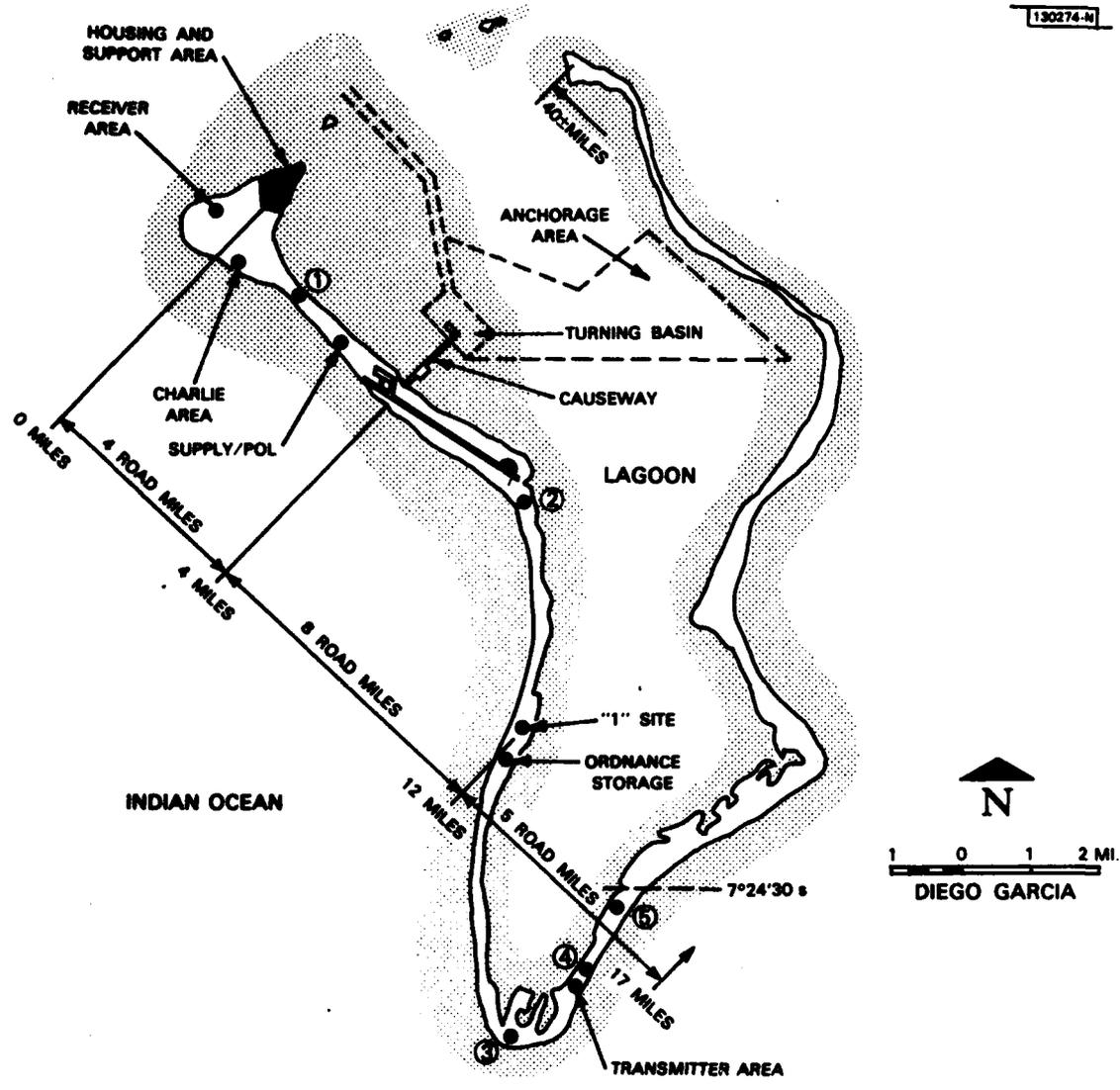
Fig. 1. A map of Diego Garcia showing the locations of the proposed sites (labelled 1-5). The dashed line above #5 is the dividing line between the American and British zones.

III. PLANNING AND PREPARATIONS FOR THE SURVEY

Early in the planning stage, it was decided that data would be collected not only at Sites 3 and 5 but also at Site 1, despite its withdrawal by the Navy. If Sites 3 and 5 should prove to be unacceptable because of heavy deposits on the optics and if Site 1 should prove to be acceptable in this respect, the basis (in data) would be on-hand to attempt to re-open the question of the location of a GEODSS installation at Site 1.

Conceptually, the collection of data was quite simple: Microscope slides were to be exposed (one side) simultaneously at the three locations. The variables were to be the time of exposure, the height above ground level, and the angle of incidence of the wind with respect to the exposed surfaces. The periods of exposure were to always include night-time conditions (i.e., GEODSS operational conditions). Finally, appropriate weather data were to be collected.

The exposed slides were to be returned to Lincoln Laboratory for analyses to indicate the effects of salt depositions on the detection capability of the GEODSS system.

Due to the shortness of the time for preparation for the trip to Diego Garcia, some compromises had to be made. Whereas it would have been desirable to collect deposition data as a function of elevation (height above ground level) at all three locations, it was decided to attempt this at Site 5 only. The reason this site was chosen was that it was clearly preferable to Site 3 because of the width of the land available from the lagoon to the ocean. Here, the telescopes could be located at least 800 feet from the beach; at Site 3 the similar distance was of the order of 200 feet. Moreover, Site 3

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appeared to be located in a flood plain, or at least in a very marshy area.

The fixed slide elevations at Sites 1 and 3 were to be approximately 30 feet, corresponding to a height above ground level of the GEODSS telescopes in a standard GEODSS facility. The additional deposition-versus-elevation data available at Site 5 would perhaps indicate the desirability of increasing the telescope heights, either by the use of land-fill or by increasing the heights of the towers, to take advantage of any indicated improvement in detection capability at these elevations.

As a result of discussions with colleagues at the Air Force Geophysics Laboratory, Mr. A. Korn agreed to lend the team an aerostat, and to instruct us in its use, for the survey. An aerostat is a blimp. This particular model requires (according to its specifications) approximately 1,000 cubic feet of helium gas to inflate it to its full length of 33 feet and to its maximum diameter of 8.5 feet. In calm winds ($\sim$ 3 kts.), the blimp has a lift of 36 lbs., an important design number.

Mr. S. Milner, of Lincoln Laboratory, fabricated the apparatus to be used on the survey. Figure 2 is a sketch of the essential parts of the blimp system showing the aluminum wind vanes, holders, and positions of the microscope slides. The vanes were free to pivot around the stainless steel cable. To change slides, or to "top-off" the helium, it was only necessary to shorten one of the three guy wires to bring the balloon to a reasonable elevation. Five vanes were provided for the blimp system. They were fixed at intervals of 10 feet, the first being 20 feet above the ground. Vanes were also fabricated for use at Sites 1 and 3. The method of suspension in these cases--perhaps poles, cherry-pickers, or cranes--was to be decided on the island since the required elevations (i.e., 30 feet) were reasonable.

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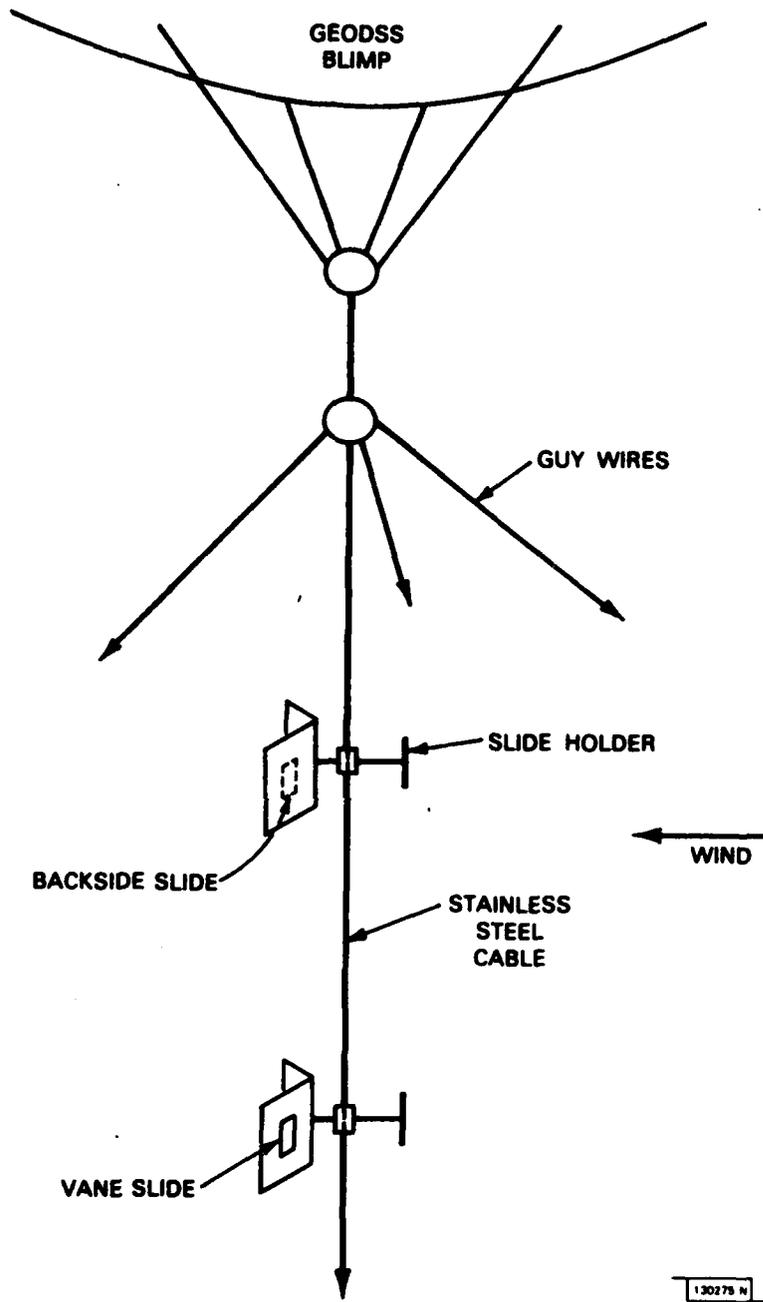
Fig. 2. The experimental arrangement for the aerostat ("blimp"). The vane slides are at 45° with respect to the direction of the prevailing wind, while the backside slides are in a protected position, simulating, to some extent, an optical surface protected by the telescope dome.

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IV. PREPARATIONS AND PROCEDURES ON THE ISLAND

The weather for the first five days on the island was poor. There was essentially complete cloud cover, gusting winds, and frequent rain storms. This extended period of solid cloud cover was, according to Navy weathermen, very unusual for this location. This is a universal reaction; i.e., bad weather is always "unusual". By Wednesday, May 4th, when there was a break in the weather pattern, land had been cleared in the area of Site 5 for the launching of the balloon, wooden poles with cross-arms (giving the appearance of gallows) had been installed at Sites 1 and 3, the weather equipment had been tested, and adequate helium had been secured for the proposed experiments.

On our visit to the Navy weather station on the afternoon of May 4th, the weatherman predicted more foul weather for the next 24-48 hours, even though the sky was blue, with scattered, broken clouds, and a gentle breeze blew from the SE. The team decided to take a chance. By 5 P.M., the blimp, with slides in place, was tethered over Site 5. Slides were installed at Site 1 (30 feet above the ground), and at Site 3 (30 and 20 feet above the ground). Later checks showed that the latter slides were actually located a few feet above the nominal values. The height of 30 feet approximated the location of the telescope above the level of the ground for a standard GEODSS tower. It was noted that the slides at 20' did not clear the average tree height in the surrounding areas. During the first exposures, all slides were oriented with the wind at 90°, measured from the face of the slide. The unusual convention will be used that this is an angle of incidence of $\phi = 90°$. Wind parallel to the face would then have an angle of incidence of $\phi = 0°$. In later exposures, slides were exposed at 45° (on the windvanes) and in

protected positions behind the vanes, simulating the telescope faceplate in the dome slit with the wind coming from behind. The 45° slides have been dubbed "vane", and the protected ones "backside" slides (See Fig. 2).

Sets of slides were exposed at all sites for differing lengths of time. Whenever a new set was inserted or removed from the holders, weather conditions were noted. Open containers served as precipitation detectors at each location. The exposed slides were stored for transport to Lincoln in covered carrying cases.

In all, 145 slides were exposed during the experiments. The data collection ended the evening of May 8th because of severe atmospheric turbulence and the prediction (which proved to be accurate) of extended rain storms. Twelve slides were of no use because of rain or severe turbulence during the exposures. There remained 133 slides to be analyzed at Lincoln. From these, an examination, "on the spot", indicated that the depositions would probably not impair the optical performance of a GEODSS installation at Site 5. Objective 2, page 1, could be accomplished!

V. LABORATORY MEASUREMENTS

Upon return to the Laboratory, while measuring the transmission of light through the exposed slides, an oscillatory transmission was noted for 25 of the specimens. An examination of the complete set of transmission data for the 133 slides indicated that the transmission values for the 25 oscillatory slides were erroneous. Several of the suspect samples were cleaned, dried, and re-evaluated. The clean substrates were defective, exhibiting the same spatially oscillatory behavior. Prior to departure, six or seven randomly selected clean slides had been checked in the apparatus, with no strange effects. Apparently, one of the three boxes of new slides taken on the survey contained part of a "bad" run.

Once it was experimentally determined that uniform background light and point source light were equally attenuated by the exposed slides, a point-source set-up was used exclusively for the measurements. Briefly, a spot-size of 30 microns was projected onto the faceplate of the 80 mm Ebsicon camera through an f=5.6 optical system across the input of which was placed a clean microscope slide. The system was then adjusted for maximum signal output as observed on an oscilloscope. The linewidth was observed at the same time. With no further adjustment, the clear slide was replaced with an exposed slide and the signal amplitude and linewidth observed. From these observations, the transmissions of the acceptable 108 slides were determined. It is to be noted that the chosen spot-size, 30 microns, corresponds to a telescope resolution of 2 arc-seconds and to an atmospheric seeing disc of the same value. RSS-ing these quantities yields 2.82 arc-seconds. Since the GEODSS (main) faceplate scale is approximately 10.6 microns/arc-second, we have 10.6 x 2.82 = 29.9 microns, a good match.

No measurable differences of the half-maximum linewidths among exposed, unexposed, and no slides (i.e., the absence of a slide in the optical path) were noted for any of the 108 individual measurements. Perhaps, this is not surprising in that the pixel size at the output of the camera (in zoom) was approximately 6 arc-seconds in diameter.

VI. THE DATA AND ITS INTERPRETATION

At this point, it is appropriate to state the spirit in which all
that which follows is to be understood. There are many variables involved--
slide elevation, wind speed, wind direction, wind uniformity, angle of
incidence, relative humidity, time of exposure, precipitation, temperature,
and cloud cover. The data are sparse--a maximum of 108 points divided among
13 positions and 10 exposures. Because of these factors--the sparcity of data
and the number of variables (some controlled, some not)--the usual goal of
research to sift through a maze to uncover, quantitatively, underlying
behavior, will be difficult, if not impossible. Perhaps, the most that can
be expected from the present effort is to note trends and to specify limits.
With this in mind, we proceed with the presentation of the data and its inter-
pretations.

A. Grouping of Experimental Runs

The exposures varied from 2 hours to approximately 10 1/2 hours.
It was possible to group them, according to exposure times, into ten "runs",
labelled A-J. An examination of Table I reveals that some of the groupings
are approximate, reflecting delays (due to turbulence and/or rain) in the
placement or removal of groups of slides. This table also indicates the
measured transmissions (in percentages) for 90° angles of incidence. By this
time, Site 5 was renamed "G-Site", to avoid confusion with GEODSS' future
eastern Atlantic site. On the same table, then, G30 and G40 refer to the
slides at 30 feet and at 40 feet, respectively, at the G-Site. The blank
entries indicate that either runs were not made at that time at that site or
that the slides were subsequently found to be defective. The letters HOH

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TABLE I

TIMES OF EXPOSURES, t, AND MEASURED TRANSMISSIONS, T

(Slides at 30', except for G40. Wind angle of incidence = 90°)

Run Label	G-Site		Site 1		Site 3		G-Site (40)	
	t	T(%)	t	T	t	T	t	T
A	2^h00^m	88	-	-	-	-	2^{00}	89
B	2^{10}	89	3^{52}	96	3^{02}	94	2^{10}	87
C	4^{15}	94	4^{55}	97	4^{51}	91	4^{15}	90
D	4^{24}	89	4^{24}	98	4^{20}	93	4^{24}	83
E	5^{54}	80	5^{52}	91	5^{54}	85	5^{54}	83
F	6^{05}	80	4^{25}	95 HOH	5^{10}	85 HOH	6^{05}	85
G	7^{25}	90	5^{00}	87 HOH	6^{40}	87	7^{25}	92
H	8^{15}	83 HOH	8^{01}	87 HOH	7^{47}	83	8^{15}	80
I	8^{15}	86	8^{13}	87	-	-	8^{15}	80
J	9^{33}	90	10^{20}	80	9^{32}	80	9^{33}	90

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indicate that moisture was found in the precipitation detectors at the time of the collection of the slides.

B. Perpendicular ($\phi = 90°$) Data

Figure 3 is a graph of the data included in Table I. The plots for G30 and for G40 do not indicate the expected gradual loss in transmission with time of exposure. The plots for Site 1 and 3 do suggest the expected behavior. The dashed curve is a least-squares curve-fit to the data of Site 3. The fit is reasonably good. For an exposure of 9 1/2 hours, the transmission, T, is 80%. A significant result is that the minimum value of T shown on the figure is 80%. It may also be noted that the degradation at Site 1 tends to be less than at the other sites except for exposures greater than approximately 8.4 hours.

The unevenness of the G-Site data and the fact that a reasonable curve-fit passing through (0,0) is not possible for these data may be explained as follows: The aerostat was used at G-Site. Frequently, in the presence of strong gusts of wind (turbulence), the balloon was momentarily deflected, sometimes downwards, sometimes sidewards, producing erratic motion at the windvanes to which the slides were fastened. As a result of these momentary excursions, the heights and the angles of incidence of the wind changed abruptly. The changing vertical heights alone would tend to average the salt depositions over a range of heights while the changing angles of inci-dence would tend, it is conjectured, to produce a different effect. It is clear that during the time of exposure of a given slide, the salt deposit already on the slide tends to dry. A shear component of the wind can then, more readily than in the 90° case, "blow away" some of the dry salt deposit.

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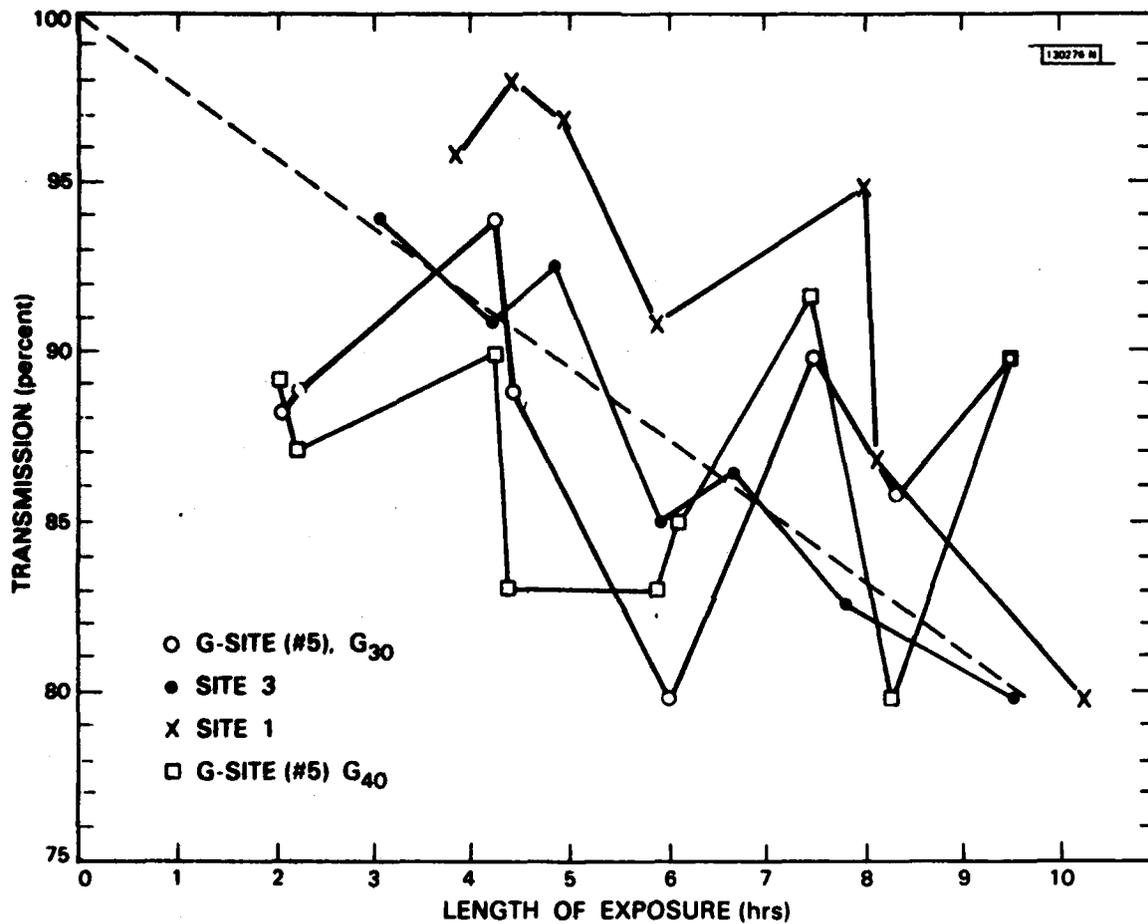
Fig. 3. Measured transmission as a function of exposure time with the wind perpendicular to the surfaces of the slides. The elevations are all 30' except G40 which is 40'. The dashed line is a fit to Site 3's data.

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In addition, for angles of incidence less than 90°, the rate of deposition, it seems, would be less than for the 90° case. These two factors--the erratic vertical motion and the changing shear component of the wind, whose effectiveness depends on its speed and on the length of the exposure--can understandably cause the final thickness of the deposit to be different from what might be anticipated for the ideal case. In retrospect, this bobbing motion probably simulates, to some extent, the motion of a GEODSS telescope during operations.

C. Climatology

Wind gusts have been mentioned in the preceeding remarks. This brings us to the climatology of Diego Garcia and to the weather conditions at the times of the present experiments. Table II indicates the climatology for a period of 26 years (1951-1977) for the month of May. It can be deduced from the temperature and humidity values entered in the table that dewing should not be an important factor insofar as the optics of a GEODSS telescope are concerned. Apparently, at these latitudes the moisture content per volume of air is relatively constant. For the period of the survey, again from the table, the mostlikely ranges of temperature and humidity are 77°F - 86°F and 72%-84%, respectively. The wind should be from a southeasterly direction with an average speed of 6 knots.

D. Measured Weather Parameters

Table III indicates the times and measured weather parameters taken at G-Site at an elevation of approximately six feet. The abbreviations used in the table are: kts for knots, v. turb. for very turbulent, g for gusts, temp. for temperature, and R.H. for relative humidity. The wind direction is given in degrees (azimuthal angle). A comparison of Tables II and III

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TABLE II

CLIMATOLOGY FOR DIEGO GARCIA FOR MAY
(1951 - 1977)

Temperature

Average minimum 77°F
Average maximum 86°F   } 81.4°F mean
Record low 70°F
Record high 91°F
Dew point 73°F

Rainfall

Average 6.7 inches
Maximum 29.9 inches   Expect average of
Minimum 1.0 inch   15 days per month
Max., 24 hrs. 14.8 inches with no rain.

Average Relative
Humidity

4 A.M.: 84%
1 P.M.: 72%

Winds

October-March: W
April-May: transition to SE   } general
June-Sept.: SE   behavior.
Prevailing direction in May: ESE
Average speed: 6 kts.
Max. recorded speed: 28 kts.

Cloud Cover

Mean coverage: 50%

Other

Ceiling > 1000 ft. } 99% of time
Visibility > 3 miles

Ceiling > 5000 ft. } 87% of time
Visibility > 5 miles

TABLE III

WEATHER CONDITIONS DURING DATA COLLECTION

Run	Date (May)	Time	Temp. (°F)	R.H. (%)	Wind
A	7	12^{55}A	81.5	82	125°, slight breeze
B	7	3^{10}P	87.5	73	80-110°, 3-4 kts.
		5^{20}P	--	--	120°, 3-4 kts, g to 7
C	7	5^{20}P	--	--	120°, 3-4 kts, g to 7
		9^{45}P	82.0	82	110°, 5 kts, v.turb.
D	4	5^{36}P	84.5	76	130°, 3 kts, g to 8
		10^{00}P	81.0	86	120°, 0-3 kts
E	5-6	9^{08}P	81.0	88	100°, 0-3 kts
		3^{02}A	79.0	79	110-130°, 2-3 kts, v.turb.
F	4-5	10^{00}P	81.0	86	120°, 0-3 kts
		4^{05}A	80.0	84	130°, gentle breeze
G	5	4^{05}A	80.0	84	130°, gentle breeze
		11^{35}A	87.0	75	140-210°, 0-4 kts, g to 7
H	7-8	9^{45}P	82.0	82	110°, 5 kts, v.turb.
		6^{00}A	81.0	77	130-140°, 5 kts, g to 9
I	6	3^{02}A	79.0	79	110-130°, 2-3 kts, v.turb.
		11^{17}A	86.0	74	140°, 5 kts, g to 9
J	5	11^{35}A	87.0	75	140-210°, 0-4 kts, g to 7
		9^{08}P	81.0	88	100°, 0-3 kts
Extra	7	7^{35}A	81.9	81	130°, 3-5 kts.

indicates that the actual temperatures and relative humidites tended to be somewhat greater than the average values expected from the 26-year history, while the wind speeds (measured approximately six feet above the ground) were less than the 26-year average. The historical data were probably collected at an elevation of nine feet, but it is not clear that this was indeed the case.

The values for the relative humidity entries in Table III require an explanation. Three of the twelve values of the relative humidity recorded on Diego Garcia were adjusted to bring them into agreement with the wet and dry bulb temperature readings which were recorded at the same time. These changes are indicated in Fig. 4 by the vertical arrows. Since the temperature values appeared to be reasonable and since the humidity values were read from a crowded plastic nomograph, the adjustment of the data seemed justified. The region between the straight lines on Fig. 4 indicates the theoretical range of humidities possible for a given ΔT (dry-wet temperatures) for the range of temperatures experienced during the survey. Figure 5 indicates the behaviors of the temperatures and of the relative humidity over 24 hours. Some of the scatter reflects the fact that the data were collected over a four-day period. However, the trends are as expected: the highest temperatures and lowest humidities were in the early afternoon and the opposite in the early morning hours. If the uncorrected values for the humidity had been used in this figure, the result would have been difficult to accept.
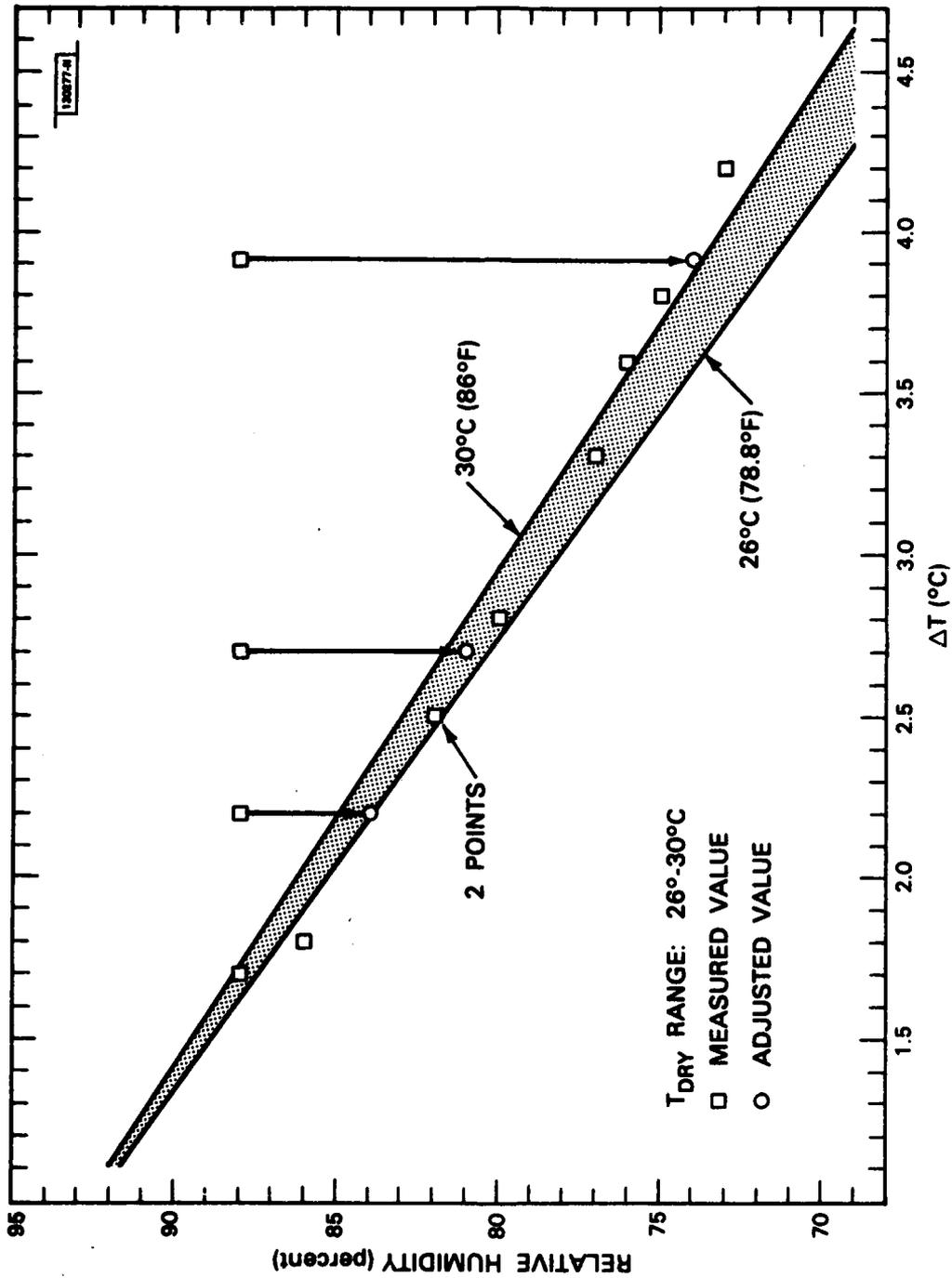
Fig. 4. Measured and adjusted values of the relative humidity versus the difference between dry and wet bulb temperatures.
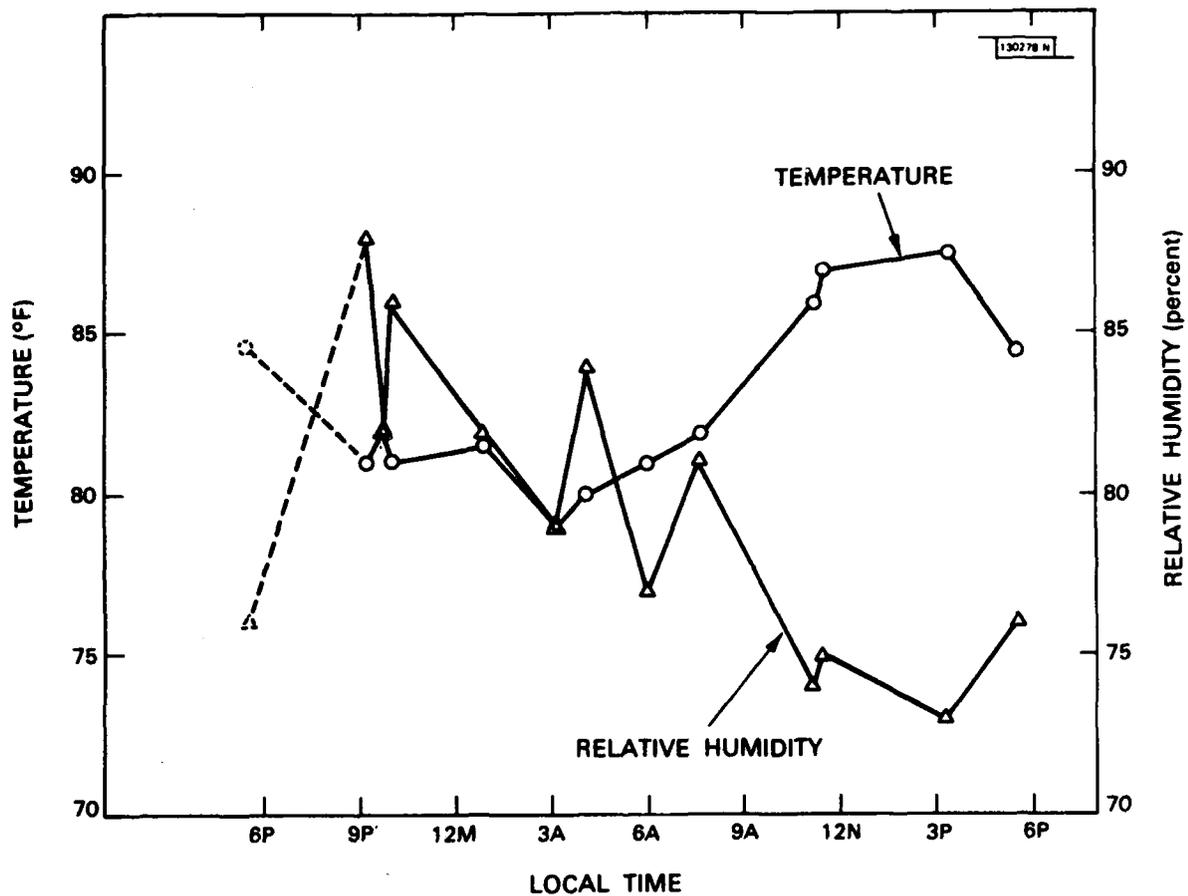
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Fig. 5. Measured temperature and relative humidity for a 24-hour period (values recorded over a period of four days).

As an aside, during the survey the comfort index, C.I., varied from a minimum of 76.2 to a maximum of 82.0 The average C.I. was 79.2. When the C.I. is 65, most people report that they are comfortable. When it is 75, about 50 percent complain. When it is 79, all complain. Finally, for 36% of the measurements the C.I. exceeded 80. Surely, the survey team was not aware of these facts!

E. Elevation Effects

Next, transmission as a function of height above the ground and time of exposure at the G-Site will be considered. Runs H and I were excluded from consideration because points were missing and because of the HOH problem (see Table I, page 12). Figure 6 presents the data for heights of 30', 40', 50', and 60'. Each included exposure is labelled and tracked from the minimum to the maximum height. The liberty has been taken in to connect the points by straight lines. If one were to compute an average value of T for each height and then delete "outliers", the resulting values would be very similar (90, 89, 90, 88%). There is no trend (experimental error of $\pm$ 1%) toward better results as the height is increased, at least over the small range used in the tests. This result suggests that the atmospheric salts are well dispersed after a long sea path and that perhaps the deposits were not affected by the local surf.

F. Time-of-day Effects

There is another way to look at the data. Runs B, C, D, and J were made from dusk to dark; A, E, and F, were obtained entirely during the dark; and, G, H, and I took place from dark to dawn. Obviously, this additional separation of the limited amount of data on hand tends to emphasize that
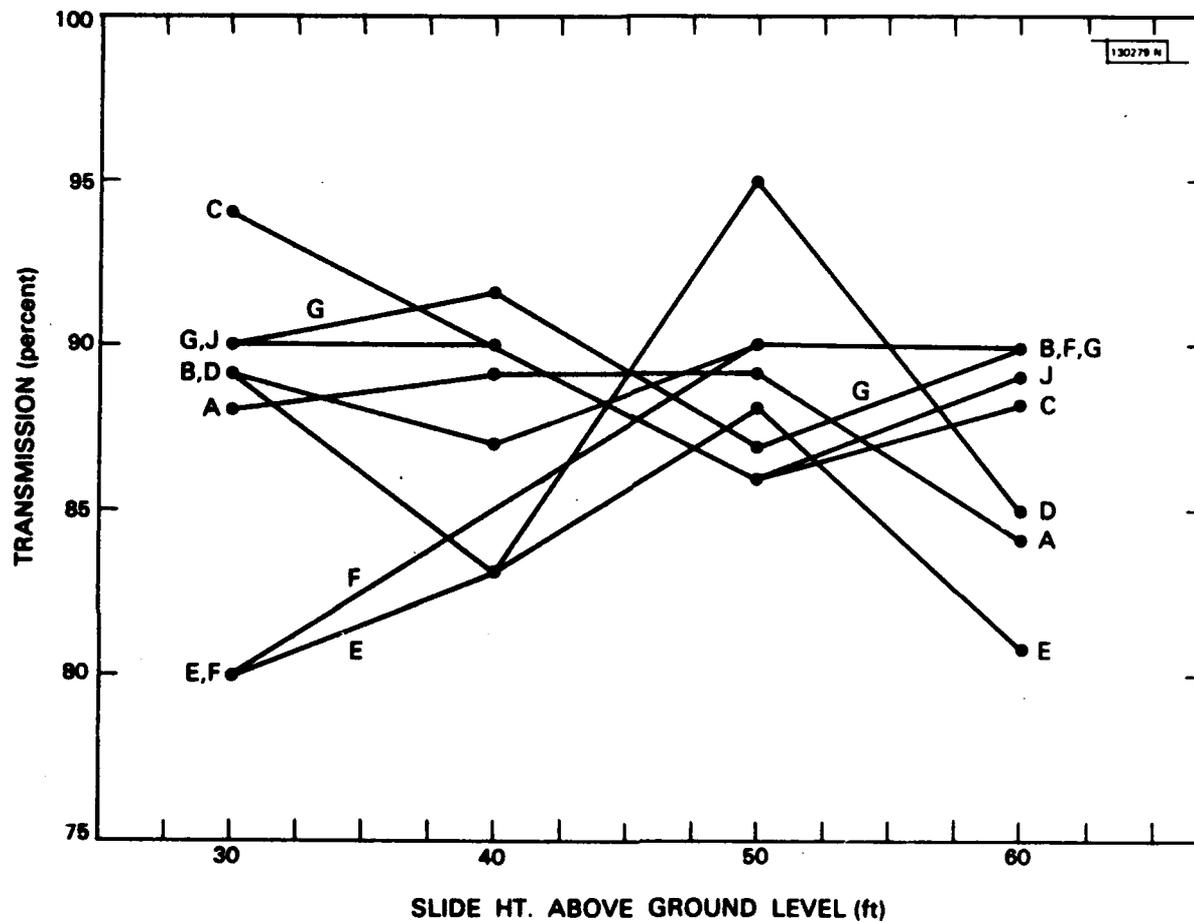
21

Fig. 6. Measured transmission versus height above the ground. Data from G-Site (#5). The runs are labelled. Runs H and I were excluded because of missing or questionable points.

shortcoming. Nevertheless, one can look for a trend. Accordingly, Figs. 7, 8, and 9 are presented for the perpendicular case (i.e., the angle of incidence, ϕ, of the wind equals 90°). These three figures show consistent behavior--that is, a decrease in transmission, T, as a function of exposure time--in all cases except for the G-Site data for exposures that took place from dusk to dark (Fig. 7). An examination of the weather data during the appropriate exposure time does not suggest a reason for this behavior at G-Site. Here, again, the bobbing motion of the balloon played a role.

G. Non-Perpendicular (ϕ=90°) Data

The presentation of the data concludes with the results obtained for exposures in which the direction of the wind was other than perpendicular (ϕ=90°) to the exposed glass surface. A total of 23 useful slides were obtained with ϕ=45°. These are the so-called "vane" slides. Six slides--the "backside" slides--were obtained in the protected "backside" position. See Fig. 2, page 6, for the locations of these positions. The vane slides sampled the atmosphere at 30' at all sites and at 60' at the G-Site for exposure times ranging from 3 to 9 3/4 hours. For a given length of exposure, the G30 transmissions tended to be better than those for G60 and in every case were better than their 30' counterparts at Sites 1 and 3. Recognizing that these differences were not very great (the 23 T-values ranged from 89 to 99 percent), average T-values were computed for each run and have been plotted as a function of exposure time (Fig. 10). Runs A and I were not included since they provided single points only; that is, slides were rejected due to water smudging or because of defective substrates. The straight line passing through the origin and the lower data points in Fig. 10 is a best fit to the data. From this line,

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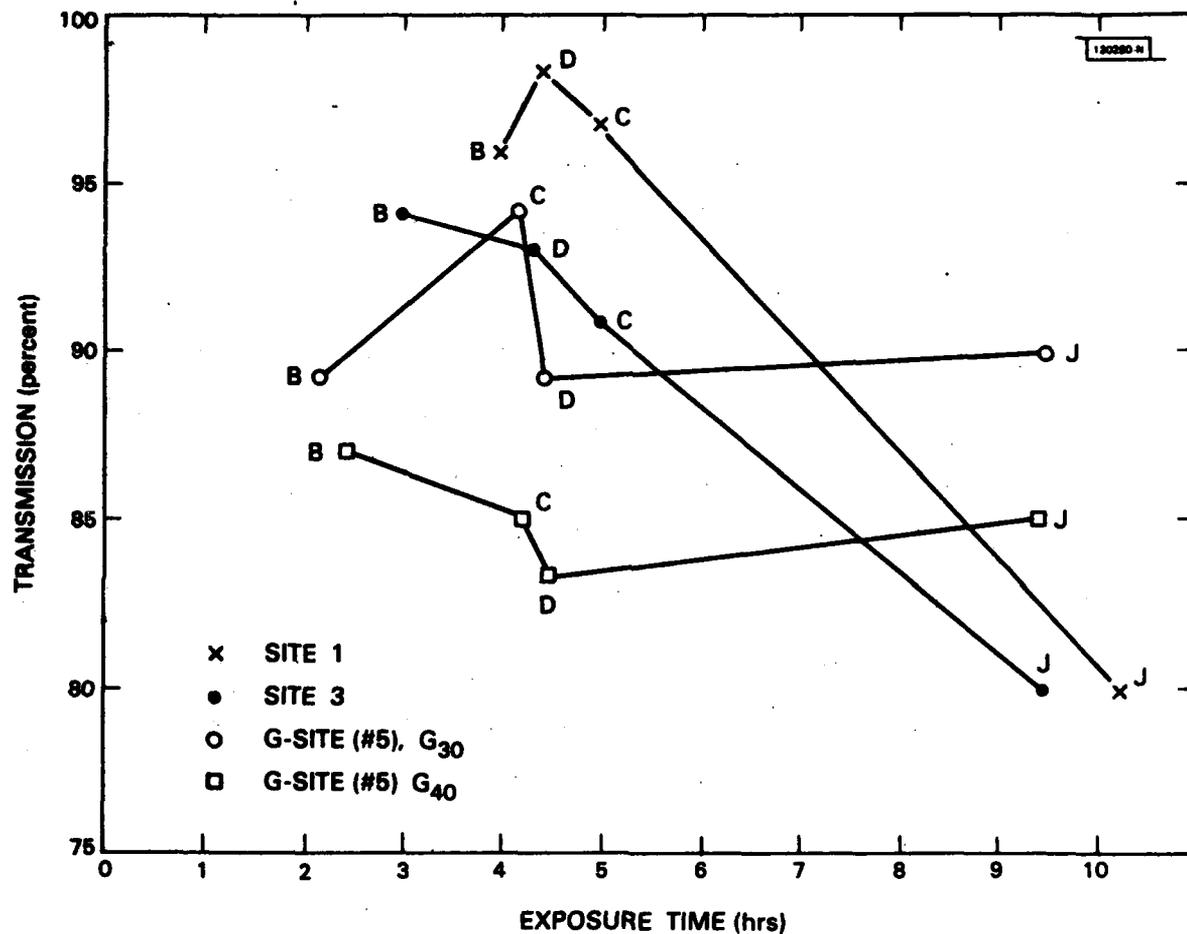
Fig. 7. Measured transmission versus exposure time for exposures made passing from dusk to dark. The individual runs are labelled.
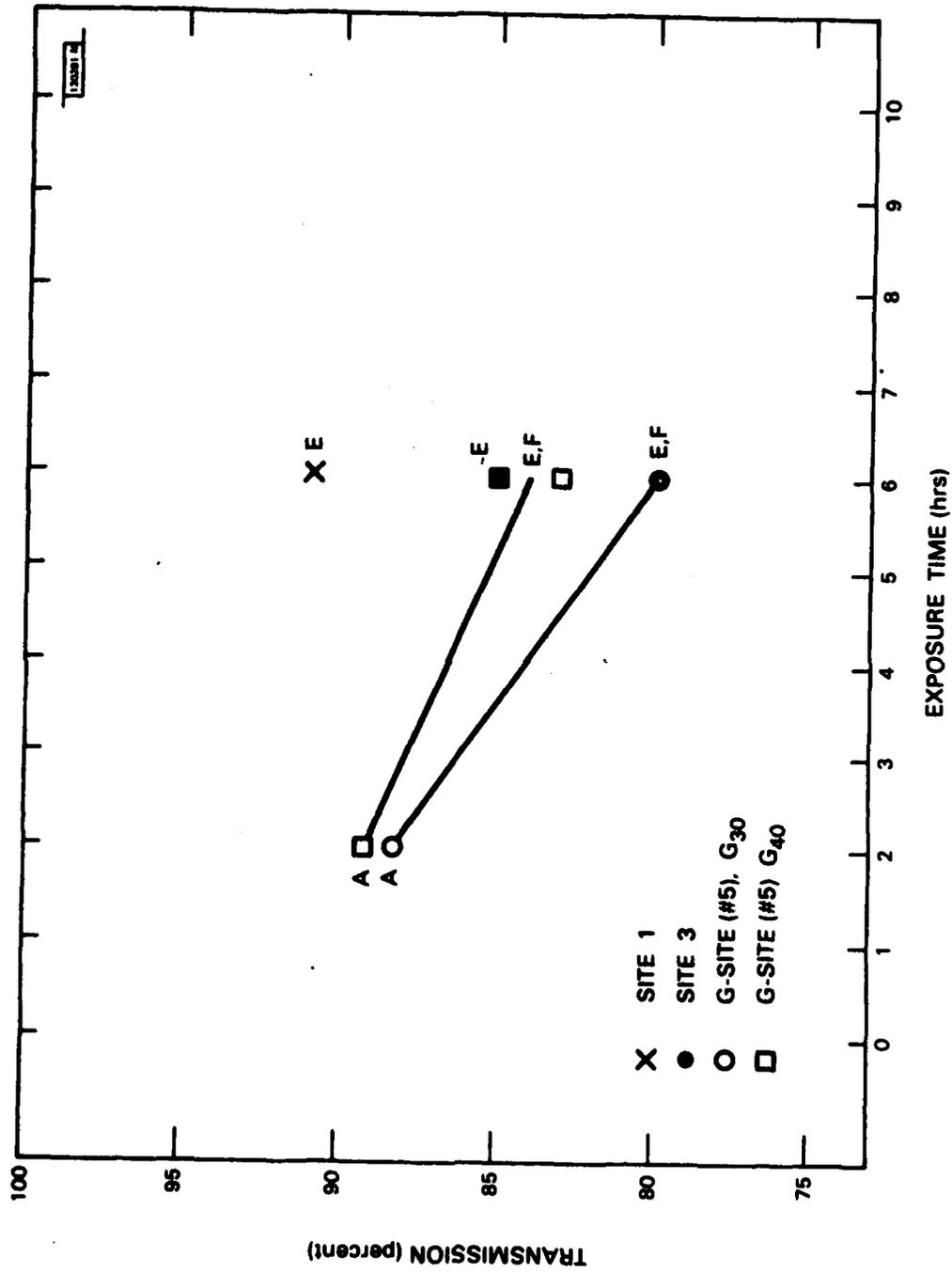
Fig. 8. Measured transmission versus exposure time for exposures made in the dark. The runs are labelled.
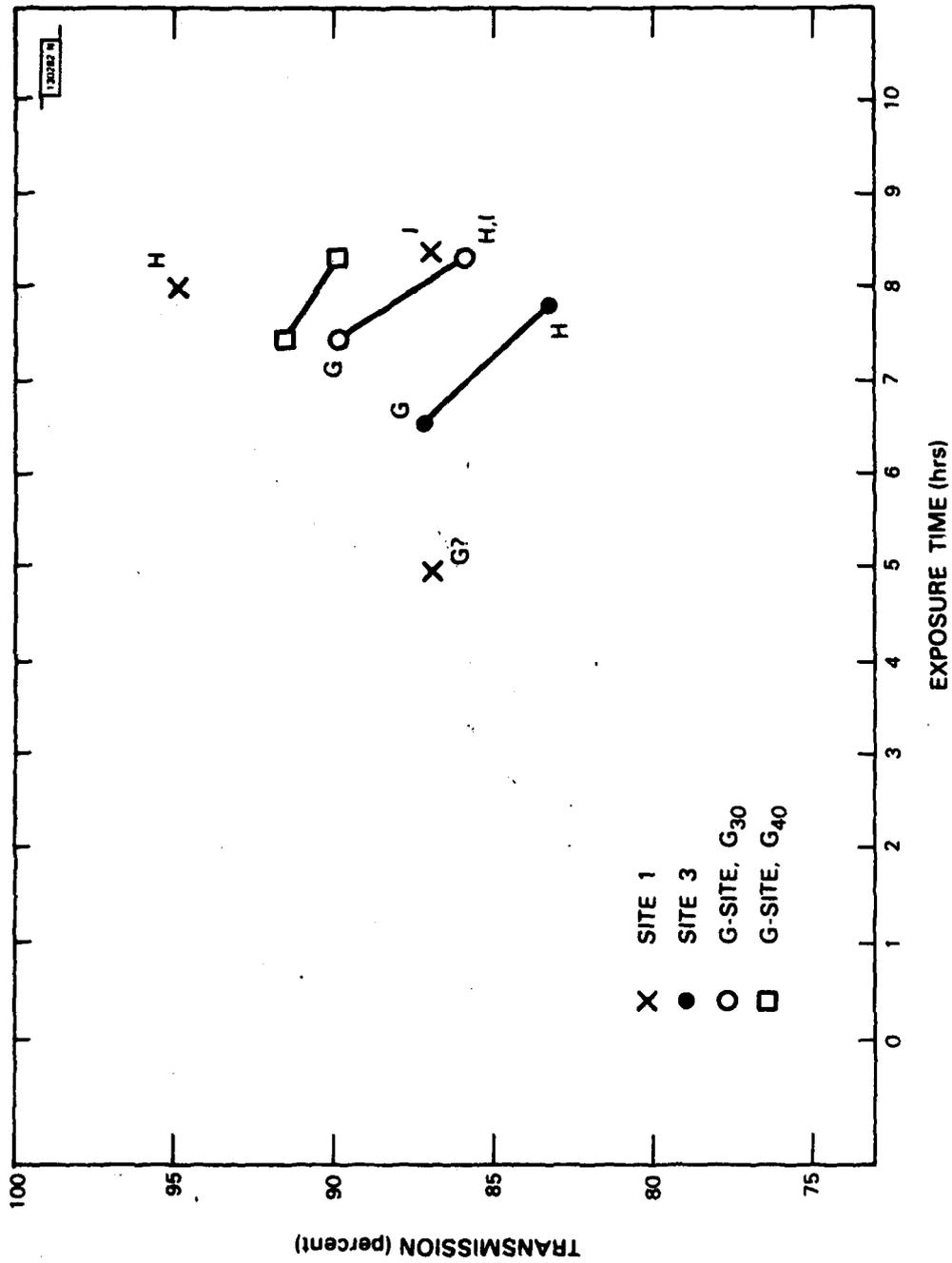
Fig. 9. Measured transmission versus exposure time for exposures made passing from dark to dawn. The runs are labelled.
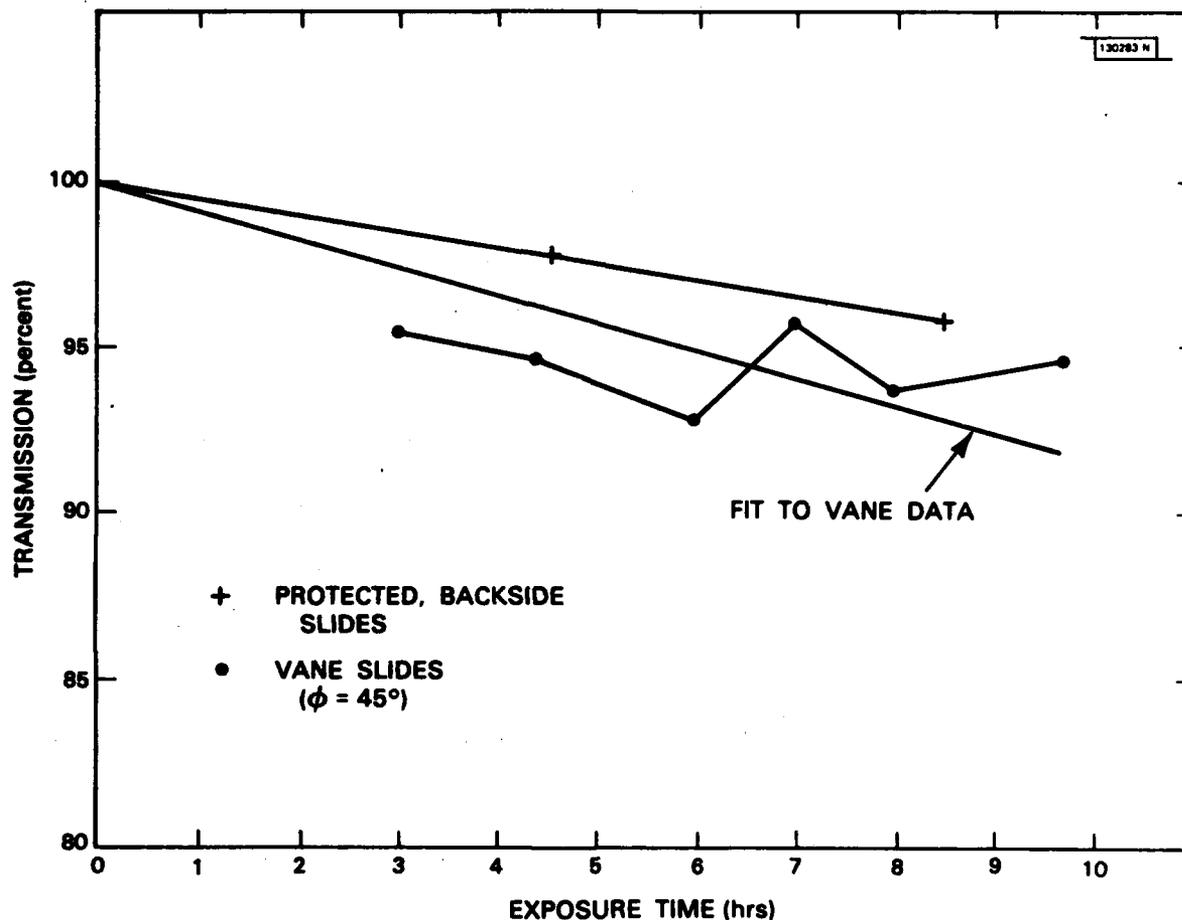
Fig. 10. Measured average transmission vs exposure time for the backside (protected) slides and for the vane ($\phi=45°$) slides. The straignt lines passing through (100%, 0) are best fits to the data. The data are from all sites. The vane range transmission was 89% to 99%. For the backside case, the range was 95% to 99% for all data points.

for an exposure time of 8 1/2 hours the transmission has been reduced to appoximately 93 percent.

Five of the protected backside slides were exposed at 30' and one at 60'. Of these two runs, one was for 4 1/2 hours, the other for 7 hours (3 data points for each run). Their averages have been plotted and a best-fit line drawn on Fig. 10 (the upper straight line). After 8 1/2 hours, T = 96 percent. The total spread here was from T = 95% to T = 99%.

H. Transmission as a Function of Wind Incidence

Even though it is realized that the protected backside slides were not at $\phi = 0°$ (i.e., wind parallel to glass surface), let us assume that they were. Surely, the difference must be small, that is, for an exposure of 8 1/2 hours in the backside position, T = 96% (Fig. 10). For the parallel case, T cannot be much greater for a similar time of exposure. For $\phi = 45°$, it is observed that T = 93% for the same exposure time. From Fig. 3, the $\phi = 90°$ case, the average value of T for t = 8 1/2 hours is approximately 84.5%. With this information, Fig. 11 was prepared. It shows the average transmission to be expected as a function of the exposure time for $\phi = 90°$ (perpendicular case), 45°, and approximately 0° (protected case). From the information given in this figure, potentially useful curves may be derived. For example, the next figure, Fig. 12, shows the average transmission to be expected as a function of the angle of incidence of the wind with respect to the optical coverplate of the telescope for exposure times of 8.5 and 12 hours. It is noted that for the $\phi = 45°$ case, for 8.5 and 12 hour exposures, the average values of the transmission are 93% and 90%, respectively.
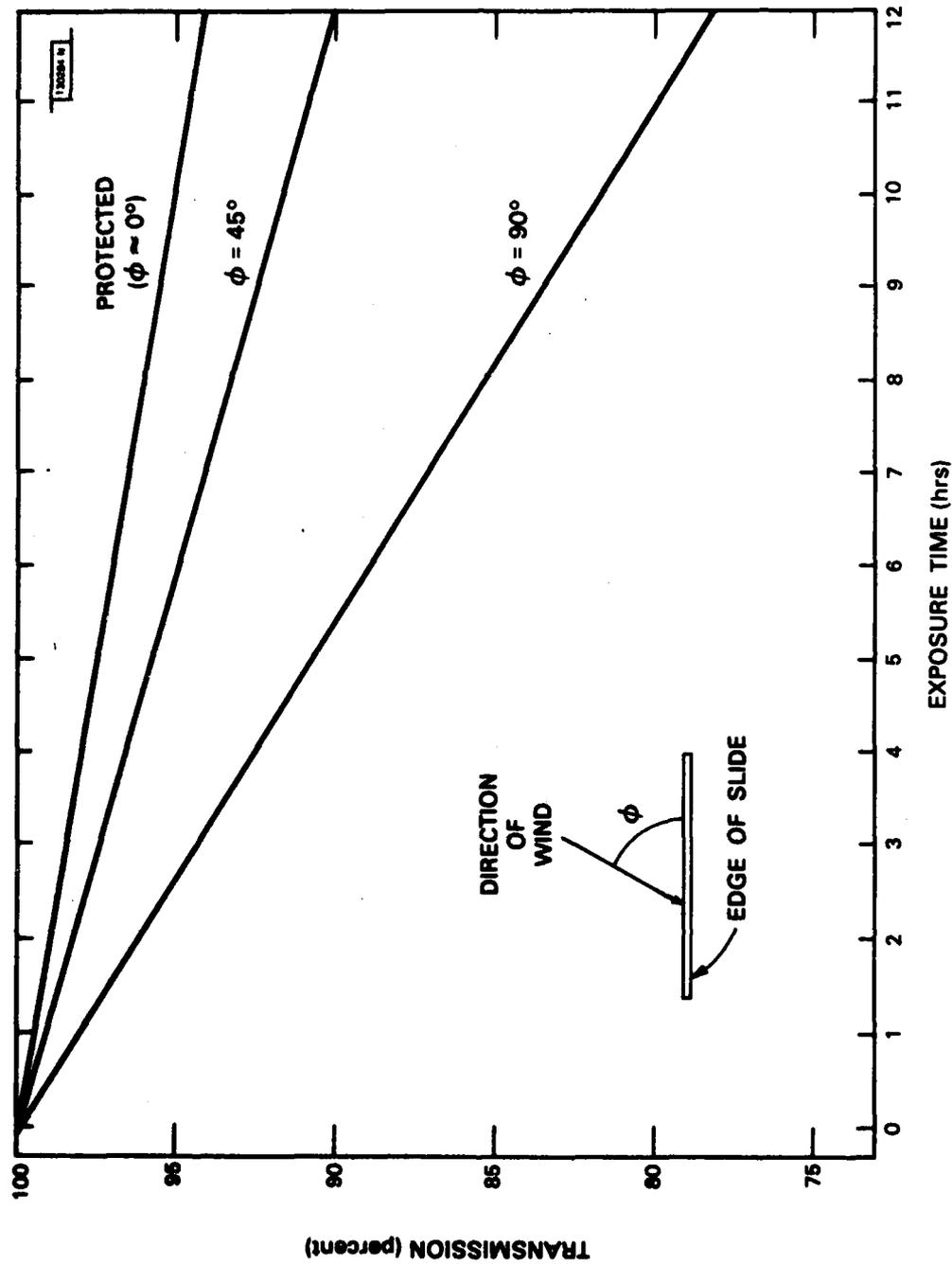
Fig. 11. Transmission as a function of exposure time with the angle of incidence of the wind, φ, as a parameter.

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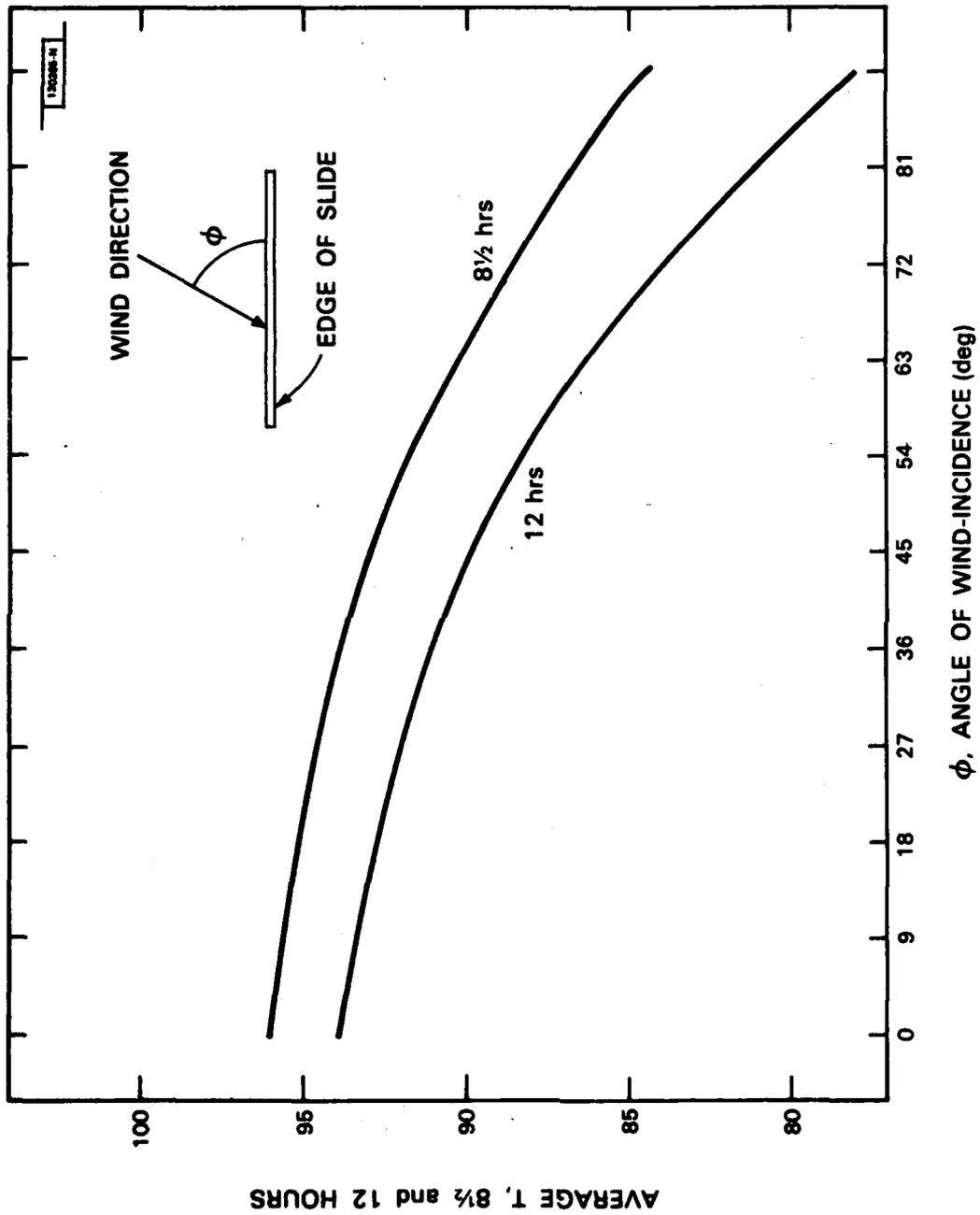
Fig. 12. Average transmission to be expected after exposures of 8.5 and 12 hours as a function of φ.

VII. EXPECTED DETECTION LOSS

We may now analyze the results to determine the expected loss in detection capability, in visual magnitudes, to be expected because of the salt deposits on the optics of a GEODSS telescope as a function of the wind direction, exposure time, and sky brightness.

To indicate the impact of the loss of point-signal and background amplitudes due to the salt depositions, it is convenient to deal in terms of the signal-to-background noise ratio (SNR). Since the signal varies as the transmittance, T, (1 is perfect) and the noise varies as the square root of T, the SNR varies at $T^{1/2}$. This is true for medium (and brighter) sky backgrounds. For the darkest of sky backgrounds, the SNR varies directly as T. This report considers the former case to be representative of typical conditions at Diego Garcia. Finally, it is to be noted that the detection loss, in visual magnitudes, is proportional to the loss of SNR. Table IV, constructed from the presented data, indicates the expected losses.

Table IV is self-explanatory. For the expected typical sky brightnesses and for an average value of $\psi = 45°$, the loss in detection capability is less than one-tenth of a visual magnitude for a 12-hour exposure. For the worst case, one that should never occur in practice, the loss is approximately three-tenths of a visual magnitude.

As indicated in Table II (Climatology), for approximately four months of the year, the prevailing direction of the wind is SE; for six months, it is W. When the predominant operational viewing angles are considered, it becomes apparent that the effective value of ϕ may we be less than 45° over the course of an operational night. Thus, the actual detection losses will be less than those indicated in Table IV.

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TABLE IV

EXPECTED DETECTION LOSSES DUE TO SALT DEPOSITS

ϕ (degrees)	Exposure (hours)	Transmission (%)	Detection Loss (visual magnitudes)	
			Typical Skies	Dark Skies
45	8.5	93	0.04	0.08
(typical case)	12.	90	.06	.11
90	8.5	84	0.10	0.19
(atypical case)	12.	78	.14	.27

ϕ = Angle of incidence of the wind with respect to the glass surface. Here, ϕ = 90° corresponds to the perpendicular case.

VIII. SITE SELECTION

As mentioned earlier, in consonance with the observations made "on the spot", the general area of the G-Site was accepted as a location for a GEODSS system. In fact, before the survey team departed from Diego Garcia, a precise location was selected between the sites marked 4 and 5 on Fig. 1. It is perhaps appropriate at this point to describe some of the observations that led to this decision. First is was noted that while the exposed $\phi = 90°$ (perpendicular) slides from Site 1 generally, but not always, had thinner deposits on them than their counterparts from the other locations, their situation with respect to the wind path was more favorable. That is, the predominant wind direction during the survey was from the SE, resulting in an immediate land path of several (5-6) miles just before the location of the slides at Site 1. At G-Site, the land path was less than 800 feet. For the six months of the year when the wind is from the West, Site 1 will no longer have the advantage of a long land path. Finally, when it was observed that there was virtually no difference between Site 1's exposed backside and vane ($\phi = 45°$) slides and those from the other two locations, the decision to accept the area of G-Site for the location of a GEODSS system was made.

IX. RECOMMENDATIONS

As has been shown, near the selected location, the data concerning the rate of deposition of sea salts as a function of elevation do not clearly indicate an optimum elevation. Nonetheless, the recommendation is made that the telescope axes be raised six feet above that height which a standard GEODSS installation would provide at that location. This additional height is best achieved by the use of land-fill. This recommendation is justified by two considerations.

The average height of the vegetation in the selected area is 60 feet. For a telescope tower located 150 feet inside the cleared area, including a 60 foot frame around the link fence, for telescope axes 34 (instead of 28) feet above the ground, viewing will be clear down to an elevation angle of $\theta = \arc\tan \{(70-34)/150\} = 9.8$ degrees. Thus, topping of the surrounding vegetation will be minimized. Of course, there are a few isolated trees whose height exceeds 60 feet; and, there remain the two extremes of the equatorial search belt when it is required that $\theta = 5°$. Still, much is to be gained by the additional height.

Second, the use of landfill is desirable to minimize flooding in the area, a distinct possibility, during stormy weather.

Experiences on Diego Garcia indicate that it is in the midst of a dynamic area as far as the formation, movement, and dissipation of clouds are concerned. Sudden, isolated cloud-bursts are frequent. Therefore, it is almost a necessity that the Diego Garcia site have precipitation detectors installed which automatically alert the operators and which quickly cause the domes to be closed. In addition to preventing water from falling on the equipment,

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efforts must be made to minimize the deposition of the air-borne salts on the equipment. One general step is to maintain a positive pressure, however slight, of clear dry air in the dome, even during operations. Next, the optical surfaces must be kept covered through the evening cool-down period prior to operations. Finally, during idle periods, the telescopes must be oriented away from the direction of the prevailing winds.

Acknowledgements

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESD-TR-83-060	**2. GOVT ACCESSION NO.** AD - A136 120	**3. RECIPIENT'S CATALOG NUMBER**
4. TITLE *(and Subtitle)* Optical Detection Loss Due to Air-Borne Salts on Diego Garcia		**5. TYPE OF REPORT & PERIOD COVERED** Project Report
		6. PERFORMING ORG. REPORT NUMBER Project Report ETS-69
7. AUTHOR(s) Robert Weber		**8. CONTRACT OR GRANT NUMBER(s)** F19628-80-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lincoln Laboratory, M.I.T. P.O. Box 73 Lexington, MA 02173-0073		**10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS** Program Element Nos. 63428F and 12424F Project Nos. 2698 and 2295
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command, USAF Andrews AFB Washington, DC 20331		**12. REPORT DATE** 28 October 1983
		13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)* Electronic Systems Division Hanscom AFB, MA 01731		**15. SECURITY CLASS.** *(of this report)* Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

air-borne sea salts   deposition of sea salts
optical transmission loss

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

From 28 April to 8 May 1983, a survey team visited Diego Garcia to determine if the loss of optical transmission due to the deposition of air-borne sea salts on its optical components would preclude the installation of a GEODSS site on the southern part of the island. This report describes the objectives, the motivation, the planning, the experimental procedures, the laboratory measurements, the collection and interpretation of the data, the analysis of the data, the expected detection loss, and the selection of a specific location for a GEODSS site. Then, recommendations are offered.

Briefly, the results indicated that with the wind from the SE and under typical operating conditions — sky brightness greater than 19.5 magnitudes per square arcsecond and for an operational night of 12 hours — the expected detection loss due to the deposition of air-borne salts on the coverplate of a GEODSS telescope would be approximately one-tenth of a visual magnitude. The maximum loss under atypical conditions would be approximately three-tenths of a magnitude. Since it became apparent during the survey that the detection losses would not be great enough to preclude the installation of a GEODSS site on the southern part of Deigo Garcia, an exact location for a site was pin-pointed by the survey team before its departure from the island.

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