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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
ECOM-5431

# FOGWASH I
# AN EXPERIMENT USING HELICOPTER DOWNWASH

By

D. H. Dickson



April 1972

Approved for public release; distribution unlimited.

ECOM



UNITED STATES ARMY ELECTRONICS COMMAND - FORT MONMOUTH, NEW JERSEY

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This report documents Project Fogwash I, an experimental program in which the technique of helicopter downwash for fog dissipation was used. Meteorological and microphysical data collected during the experiment are presented. Meteorological data indicated an improvement in visibility as a result of the downwash. There were indications in the microphysical data obtained that particulate number varies directly as relative humidity and inversely as temperature and that sulfate particles increase with increased relative humidity.

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## ABSTRACT

This report documents Project Fogwash I, an experimental program in which the technique of helicopter downwash for fog dissipation was used. Meteorological and microphysical data collected during the experiment are presented. Meteorological data indicated an improvement in visibility as a result of the downwash. There were indications in the microphysical data obtained that particulate number varies directly as relative humidity and inversely as temperature and that sulfate particles increase with increased relative humidity.

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## INTRODUCTION

Many years of research have been devoted to methods of improving visibility within fogs. A relatively new fog-dissipation technique is the use of helicopter downwash. The first documented experiments which made use of this technique were performed in Greenland in 1964 [1]. It was not until 1968, however, that additional tests [2] were conducted, which led to further testing in 1969 [3]. It became apparent that if this technique was to be advanced in an orderly manner, more detailed meteorological and microphysical data concerning the life cycle of fogs were needed.

Project Fogwash I, an experimental program which used the technique of helicopter downwash to create holes in fog, was carried out in February 1971 at Fort Rucker, Alabama, in conjunction with the U. S. Army Aviation School. In selecting the site for the experiment, the statistically low fog probability at Fort Rucker (Table I) was more than offset by the availability of a variety of rotary-wing aircraft and the opportunity for the Aviation School to gain first-hand knowledge of this dissipation technique.

Two radiation fogs, (16-17 February and 18 February) provided the opportunity to demonstrate the feasibility of fog dissipation by helicopter and to gather microphysical data required in establishing modification procedures and in numerical modeling.

Data acquired during the experiment both within and outside the realm of helicopter influence are presented in terms of meteorological conditions, fog measurements, and helicopter effects. Listings of project participants and in-flight data are provided in the appendices. The in-flight data have been reproduced, unedited, from the pilots' logs.

## EXPERIMENTAL TECHNIQUE

The basic experimental technique of Fogwash I was to employ helicopters singly and in pairs to dissipate fog at a target area on Skelly Army Air Field (AAF) and at the same time to measure microphysical and meteorological parameters related to that fog. Figures 1 and 2 show the relative positions of the target area, Mobile Cloud Physics Laboratory (MCPL), and instrumentation. Meteorological observations and selected samples of microphysical parameters were taken in and around the downwash-affected area as well as in the undisturbed MCPL area north of the target.

### Sequence of Events

A fog forecast for Skelly AAF, supplied by the 9th Detachment, 16th Weather Squadron, U. S. Air Force, at Cairns Army Air Field (approximately

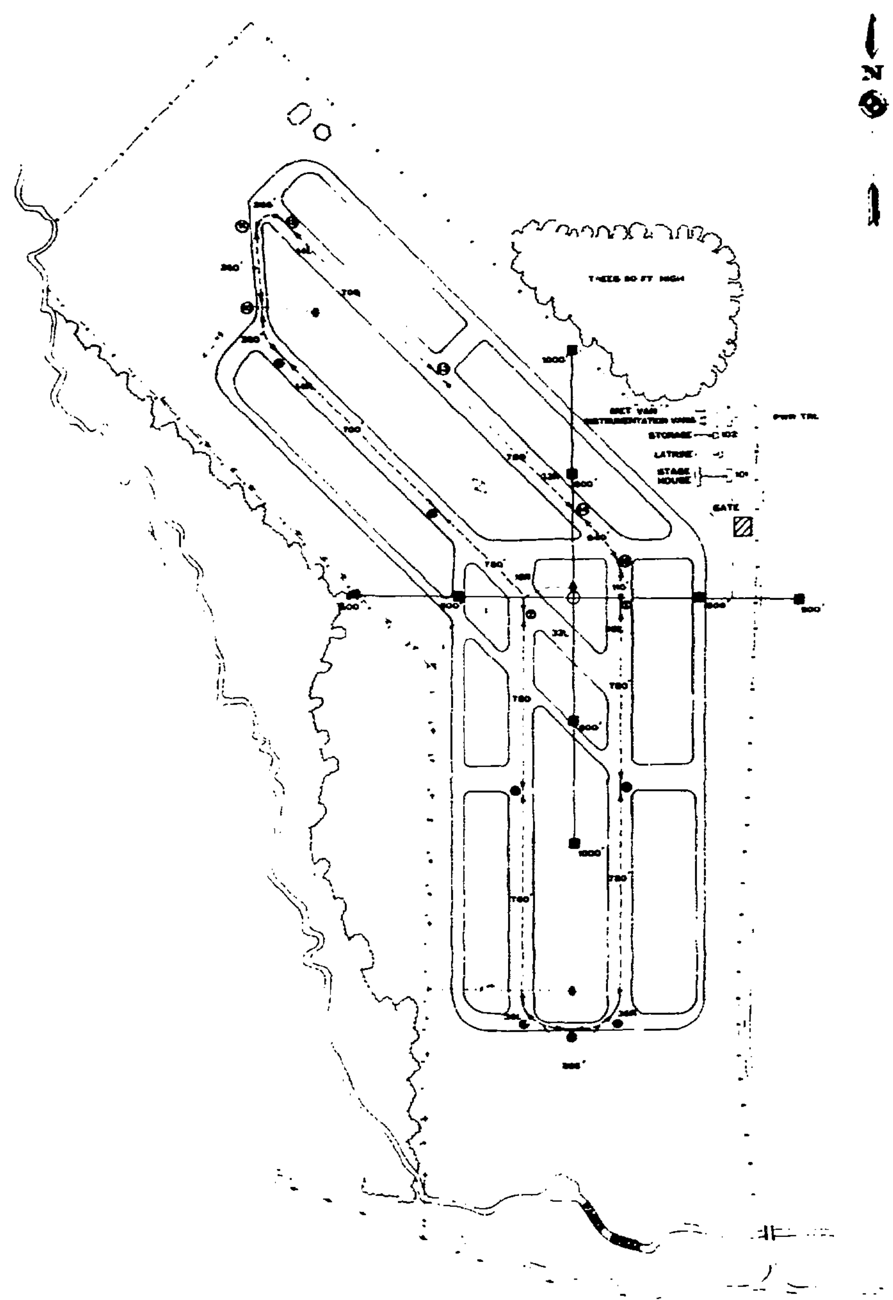
TABLE I

Occurrence of Fog as Tabulated by Detachment 9, 16th Weather Squadron, U.S. Air Force, Fort Rucker, Alabama

Percent of Occurrence Below Aircraft Takeoff or Landing Minimums of 200 feet Vertical Visibility and 2400 feet Ground Horizontal Visibility

| TIME OF DAY (HRS) | JANUARY % | FEBRUARY % | MARCH % |
|---|---|---|---|
| 0000 - 0300 | 6 | 5 | 3 |
| 0300 - 0600 | 7 | 8 | 8 |
| 0600 - 0900 | 8 | 8 | 6 |
| 0900 - 1200 | 3 | 2 | 1 |


Figure 1. General Site Map.




| POINTS | TIME | DISTANCE |
|---|---|---|
| 15 | | |
| 1 | 4 SEC | 110' |
| 2 | 32 SEC | 780' |
| 3 | 35.5 SEC | 780' |
| 4 | 18.5 SEC | [illegible] |
| 5 | 20 SEC | [illegible] |
| 6 | 36 SEC | 750' |
| 7 | 34 SEC | 760' |
| 8 | 34.8 SEC | 760' |
| 9 | 34 SEC | 700' |
| 10 | 12 SEC | 250' |
| 11 | 13 SEC | 280' |
| 12 | 11 SEC | 250' |
| 13 | 32.8 SEC | 700' |
| 14 | 36 SEC | 750' |
| 15 | 30 SEC | 640' |
| TOTAL | 410 SEC | 7936' |

AV SPEED 15.6 FT/SEC

LEGEND

PROPOSED PAVING
EXISTING PAVING (BITUMINOUS)
EXISTING FENCE
STABILIZED OVERRUNS
ELEC POWER (AERIAL)
ELEC POWER (UNDERGROUND) & OUTLET

FIELD ELEVATION 198'

KYTOON SITE 2260' FROM TARGET
VISIBILITY MARKERS — FOR HORIZONTAL VISIBILITY CAMERA LOCATED ON TOTAL NOTE MARKER LINE WILL BE SLIGHTLY CURVED
TARGET
HE TRAILER
INSTRUMENTATION VANS GMDS OPERATIONS
MARKER BALLONS TETHER POINT CONFIGURATION @ PILOTS DISCRETION
MONET TRACK

200 FT 0 200 FT 400 FT

Figure 2. Skelly AAF Target Area.

25 miles east of the target area) initiated the following sequence of events:

All personnel were alerted as to a T-0*. All project porsonnel, except the pilots, reported to their duty stations at T-180 minutes to perform operational checks and adjustments. At T-120 minutes the first balloon-borne radiosonde was released to obtain temperature and relative humidity data and was tracked for six minutes or until it reached an altitude of 6000 feet MSL.

At T-90 minutes, a Kytoon was launched to provide a lifting mechanism for a modified radiosonde package. At T-30 minutes, tethered marker balloons were launched and allowed to ascend to an altitude of approximately 200 feet above the fog top to mark the downwash target area. At T-5 minutes, the mobile met station (measuring temperature and humidity) began its traverse of the target area and periphery which continued until the day's mission was terminated. Operation of horizontal and vertical visibility sensors was also initiated at T-5 minutes.

At T-0, the first helicopter (CH-54) arrived over the target area and hovered at an altitude of 1230 feet MSL (Skelly elevation 188 feet MSL) for a period of five minutes. The helicopter, guided by marker balloons, then vertically descended in 200-foot increments, hovering at each level for five minutes, until it reached an altitude of 630 feet MSL, where it remained until T+31 minutes. At that time the helicopter departed, and the marker balloons were repositioned at an altitude of 200 feet above the fog. Nine minutes after departure of the first helicopter, a second aircraft (CH-47) arrived over the area, hovered, vertically descended, and departed. Nine minutes later, the third and fourth aircraft (UH-I's) arrived side by side, vertically descended, and departed.

It should be noted that the hover and downwash portion of the experiment took approximately 31 minutes and that a time of 9 minutes was allotted between downwash experiments. At the termination of the test, following the departure of the third and fourth helicopters, a radiosonde was launched and tracked, and all other equipment was secured. Surface wind and dry- and wet-bulb temperatures were monitored at the meteorological van throughout the experiment.

## SYNOPTIC PATTERN

Analysis of the national weather picture for February 17 and 18 indicated that similar national and local weather patterns existed for each date.

---

*T-0 was that predetermined time at which the first helicopter began dissipation efforts each day a fog was encountered.

Generally, frontal systems were located to the distant north and northwest of Fort Rucker over the plains or midwest region, while a large high pressure system dominated the eastern third or half of the country. On both days, a high pressure center was off the North Carolina coast and moving northeastward. As the high advanced northeastward, circulation around the high pressure center began pumping warmer, moist, light southeasterly winds off the Gulf of Mexico over the cooler land of southern Alabama.

## MEASUREMENT METHODS AND RESULTS

Data gathered in the downwash-affected area were telemetered to either the meteorological van or instrumentation van and recorded. Data obtained in an area of the fog undisturbed by the helicopter, approximately 1.5 miles north of the target area (Figure 1) were recorded at that site in the Atmospheric Sciences Laboratory (ASL) Mobile Cloud Physics Laboratory (MCPL) van. Instrumentation utilized during the test period is summarized in Table II.

### METEOROLOGICAL MEASUREMENTS

#### Mobile Met Station (MOMET)

Sensing instrumentation, consisting of a radiosonde which was modified for continuous readout, was attached to the center of the front bumper of a jeep such that the radiosonde was located seven feet above ground level. The vehicle traveled a pattern around the target area (Figure 2) as follows: Starting at the center of Skelly AAF, traveling south on 36R, then west on taxiway, then north on 36L and northwest on 14R, then north on taxiway and southeast on 14L returning to the center. The MOMET gathered temperature and relative humidity data continuously from T-5 to T+35 minutes, and the data were recorded on a standard AN/TMQ-5. Information concerning the position of the jeep was recorded on a Sanborn Model 350 recorder.

The MOMET data were reduced to provide the temperatures and relative humidities as functions of distance of the instrument-carrying jeep from the expected location of helicopter hover. The results of these measurements are illustrated in Figures 3-6.

#### Vertical Profiles of Temperature and Relative Humidity

Two AN/AMT-4 Radiosondes were released from the meteorological van for each mission, one at T-120 minutes and the other at T+150 minutes.

TABLE II

| INSTRUMENTATION | FUNCTION | SAMPLING | TIME INVERVAL |
| --- | --- | --- | --- |
| Mobile Met Station<br>High Resolution Radiosonde (1)(2) mounted on forward end and above jeep. Tracked with a Rawin Set (3) and recorded on Radiosonde Recorder (4) and a Sanborn Model 350 Recorder (5) with position data. | Temperature<br>Relative Humidity | See Figure 2 for Routing. In and out of target area, 7 ft AGL | T-5 min to T+35 min |
| Vertical Profiles of Temp & Relative Humidity<br>High Resolution Radiosonde (1)(2) tracked by Rawin Set (3) and recorded by a Radiosonde Recorder (4). | Temperature<br>Relative Humidity | Vertically from surface to 5000 ft AGL in unaffected fog | Released at T-120 min and T+150 min |
| Kytoon Vertical Met Data<br>A Jalbert Aerological Inc. Model J-12 (6) with High Resolution Radiosonde (1)(2) attached, tracked by Rawin Set (3) and recorded by a Radiosonde Recorder (4) | Temperature<br>Relative Humidity | Continuously raised and lowered every 5 min from surface to 1000 ft AGL in unaffected fog | T-90 min to T+160 min |
| Horizontal Visibility Camera<br>35mm Automax G-2 cinepulse with automatic sequencing and exposure control. Film-B&W Lineograph Shell Burst FSN 6750-965-4588 | Horizontal Visibility | At 500 ft and 1000 ft from the camera in each cardinal direction. Camera in center of target area. A 150 watt lamp positioned 3 ft and 8 ft AGL at each of the 8 locations | Every 20 ec from T-5 min to T+35 min |

TABLE II (continued)

| | | | |
|---|---|---|---|
| Vertical Visibility Camera<br>Same type camera as horizontal visibility camera Film: color Eastman MS<br>FSN 6750-916-2809 | Vertical Visibility | From CH-54 aircraft altitude down to fog tops or ground | Every 20 sec from T-5 min to T+35 min |
| Marker Balloons<br>ML-537 1100 gram balloons<br>FSN 6660-892-1718 | Aircraft positioning | Tethered at predetermined aircraft hover altitude upwind from target | T-30 min to end of mission |
| Thermal Diffusion Chamber<br>Modified version of Naval Research Lab, prototype (7) | Cloud Condensation Nuclei Number Density | 16 ft AGL unaffected fog "MCPL" (10) | Every 30 min from 2 hrs prior to fog until 2 hrs after dissipation |
| Single-Stage Impactor<br>Hand-held Kumai type droplet Replicators (8) | Drop Size Distribution | 3 ft AGL both in unaffected and affected fog "MCPL" | Every 30 min during fog |
| Andersen 6-Stage Sampler<br>Medi-Comp R&D Company Model 705 | Sulfate Number Concentrations | 3 ft AGL unaffected fog "MCPL" | Before and after fog |
| Condensation Nuclei Counter<br>General Electric<br>GE No. 112L428G1<br>GEI No. 45069 dtd Feb 67 | Number concentrations of Particulates | 3 ft AGL unaffected fog "MCPL" | Before, during and after fog |
| Anemometers<br>AN/GMQ-12 Wind Measuring Set (9) | Wind speed and direction | 18 ft AGL unaffected fog "MCPL" | Continuous |

TABLE II (continued)

| | | | |
|---|---|---|---|
| Psychrometer<br>Bendix Electric Psychron Model 566 (5) | Wet-and dry-bulb temperatures | 6 ft unaffected fog "MCPL" | Every 30 min during fog |
| Transmissometer<br>Four-directional system-experimental design (See p 14 of text). | Visibility | Light source in center of target area with receivers located 6 ft AGL at 500 ft and 1000 ft from the light source in each cardinal direction | 1 pulse per minute continuously during fog |

1) AN/TMQ-4 High Resolution Radiosonde ESSA Technical Memorandum WBTM WR-41 dtd Aug 1967
2) AN/AMT-4 Radiosonde - TM 11-2432A dtd June 1958
3) AN/GMD-1 Rawin Set - TM 11-6660-206-20 dtd Sept 61
4) AN/TMQ-5 Radiosonde Recorder - TM 11-2436 dtd March 1955
5) Sanborn Model 350 Recorder Mfr. Instruction Manual
6) Jalbert Aerological Inc., Instruction Manual for J-12 Kytoon
7) Bonner, R. S., "Characteristics and Operation of a Thermal Diffusion Chamber in the Detection of Cloud Condensation Nuclei," ECOM Tech Report (in Preparation).
8) O'Brien, H. W., and M. Kumai, "Electrically Operated Impactors for Hydrometeor Sampling," US Army Terrestrial Sciences Center, Hanover, N.H. 15 pp. Technical Report 170 (1965) [6]
9) AN/GMQ 12 Wind Measuring Set - TM 11-2446 dtd May 1957
10) Mobile Cloud Physics Laboratory

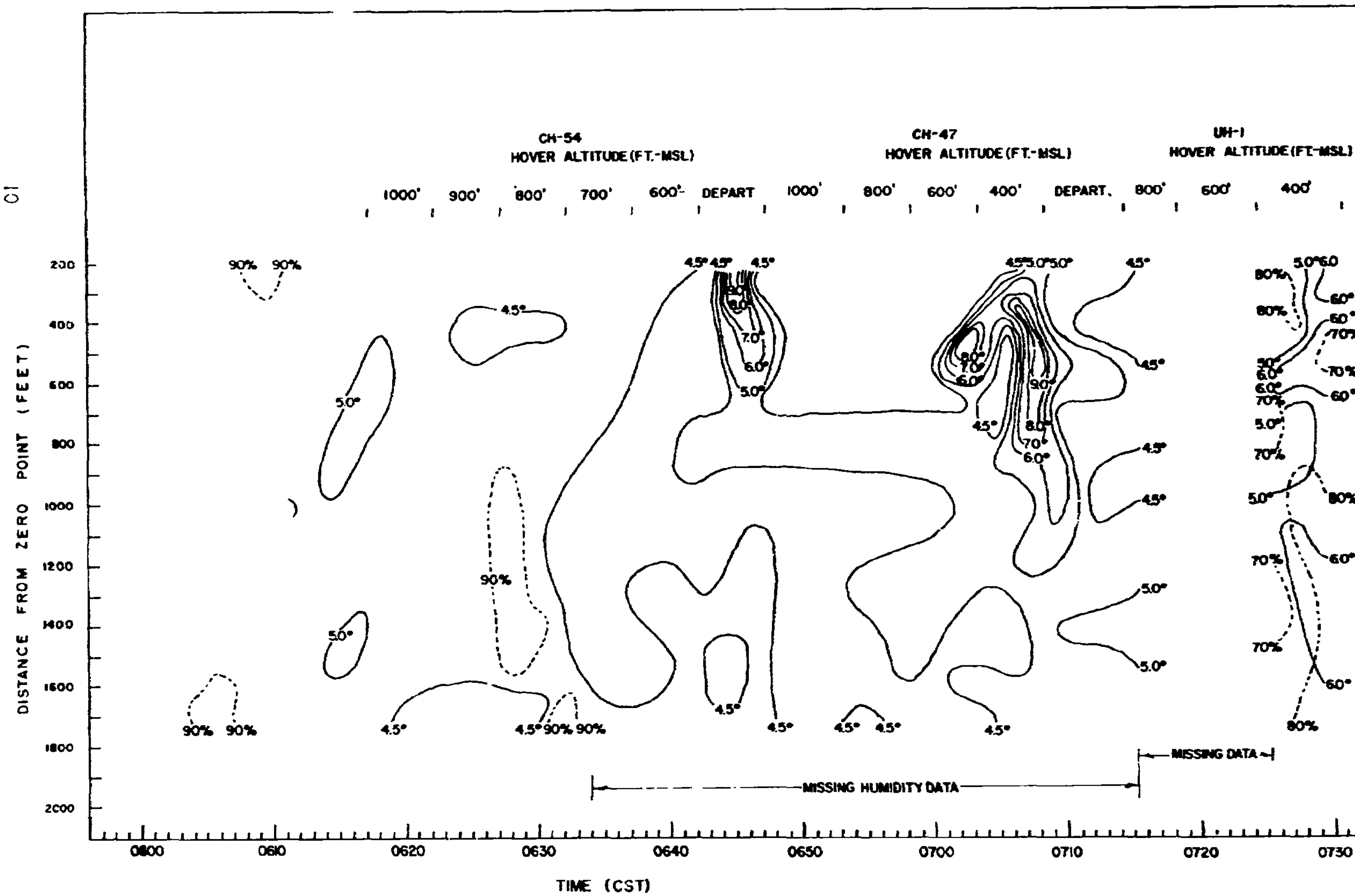



Figure 3. Ground Level Temperature (C) and Relative Humidity (%) Skelly AAF, 17 Feb 1971.

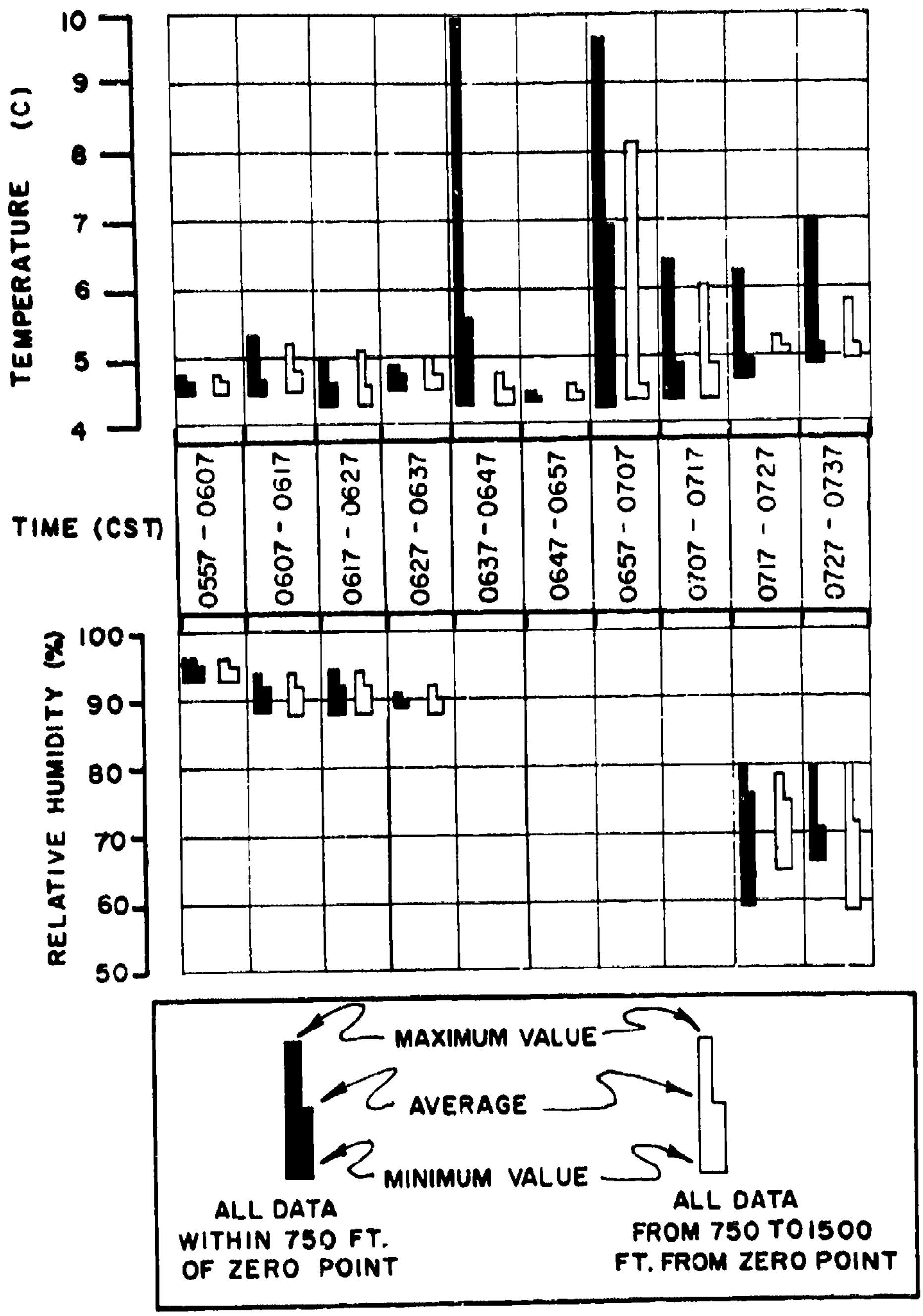



Figure 4. 10-Minute Interval Means and Extremes of Temperature (C) and Relative Humidity (%), Skelly AAF, 17 Feb 1971.

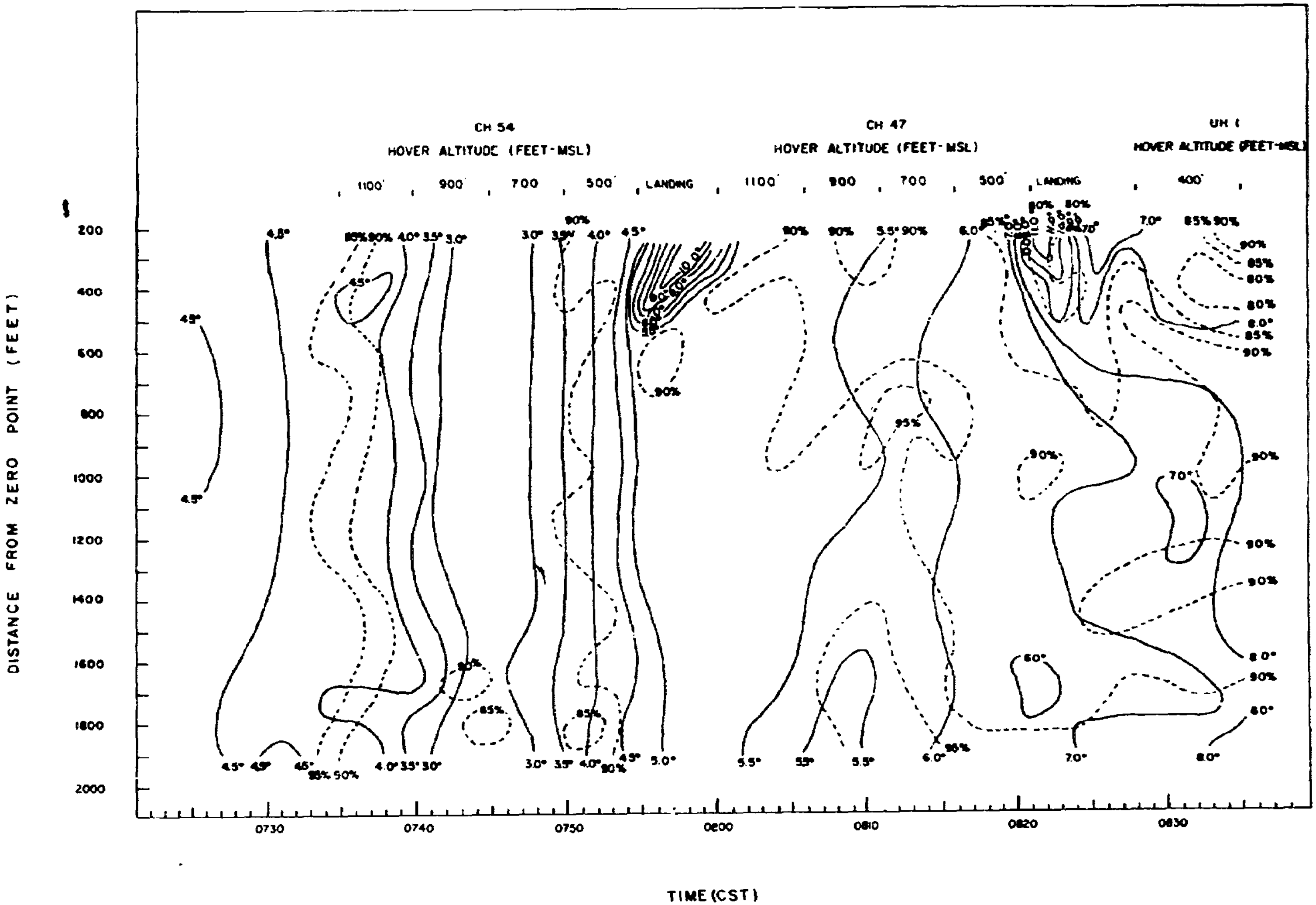



Figure 5. Ground Level Temperature (C) and Relative Humidities (%) . Skelly AFF, 18 Feb 1971.

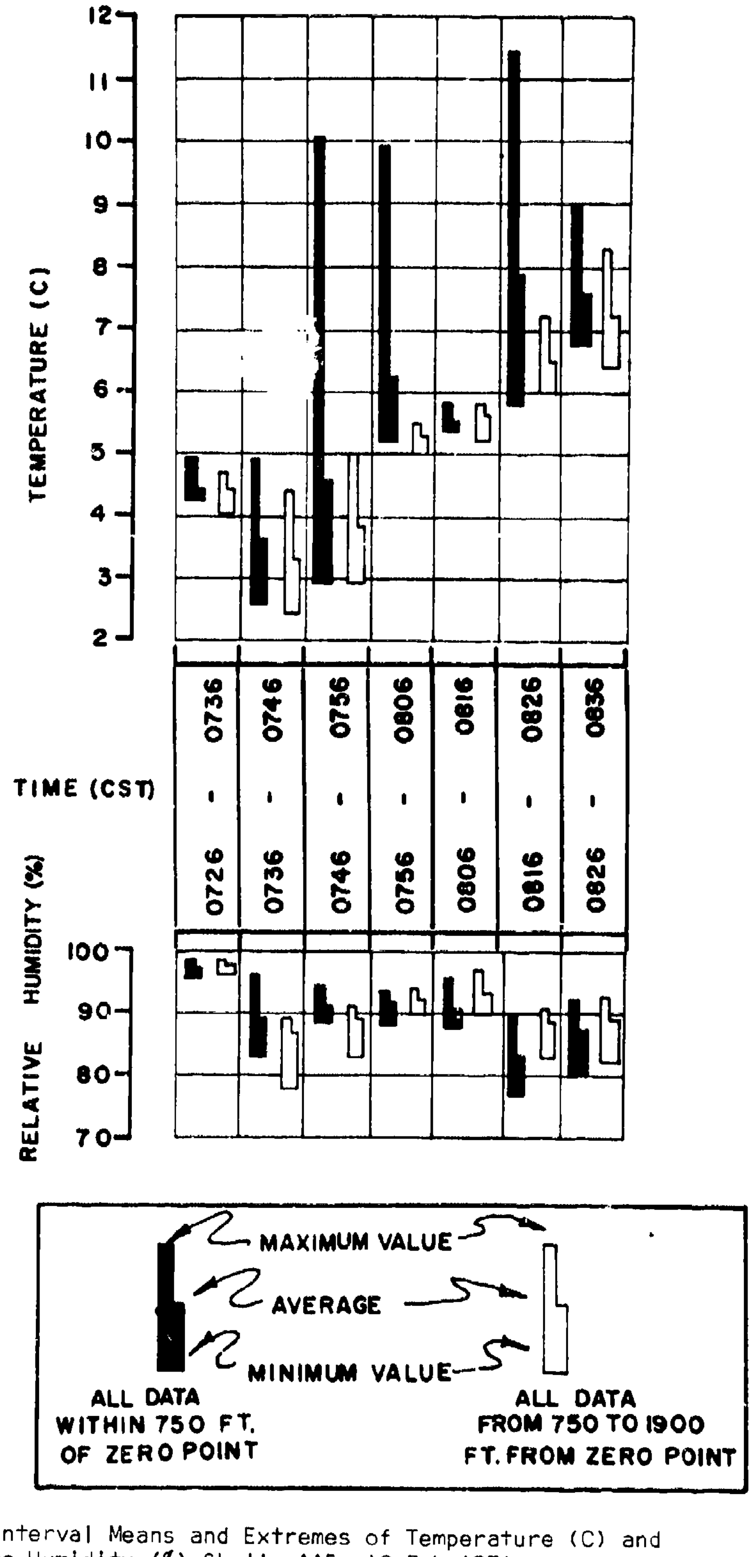



Figure 6. 10-Minute Interval Means and Extremes of Temperature (C) and and Relative Humidity (%) Skelly AAF, 18 Feb 1971.

Temperature and relative humidity data were obtained continuously from the surface to approximately 6000 feet above ground level; data received by the AN/GMD-1( ) were recorded on an AN/TMQ-5 recorder.

Kytoon Vertical Meteorological Data

Meteorological data concerning the state of the environment near but outside the area affected by helicopter downwash were collected by use of continuous measurements of temperature and relative humidity at Kytoon Site (Figure 2). A J-12 Kytoon balloon (length, 45'6"; maximum diameter, 16'9"; total volume, 6000 $ft^3$ helium) was used to lift a radiosonde to an initial altitude of 1000 feet above ground level; the radiosonde was continuously raised and lowered every 5 minutes from T-90 to T+60 minutes. Data received by the AN/GMD-1( ) were recorded on an AN/TMQ-5 recorder. The results are presented in Figures 7 and 8 in which, for pictorial purposes, fog was assumed to exist at all relative humidities greater than 95%. One successful radiosonde observation was obtained, and the data are shown in Table III and Figure 9.

Visibility Data

Visibility was determined by two methods: horizontal relative visibility transmissometer values and both horizontal and vertical photographic indications.

Transmissometer. Transmissometer data were acquired by a four-path system consisting of a large Xenon flash lamp located in the center of the target area and four receivers (Figure 10) mounted on tripods used for horizontal visibility markers as shown in Figure 2. The receivers consisted of photocells (type 5653) followed by pulse-stretching circuitry and an operational amplifier (Figure 11).

In the data reduction, it was assumed that the highest value of light intensity recorded on each record was the value corresponding to a clear-air transmission coefficient, and all values were normalized with respect to this coefficient; this procedure obviated external calibration but required the assumption of system stability over the time interval involved. The normalized values are shown in Figure 12. Although this figure depicts relative visibility over the transmissometer path, it is somewhat misleading in that a zero value may or may not be complete visual obscuration and likewise for the other extreme. A more definitive display appears in Figure 13 in which visibility is given in terms of attenuation coefficient as a function of time; the attenuation coefficient is the transmission coefficient corrected for a 1 km path length.

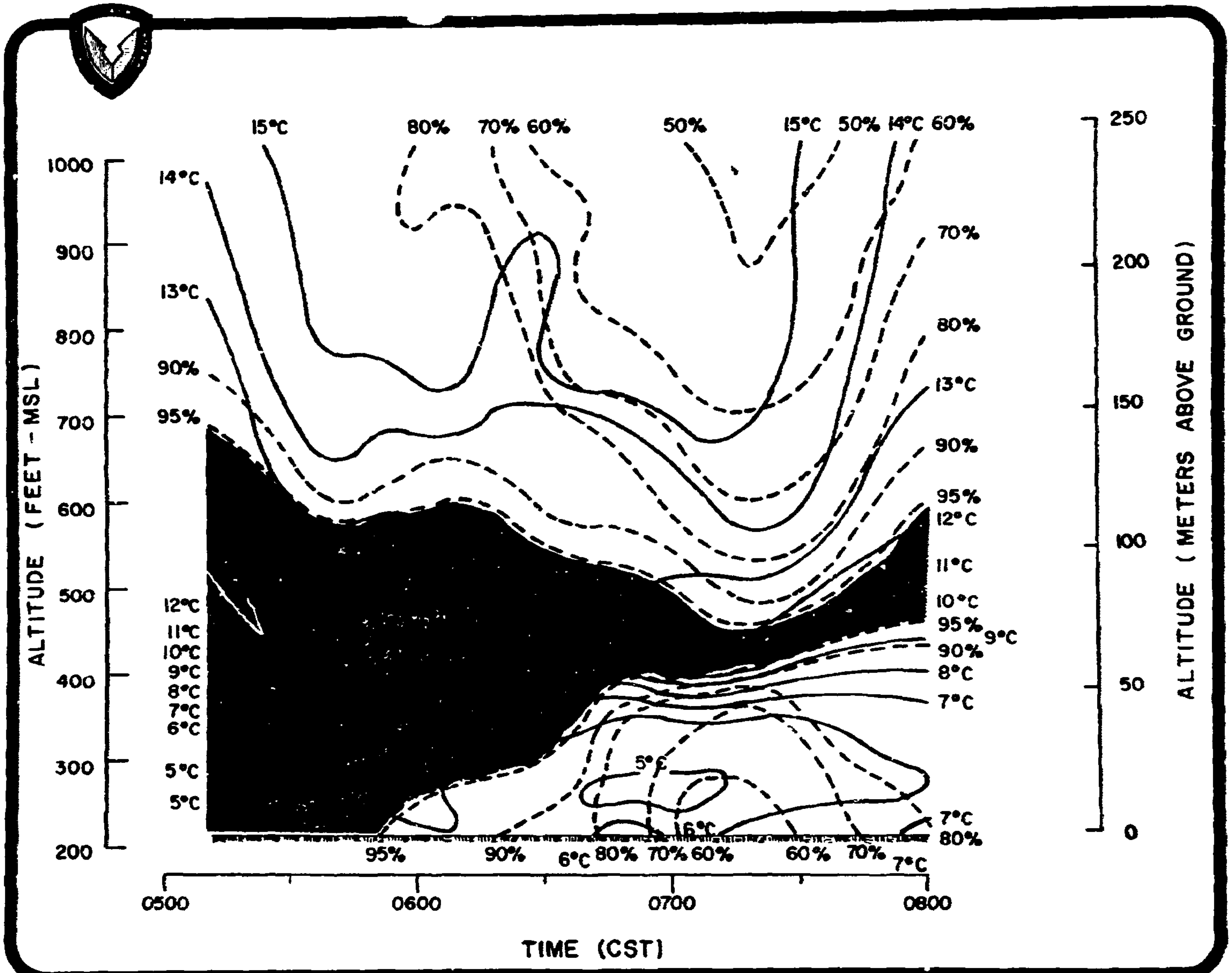



Figure 7. Kytoon Site, Skelly AAF, 17 Feb 1971, Temperature and Relative Humidity Profiles.

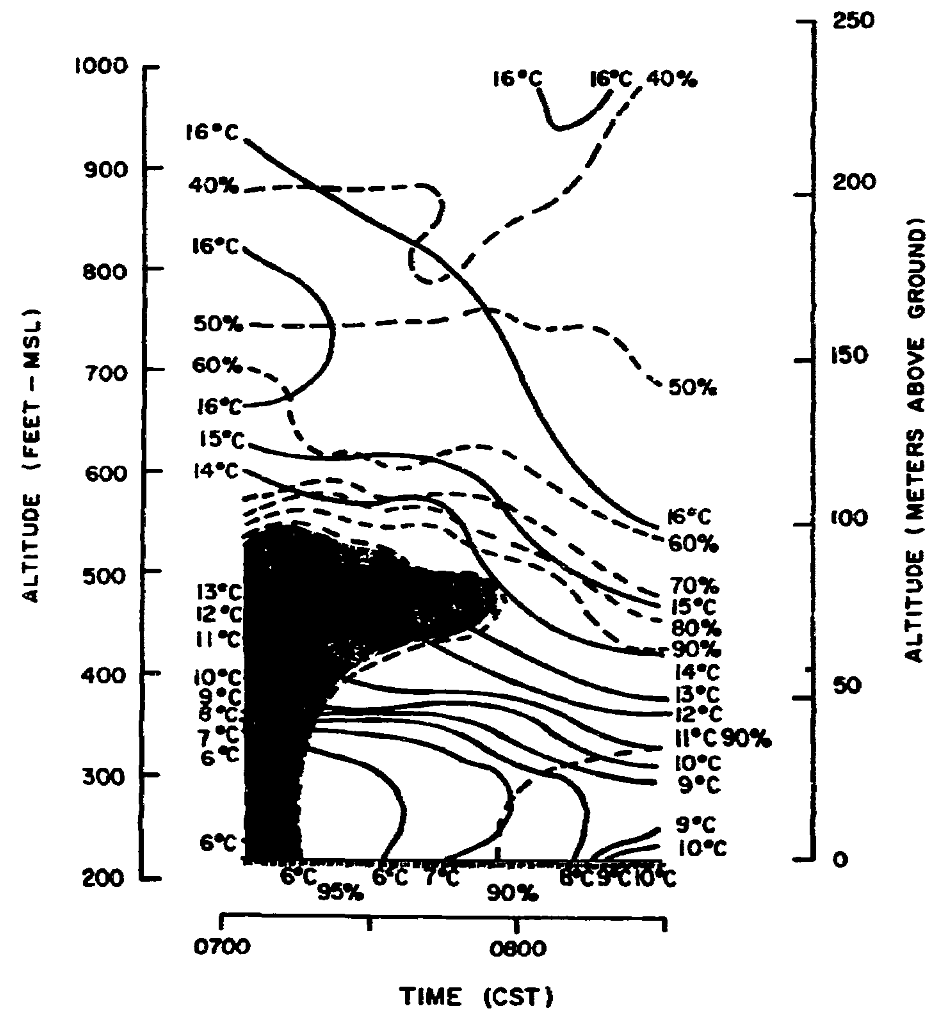



Figure 8. Kytoon Site, Skelly AAF, 18 Feb 1971, Temperature and Relative Humidity Profiles.

| TIME CST | ALT (M) AGL | PRESS (MB) | T (C) | TD (C) | RH (PC) | XK (G/KG) | RHO (KG/M3) | E-W (MPS) | N-S (MPS) | ALT (FT-MSL) | DDD/FF (KTS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 800 | 0 | 1023 | 7.1 | 3.9 | 80 | 4.94 | 1.27 | 0 | 0 | 220 | 0/ 0 |
| 800 | 12 | 1022 | 6.4 | 3.2 | 80 | 4.71 | 1.27 | 0 | 0 | 260 | 0/ 0 |
| 800 | 24 | 1020 | 6.2 | 3.4 | 82 | 4.78 | 1.27 | 0 | 0 | 300 | 0/ 0 |
| 800 | 37 | 1019 | 6.6 | 3.9 | 83 | 4.96 | 1.26 | 0 | 0 | 340 | 0/ 0 |
| 800 | 49 | 1017 | 7.3 | 5.0 | 85 | 5.36 | 1.26 | 0 | 0 | 380 | 0/ 0 |
| 800 | 61 | 1016 | 8.4 | 6.6 | 88 | 6.02 | 1.25 | 0 | 0 | 420 | 0/ 0 |
| 800 | 73 | 1015 | 9.5 | 8.2 | 92 | 6.75 | 1.25 | 0 | 0 | 460 | 0/ 0 |
| 800 | 85 | 1013 | 10.5 | 9.9 | 96 | 7.55 | 1.24 | 0 | 0 | 500 | 0/ 0 |
| 800 | 98 | 1012 | 11.6 | 11.5 | 99 | 8.44 | 1.23 | 0 | 0 | 540 | 0/ 0 |
| 800 | 110 | 1010 | 12.0 | 11.6 | 97 | 8.52 | 1.23 | 0 | 0 | 580 | 0/ 0 |
| 800 | 122 | 1009 | 12.2 | 11.3 | 94 | 8.39 | 1.23 | 0 | 0 | 620 | 0/ 0 |
| 800 | 134 | 1007 | 12.5 | 11.1 | 91 | 8.25 | 1.22 | 0 | 0 | 660 | 0/ 0 |
| 800 | 146 | 1006 | 12.7 | 10.8 | 88 | 8.10 | 1.22 | 0 | 0 | 700 | 0/ 0 |
| 801 | 158 | 1005 | 13.0 | 10.5 | 85 | 7.94 | 1.22 | 0 | 0 | 740 | 0/ 0 |
| 801 | 171 | 1003 | 13.2 | 10.1 | 81 | 7.77 | 1.21 | 0 | 0 | 780 | 0/ 0 |
| 801 | 183 | 1002 | 13.5 | 9.8 | 78 | 7.59 | 1.21 | 0 | 0 | 820 | 0/ 0 |
| 801 | 195 | 1000 | 13.5 | 9.2 | 75 | 7.32 | 1.21 | 0 | 0 | 860 | 0/ 0 |
| 801 | 207 | 999 | 13.6 | 8.6 | 72 | 7.04 | 1.21 | 0 | 0 | 900 | 0/ 0 |
| 801 | 219 | 998 | 13.6 | 8.0 | 69 | 6.75 | 1.21 | 0 | 0 | 940 | 0/ 0 |
| 801 | 232 | 996 | 13.7 | 7.3 | 65 | 6.46 | 1.21 | 0 | 0 | 980 | 0/ 0 |
| 801 | 244 | 995 | 13.7 | 6.6 | 62 | 6.17 | 1.20 | 0 | 0 | 1020 | 0/ 0 |
| 801 | 256 | 993 | 13.8 | 5.9 | 59 | 5.88 | 1.20 | 0 | 0 | 1060 | 0/ 0 |
| 801 | 268 | 992 | 13.8 | 5.4 | 57 | 5.69 | 1.20 | 0 | 0 | 1100 | 0/ 0 |
| 801 | 280 | 991 | 13.8 | 5.1 | 56 | 5.55 | 1.20 | 0 | 0 | 1140 | 0/ 0 |
| 801 | 293 | 989 | 13.8 | 4.7 | 54 | 5.42 | 1.20 | 0 | 0 | 1180 | 0/ 0 |
| 801 | 305 | 988 | 13.8 | 4.4 | 53 | 5.30 | 1.20 | 0 | 0 | 1220 | 0/ 0 |
| 801 | 317 | 986 | 13.7 | 4.2 | 53 | 5.24 | 1.19 | 0 | 0 | 1260 | 0/ 0 |
| 801 | 329 | 985 | 13.6 | 4.0 | 52 | 5.18 | 1.19 | 0 | 0 | 1300 | 0/ 0 |
| 801 | 341 | 984 | 13.5 | 3.8 | 52 | 5.12 | 1.19 | 0 | 0 | 1340 | 0/ 0 |
| 801 | 354 | 982 | 13.4 | 3.7 | 52 | 5.07 | 1.19 | 0 | 0 | 1380 | 0/ 0 |
| 801 | 366 | 981 | 13.4 | 3.5 | 51 | 5.01 | 1.19 | 0 | 0 | 1420 | 0/ 0 |
| 801 | 378 | 980 | 13.3 | 3.3 | 51 | 4.96 | 1.19 | 0 | 0 | 1460 | 0/ 0 |
| 801 | 390 | 978 | 13.2 | 3.1 | 50 | 4.90 | 1.19 | 0 | 0 | 1500 | 0/ 0 |
| 801 | 402 | 977 | 13.1 | 3.0 | 50 | 4.85 | 1.19 | 0 | 0 | 1540 | 0/ 0 |
| 801 | 415 | 975 | 13.0 | 2.8 | 50 | 4.79 | 1.18 | 0 | 0 | 1580 | 0/ 0 |

TABLE III. SKELLY AAF – RAWINSONDE OBSERVATIONS (HEIGHTS ABOVE GROUND)
GROUND LEVEL = 220 FEET MSL, 17 FEB 71, SKELLY FLD, ALABAMA, RELEASED AT 800 CST

| TIME CST | ALT (M) AGL | PRESS (MB) | T (C) | TD (C) | RH (PC) | XK (G/KG) | RHO (KG/M3) | E-W (MPS) | N-S (MPS) | ALT (FT-MSL) | DDD/FF (KTS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 801 | 427 | 974 | 12.9 | 2.6 | 49 | 4.74 | 1.18 | 0 | 0 | 1620 | 0/ 0 |
| 801 | 439 | 973 | 12.8 | 2.4 | 49 | 4.68 | 1.18 | 0 | 0 | 1660 | 0/ 0 |
| 801 | 451 | 971 | 12.8 | 2.2 | 49 | 4.63 | 1.18 | 0 | 0 | 1700 | 0/ 0 |
| 802 | 463 | 970 | 12.7 | 2.1 | 48 | 4.58 | 1.18 | 0 | 0 | 1740 | 0/ 0 |
| 802 | 475 | 969 | 12.6 | 1.9 | 48 | 4.52 | 1.18 | 0 | 0 | 1780 | 0/ 0 |
| 802 | 488 | 967 | 12.5 | 1.7 | 48 | 4.46 | 1.18 | 0 | 0 | 1820 | 0/ 0 |
| 802 | 500 | 966 | 12.4 | 1.5 | 47 | 4.40 | 1.18 | 0 | 0 | 1860 | 0/ 0 |
| 802 | 512 | 964 | 12.3 | 1.3 | 47 | 4.34 | 1.17 | 0 | 0 | 1900 | 0/ 0 |
| 802 | 524 | 963 | 12.2 | 1.1 | 46 | 4.28 | 1.17 | 0 | 0 | 1940 | 0/ 0 |
| 802 | 536 | 962 | 12.1 | .8 | 46 | 4.23 | 1.17 | 0 | 0 | 1980 | 0/ 0 |
| 802 | 549 | 960 | 12.0 | .6 | 45 | 4.17 | 1.17 | 0 | 0 | 2020 | 0/ 0 |
| 802 | 561 | 959 | 12.0 | .4 | 45 | 4.11 | 1.17 | 0 | 0 | 2060 | 0/ 0 |
| 802 | 573 | 958 | 11.9 | .2 | 45 | 4.05 | 1.17 | 0 | 0 | 2100 | 0/ 0 |
| 802 | 585 | 956 | 11.8 | -.0 | 44 | 4.00 | 1.17 | 0 | 0 | 2140 | 0/ 0 |
| 802 | 597 | 955 | 11.7 | -.2 | 44 | 3.94 | 1.17 | 0 | 0 | 2180 | 0/ 0 |
| 802 | 610 | 954 | 11.6 | -.4 | 43 | 3.88 | 1.16 | 0 | 0 | 2220 | 0/ 0 |
| 802 | 622 | 952 | 11.5 | -.7 | 43 | 3.83 | 1.16 | 0 | 0 | 2260 | 0/ 0 |
| 802 | 634 | 951 | 11.4 | -.9 | 43 | 3.77 | 1.16 | 0 | 0 | 2300 | 0/ 0 |
| 802 | 646 | 950 | 11.3 | -1.1 | 42 | 3.72 | 1.16 | 0 | 0 | 2340 | 0/ 0 |
| 802 | 658 | 948 | 11.4 | -4.3 | 33 | 2.92 | 1.16 | 0 | 0 | 2380 | 0/ 0 |
| 802 | 671 | 947 | 11.5 | -10.3 | 21 | 1.83 | 1.16 | 0 | 0 | 2420 | 0/ 0 |
| 802 | 683 | 946 | 11.5 | -14.2 | 15 | 1.35 | 1.16 | 0 | 0 | 2460 | 0/ 0 |
| 802 | 695 | 944 | 11.5 | -14.1 | 15 | 1.36 | 1.15 | 0 | 0 | 2500 | 0/ 0 |
| 802 | 707 | 943 | 11.4 | -13.9 | 15 | 1.38 | 1.15 | 0 | 0 | 2540 | 0/ 0 |
| 802 | 719 | 942 | 11.4 | -13.8 | 16 | 1.39 | 1.15 | 0 | 0 | 2580 | 0/ 0 |
| 802 | 732 | 940 | 11.4 | -13.7 | 16 | 1.41 | 1.15 | 0 | 0 | 2620 | 0/ 0 |
| 802 | 744 | 939 | 11.3 | -13.6 | 16 | 1.42 | 1.15 | 0 | 0 | 2660 | 0/ 0 |
| 802 | 756 | 938 | 11.3 | -13.5 | 16 | 1.44 | 1.15 | 0 | 0 | 2700 | 0/ 0 |
| 803 | 768 | 936 | 11.3 | -13.4 | 16 | 1.45 | 1.15 | 0 | 0 | 2740 | 0/ 0 |
| 803 | 780 | 935 | 11.2 | -13.3 | 17 | 1.47 | 1.14 | 0 | 0 | 2780 | 0/ 0 |
| 803 | 792 | 934 | 11.2 | -13.2 | 17 | 1.48 | 1.14 | 0 | 0 | 2820 | 0/ 0 |
| 803 | 805 | 932 | 11.2 | -13.0 | 17 | 1.50 | 1.14 | 0 | 0 | 2860 | 0/ 0 |
| 803 | 817 | 931 | 11.2 | -12.9 | 17 | 1.51 | 1.14 | 0 | 0 | 2900 | 0/ 0 |
| 803 | 829 | 930 | 11.1 | -12.8 | 17 | 1.53 | 1.14 | 0 | 0 | 2940 | 0/ 0 |
| 803 | 841 | 928 | 11.1 | -12.7 | 17 | 1.54 | 1.14 | 0 | 0 | 2980 | 0/ 0 |

TABLE III (CONT)

| TIME CST | ALT (M) AGL | PRESS (MB) | T (C) | TD (C) | RH (PC) | XK (G/KG) | RHO (KG/M3) | E-W (MPS) | N-S (MPS) | ALT (FT-MSL) | DDD/FF (KTS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 803 | 853 | 927 | 11.1 | -12.6 | 18 | 1.56 | 1.14 | 0 | 0 | 3020 | 0/ 0 |
| 803 | 866 | 926 | 11.0 | -12.5 | 18 | 1.57 | 1.13 | 0 | 0 | 3060 | 0/ 0 |
| 803 | 878 | 924 | 11.0 | -12.4 | 18 | 1.59 | 1.13 | 0 | 0 | 3100 | 0/ 0 |
| 803 | 890 | 923 | 10.9 | -11.7 | 19 | 1.69 | 1.13 | 0 | 0 | 3140 | 0/ 0 |
| 803 | 902 | 922 | 10.8 | -10.8 | 21 | 1.82 | 1.13 | 0 | 0 | 3180 | 0/ 0 |
| 803 | 914 | 920 | 10.7 | -9.9 | 22 | 1.95 | 1.13 | 0 | 0 | 3220 | 0/ 0 |
| 803 | 927 | 919 | 10.5 | -9.1 | 24 | 2.08 | 1.13 | 0 | 0 | 3260 | 0/ 0 |
| 803 | 939 | 918 | 10.4 | -8.4 | 26 | 2.21 | 1.13 | 0 | 0 | 3300 | 0/ 0 |
| 803 | 951 | 917 | 10.3 | -7.7 | 27 | 2.33 | 1.12 | 0 | 0 | 3340 | 0/ 0 |
| 803 | 963 | 915 | 10.1 | -7.1 | 29 | 2.46 | 1.12 | 0 | 0 | 3380 | 0/ 0 |
| 803 | 975 | 914 | 10.0 | -6.5 | 31 | 2.58 | 1.12 | 0 | 0 | 3420 | 0/ 0 |
| 803 | 988 | 913 | 9.9 | -5.9 | 32 | 2.70 | 1.12 | 0 | 0 | 3460 | 0/ 0 |
| 803 | 1000 | 911 | 9.8 | -5.3 | 34 | 2.81 | 1.12 | 0 | 0 | 3500 | 0/ 0 |
| 803 | 1012 | 910 | 9.6 | -4.8 | 36 | 2.93 | 1.12 | 0 | 0 | 3540 | 0/ 0 |
| 803 | 1024 | 909 | 9.5 | -4.4 | 37 | 3.04 | 1.12 | 0 | 0 | 3580 | 0/ 0 |
| 803 | 1036 | 907 | 9.4 | -3.9 | 39 | 3.15 | 1.12 | 0 | 0 | 3620 | 0/ 0 |
| 803 | 1049 | 906 | 9.3 | -3.6 | 40 | 3.22 | 1.12 | 0 | 0 | 3660 | 0/ 0 |
| 803 | 1061 | 905 | 9.2 | -3.7 | 40 | 3.20 | 1.11 | 0 | 0 | 3700 | 0/ 0 |
| 804 | 1073 | 904 | 9.1 | -3.8 | 40 | 3.18 | 1.11 | 0 | 0 | 3740 | 0/ 0 |
| 804 | 1085 | 902 | 9.0 | -3.9 | 40 | 3.17 | 1.11 | 0 | 0 | 3780 | 0/ 0 |
| 804 | 1097 | 901 | 8.9 | -4.0 | 40 | 3.15 | 1.11 | 0 | 0 | 3820 | 0/ 0 |
| 804 | 1109 | 900 | 8.8 | -4.1 | 40 | 3.13 | 1.11 | 0 | 0 | 3860 | 0/ 0 |
| 804 | 1122 | 898 | 8.7 | -4.2 | 40 | 3.11 | 1.11 | 0 | 0 | 3900 | 0/ 0 |
| 804 | 1134 | 897 | 8.6 | -4.3 | 40 | 3.09 | 1.11 | 0 | 0 | 3940 | 0/ 0 |
| 804 | 1146 | 896 | 8.5 | -4.4 | 40 | 3.07 | 1.11 | 0 | 0 | 3980 | 0/ 0 |
| 804 | 1158 | 894 | 8.4 | -4.5 | 40 | 3.05 | 1.10 | 0 | 0 | 4020 | 0/ 0 |
| 804 | 1170 | 893 | 8.3 | -4.6 | 40 | 3.03 | 1.10 | 0 | 0 | 4060 | 0/ 0 |
| 804 | 1183 | 892 | 8.2 | -4.7 | 40 | 3.01 | 1.10 | 0 | 0 | 4100 | 0/ 0 |
| 804 | 1195 | 890 | 8.1 | -4.8 | 40 | 3.00 | 1.10 | 0 | 0 | 4140 | 0/ 0 |
| 804 | 1207 | 889 | 8.0 | -4.9 | 40 | 2.98 | 1.10 | 0 | 0 | 4180 | 0/ 0 |
| 804 | 1219 | 888 | 7.9 | -5.0 | 39 | 2.96 | 1.10 | 0 | 0 | 4220 | 0/ 0 |
| 804 | 1231 | 887 | 7.8 | -5.1 | 39 | 2.94 | 1.10 | 0 | 0 | 4260 | 0/ 0 |
| 804 | 1244 | 885 | 7.7 | -5.2 | 39 | 2.92 | 1.10 | 0 | 0 | 4300 | 0/ 0 |
| 804 | 1256 | 884 | 7.6 | -5.3 | 39 | 2.90 | 1.09 | 0 | 0 | 4340 | 0/ 0 |
| 804 | 1268 | 883 | 7.5 | -5.4 | 39 | 2.89 | 1.09 | 0 | 0 | 4380 | 0/ 0 |

TABLE III (CONT)

| TIME CST | ALT (M) AGL | PRESS (MB) | T (C) | TD (C) | RH (PC) | XK (G/KG) | RHO (KG/M3) | E-W (MPS) | N-S (MPS) | ALT (FT-MSL) | DDD/FF (KTS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 804 | 1280 | 881 | 7.4 | -5.5 | 39 | 2.87 | 1.09 | 0 | 0 | 4420 | 0/ 0 |
| 804 | 1292 | 880 | 7.3 | -5.6 | 39 | 2.85 | 1.09 | 0 | 0 | 4460 | 0/ 0 |
| 804 | 1305 | 879 | 7.2 | -5.7 | 39 | 2.83 | 1.09 | 0 | 0 | 4500 | 0/ 0 |
| 804 | 1317 | 878 | 7.1 | -5.8 | 39 | 2.82 | 1.09 | 0 | 0 | 4540 | 0/ 0 |
| 804 | 1329 | 876 | 7.0 | -5.9 | 39 | 2.80 | 1.09 | 0 | 0 | 4580 | 0/ 0 |
| 804 | 1341 | 875 | 6.9 | -6.0 | 39 | 2.78 | 1.09 | 0 | 0 | 4620 | 0/ 0 |
| 804 | 1353 | 874 | 6.8 | -6.1 | 39 | 2.76 | 1.09 | 0 | 0 | 4660 | 0/ 0 |
| 804 | 1366 | 873 | 6.7 | -6.2 | 39 | 2.75 | 1.08 | 0 | 0 | 4700 | 0/ 0 |
| 805 | 1378 | 871 | 6.6 | -6.3 | 39 | 2.73 | 1.08 | 0 | 0 | 4740 | 0/ 0 |
| 805 | 1390 | 870 | 6.5 | -6.4 | 39 | 2.71 | 1.08 | 0 | 0 | 4780 | 0/ 0 |
| 805 | 1402 | 869 | 6.4 | -6.5 | 39 | 2.70 | 1.08 | 0 | 0 | 4820 | 0/ 0 |
| 805 | 1414 | 868 | 6.3 | -6.6 | 39 | 2.68 | 1.08 | 0 | 0 | 4860 | 0/ 0 |
| 805 | 1426 | 866 | 6.2 | -6.7 | 39 | 2.66 | 1.08 | 0 | 0 | 4900 | 0/ 0 |
| 805 | 1439 | 865 | 6.1 | -6.8 | 39 | 2.65 | 1.08 | 0 | 0 | 4940 | 0/ 0 |
| 805 | 1451 | 864 | 6.0 | -6.9 | 39 | 2.63 | 1.08 | 0 | 0 | 4980 | 0/ 0 |
| 805 | 1463 | 862 | 5.9 | -7.0 | 39 | 2.61 | 1.07 | 0 | 0 | 5020 | 0/ 0 |
| 805 | 1475 | 861 | 5.8 | -7.1 | 39 | 2.60 | 1.07 | 0 | 0 | 5060 | 0/ 0 |
| 805 | 1487 | 860 | 5.7 | -7.2 | 39 | 2.58 | 1.07 | 0 | 0 | 5100 | 0/ 0 |
| 805 | 1500 | 859 | 5.7 | -7.3 | 39 | 2.56 | 1.07 | 0 | 0 | 5140 | 0/ 0 |
| 805 | 1512 | 857 | 5.6 | -7.4 | 39 | 2.55 | 1.07 | 0 | 0 | 5180 | 0/ 0 |
| 805 | 1524 | 856 | 5.5 | -7.5 | 39 | 2.53 | 1.07 | 0 | 0 | 5220 | 0/ 0 |
| 805 | 1536 | 855 | 5.4 | -7.6 | 39 | 2.52 | 1.07 | 0 | 0 | 5260 | 0/ 0 |
| 805 | 1548 | 854 | 5.3 | -7.7 | 39 | 2.50 | 1.07 | 0 | 0 | 5300 | 0/ 0 |
| 805 | 1561 | 853 | 5.2 | -7.8 | 38 | 2.48 | 1.07 | 0 | 0 | 5340 | 0/ 0 |
| 805 | 1573 | 851 | 5.1 | -7.9 | 38 | 2.47 | 1.06 | 0 | 0 | 5380 | 0/ 0 |
| 805 | 1585 | 850 | 5.0 | -8.0 | 38 | 2.45 | 1.06 | 0 | 0 | 5420 | 0/ 0 |
| 805 | 1597 | 849 | 4.9 | -8.1 | 38 | 2.44 | 1.06 | 0 | 0 | 5460 | 0/ 0 |
| 805 | 1609 | 848 | 4.8 | -8.2 | 38 | 2.42 | 1.06 | 0 | 0 | 5500 | 0/ 0 |
| 805 | 1622 | 846 | 4.7 | -8.3 | 38 | 2.41 | 1.06 | 0 | 0 | 5540 | 0/ 0 |
| 805 | 1634 | 845 | 4.6 | -8.4 | 38 | 2.39 | 1.06 | 0 | 0 | 5580 | 0/ 0 |
| 805 | 1646 | 844 | 4.5 | -8.5 | 38 | 2.38 | 1.06 | 0 | 0 | 5620 | 0/ 0 |
| 805 | 1658 | 843 | 4.4 | -8.6 | 38 | 2.36 | 1.06 | 0 | 0 | 5660 | 0/ 0 |
| 805 | 1670 | 841 | 4.3 | -8.7 | 38 | 2.35 | 1.05 | 0 | 0 | 5700 | 0/ 0 |
| 806 | 1682 | 840 | 4.2 | -8.8 | 38 | 2.33 | 1.05 | 0 | 0 | 5740 | 0/ 0 |
| 806 | 1695 | 839 | 4.1 | -8.9 | 38 | 2.32 | 1.05 | 0 | 0 | 5780 | 0/ 0 |

TABLE III (CONT)

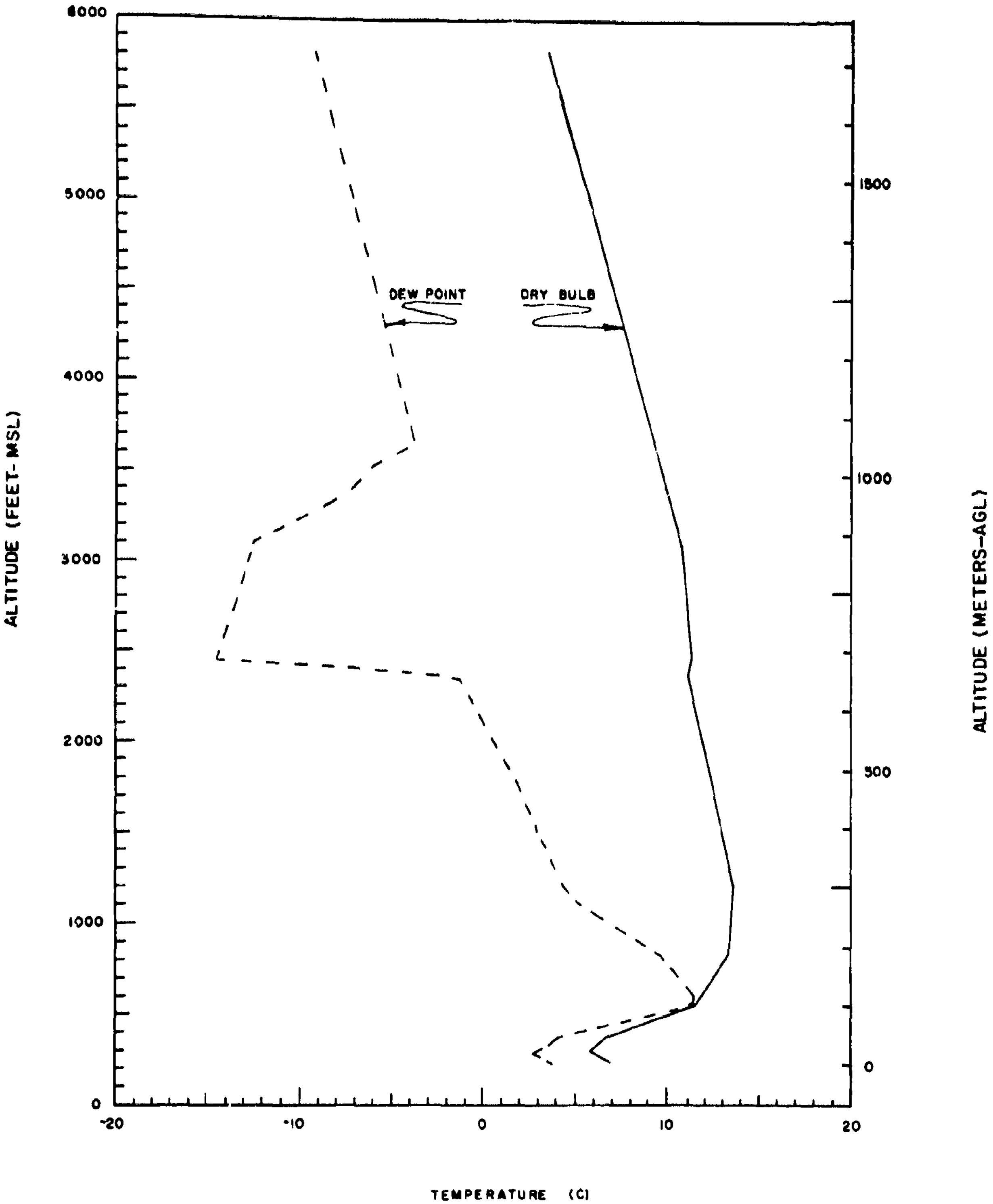



Figure 9. Skelly AAF, 17 Feb 1971, Radiosonde Profile.

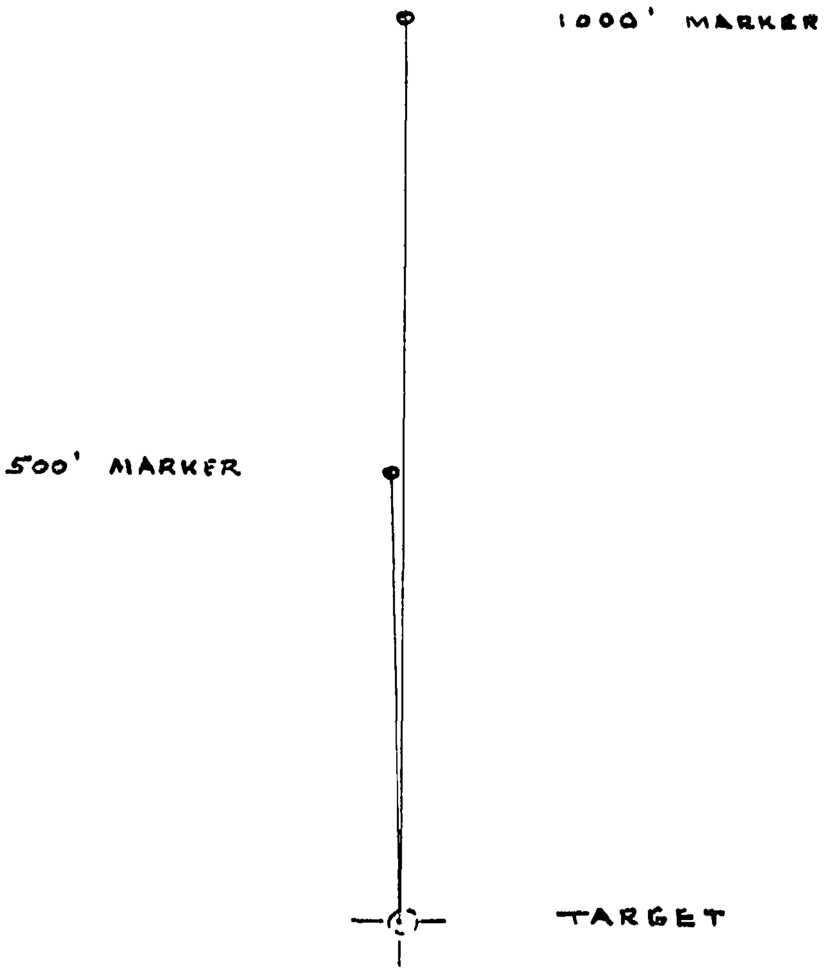



FIGURE 10. Typical horizontal visibility marker and transmissometer layout.

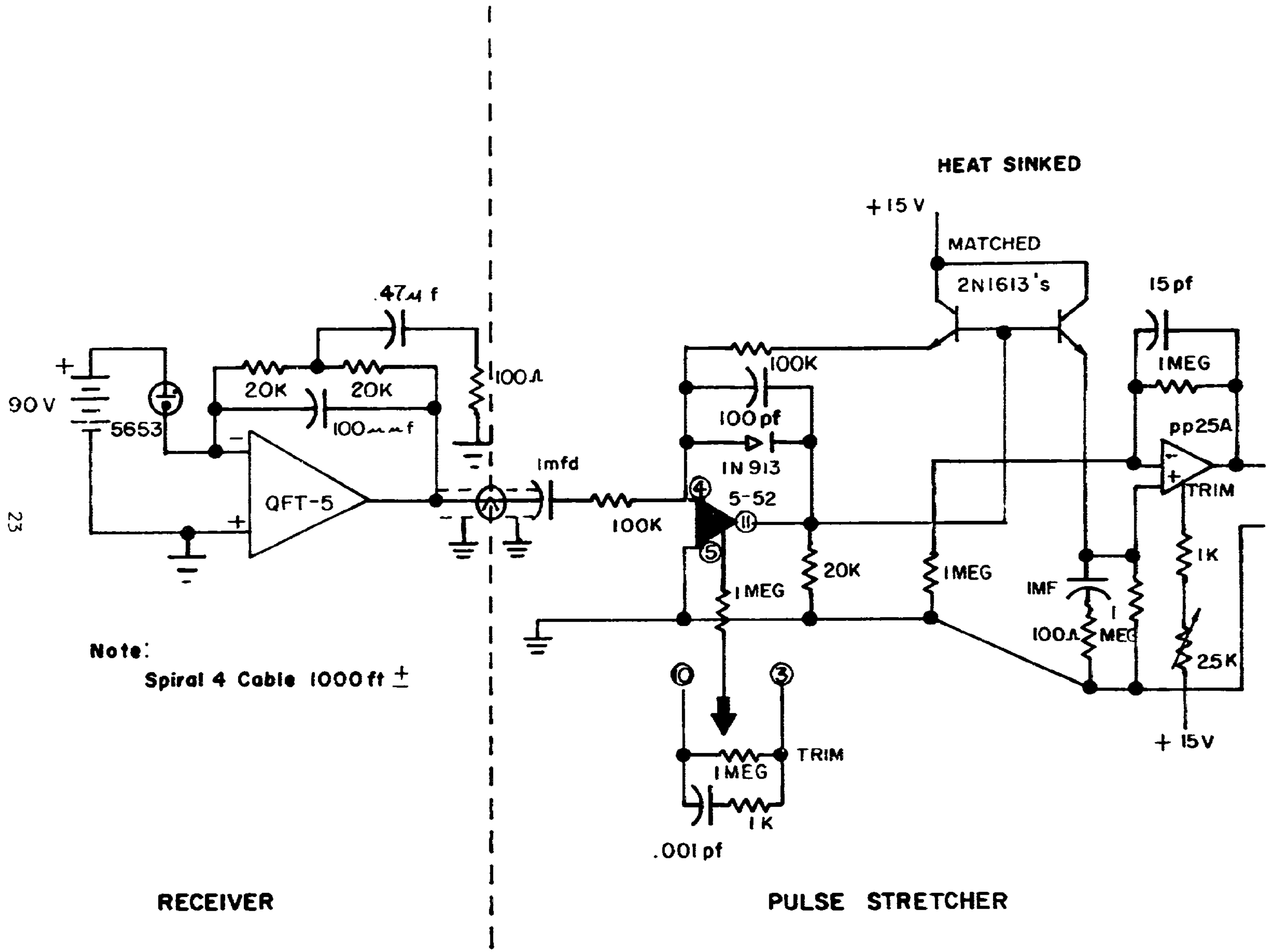



Figure 11. Transmissometer Schematic.

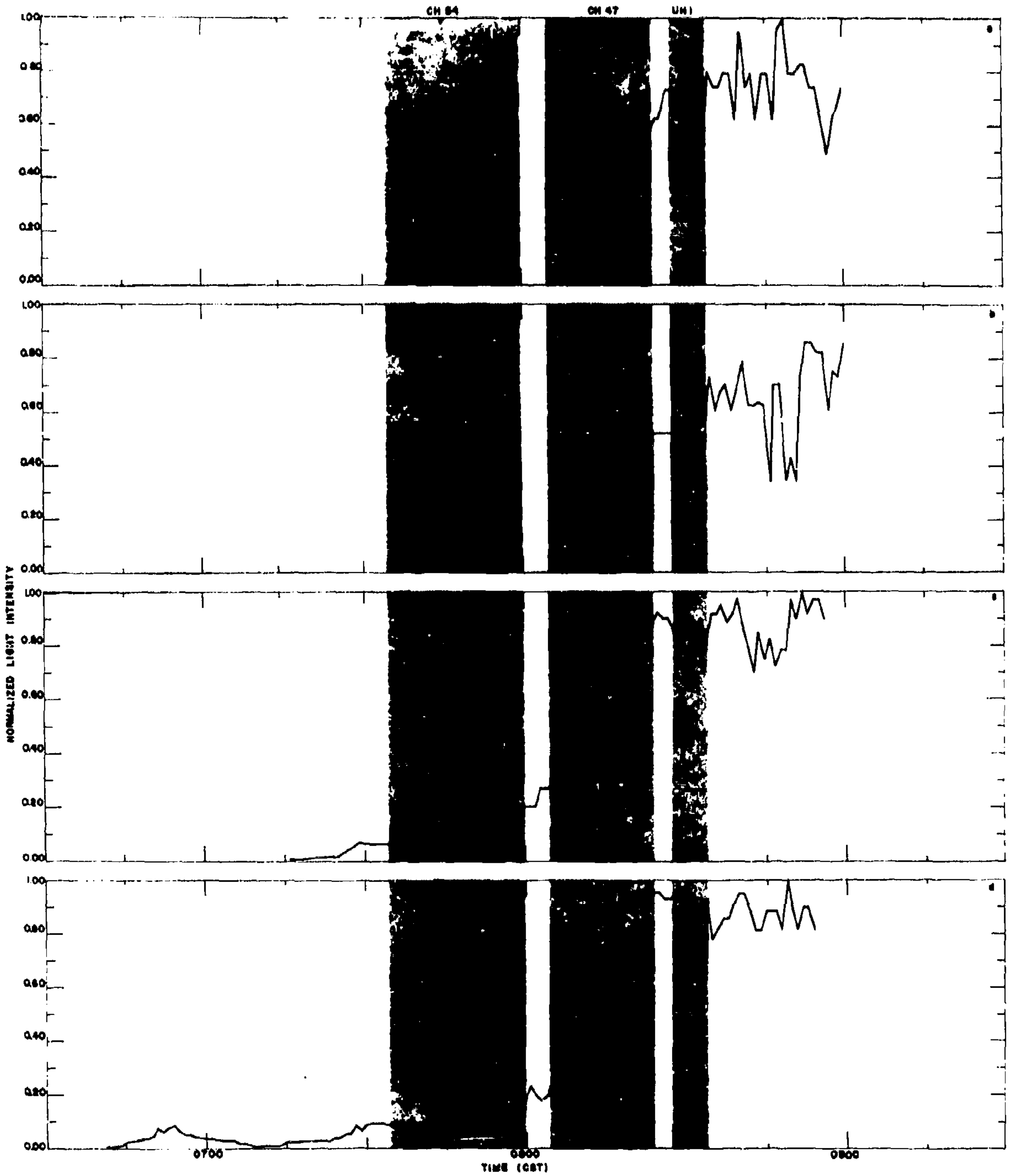



Figure 12. Transmissometer Normalized Light Intensity, 18 Feb 1971.
A) South, B) West, C) North, D) East

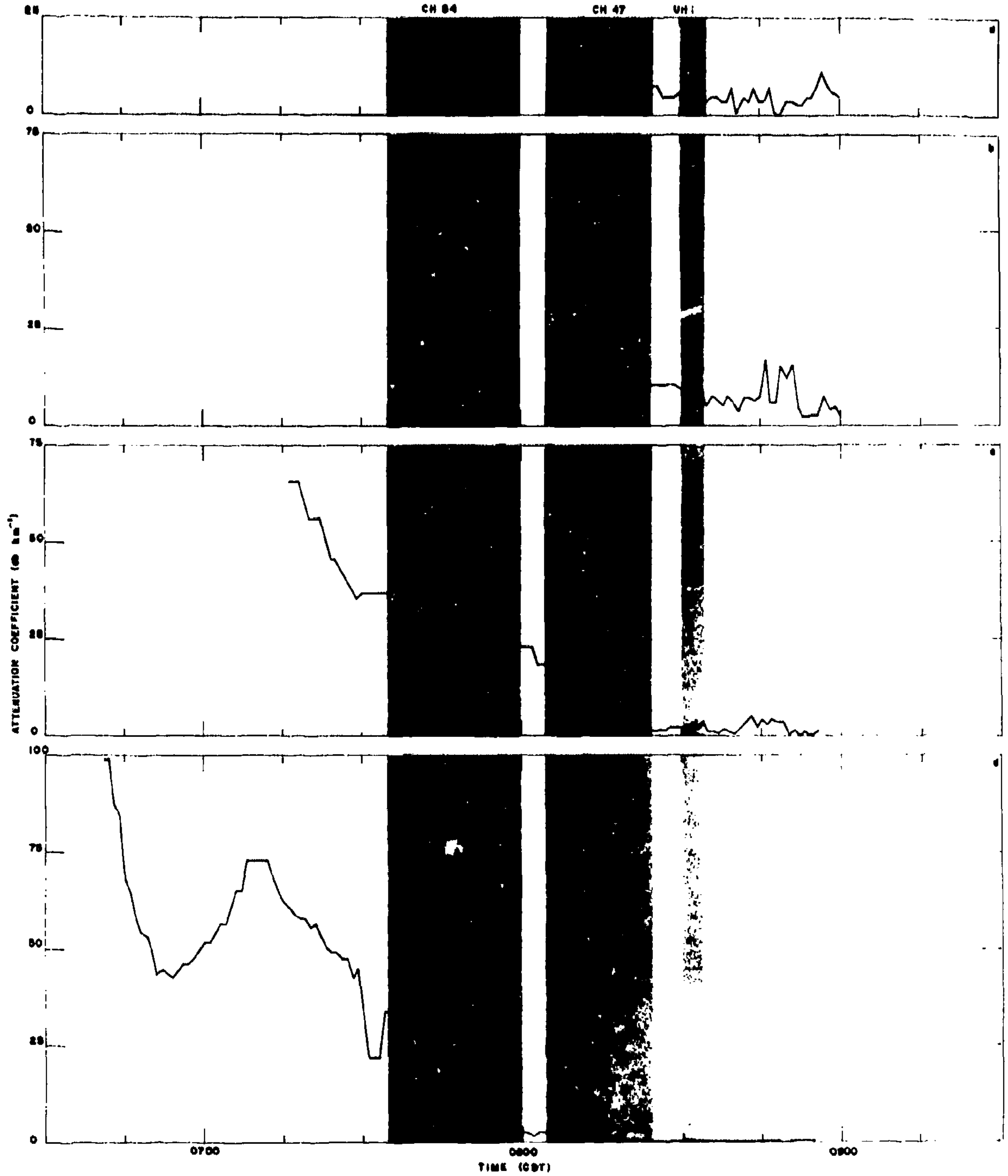



Figure 13. Transmissometer Attenuation Coefficients.
A) South, B) West, C) North, D) East

Photographic Indications. Two 35mm Automax G-2 cinepulse cameras with automatic exposure control and 400-foot Mitchell magazines were used to record light attenuation. One, for horizontal visibility determinations, was positioned in the center of the target area; the other, for vertical visibility determinations, was mounted on the CH-54 helicopter and pointed vertically downward at the target area. The cameras were activated every 20 seconds by a cam-operated switch. Eastman FM color film (FSN 6750-916-2809) was used in the airborne camera, and black and white lineograph shell burst film (FSN 6750-965-4588) in the ground-based camera (300mm lens set at f/22, focussed at infinity, and shutter speed fixed at 1/64 second). The airborne camera aperture setting was controlled by an automatic sensing device.

Light sources were 150-watt flood lamps mounted three feet and 8 feet above ground level on tripods. In each cardinal direction, two lamps were positioned 500-feet from the ground-based camera; in the north and south directions, lamps were also placed 1000 feet from the camera, while in the east and west directions, because of terrain factors, the lamps were placed 900 feet from the camera. (Calculations, however, were made for 1000 feet, the 100 foot difference being neglected.) Their light was reflected by a four-sided pyramid of mirrors into the camera in the center of the array. The strength of the photographic light images was considered an indication of light attenuation (visibility) in the fog. Each exposed frame (Figure 14) includes, in addition to the raw data, time (CST), frame number, and date slate. The system operated from 0500 to 0800 hours CST on 17 February and from 0620 to 0840 on 18 February.

Photographic data were reduced by use of eight photosensitive devices (IN2175). The negative film strip was projected and eight holes were cut where the light images impinged. A light diode was placed behind each hole, which was masked down smaller than the size of the image. The voltages from each cell were amplified and recorded. Continuous comparisons were made to confirm that the readings corresponded to the apparent visual darkness of the images, and frequent spot checks were made on diode and amplifier stability.

Voltage values from each sensor corresponding to complete visibility ($C_V$) and complete obscuration ($C_O$) were measured prior to recording the data voltages (V). The ratios $(V-C_V)(C_O-C_V)$ were calculated, 100% corresponding to complete obscuration and 1% or less to unobscured visibility. This is a monotonic function of relative transmissivity.

Results for each light source are shown in Figures 15 and 16, for February 17 and 18, respectively. The fog sometimes caused complete obscuration of the lights at 1000 feet, while the lights at 500 feet were always visible to some extent. Terrain differences which might have contributed to the variations in the data from the individual light sources are listed in Table IV.

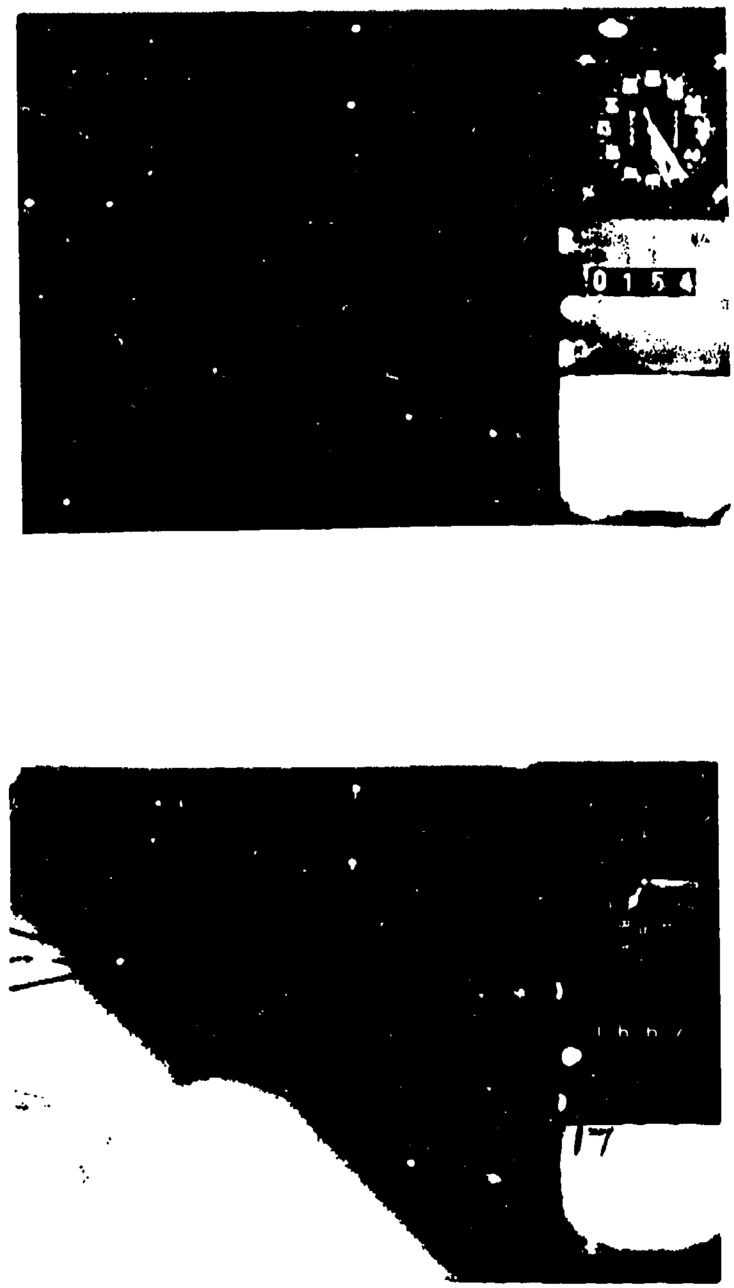



Figure 14. Sample of Horizontal Visibility Camera Raw Data, Skelly AAF, 17 Feb 1971.

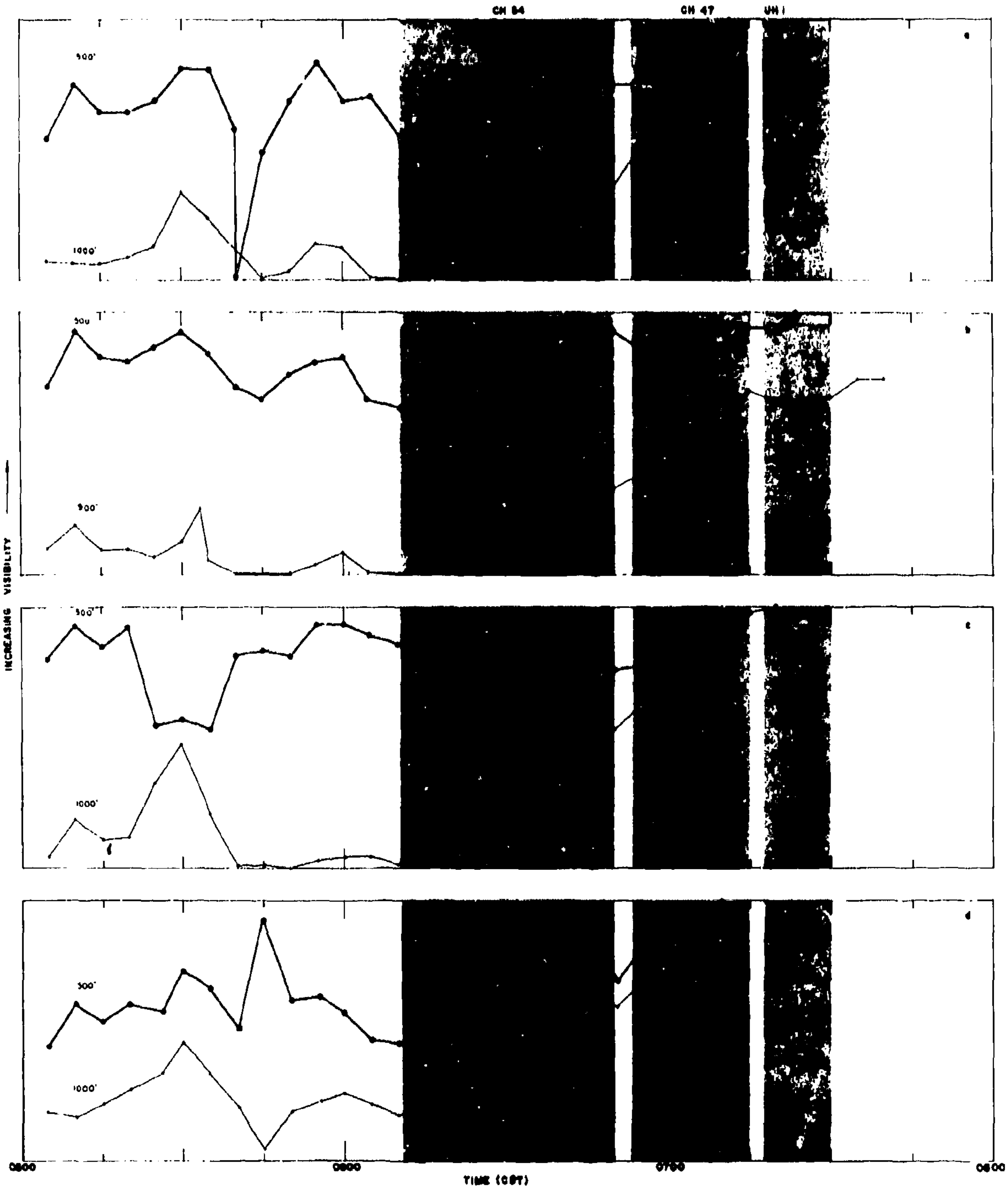



Figure 15. Horizontal Visibility Measurements, 17 Feb 1971.
A) East, B) West, C) North, D) South

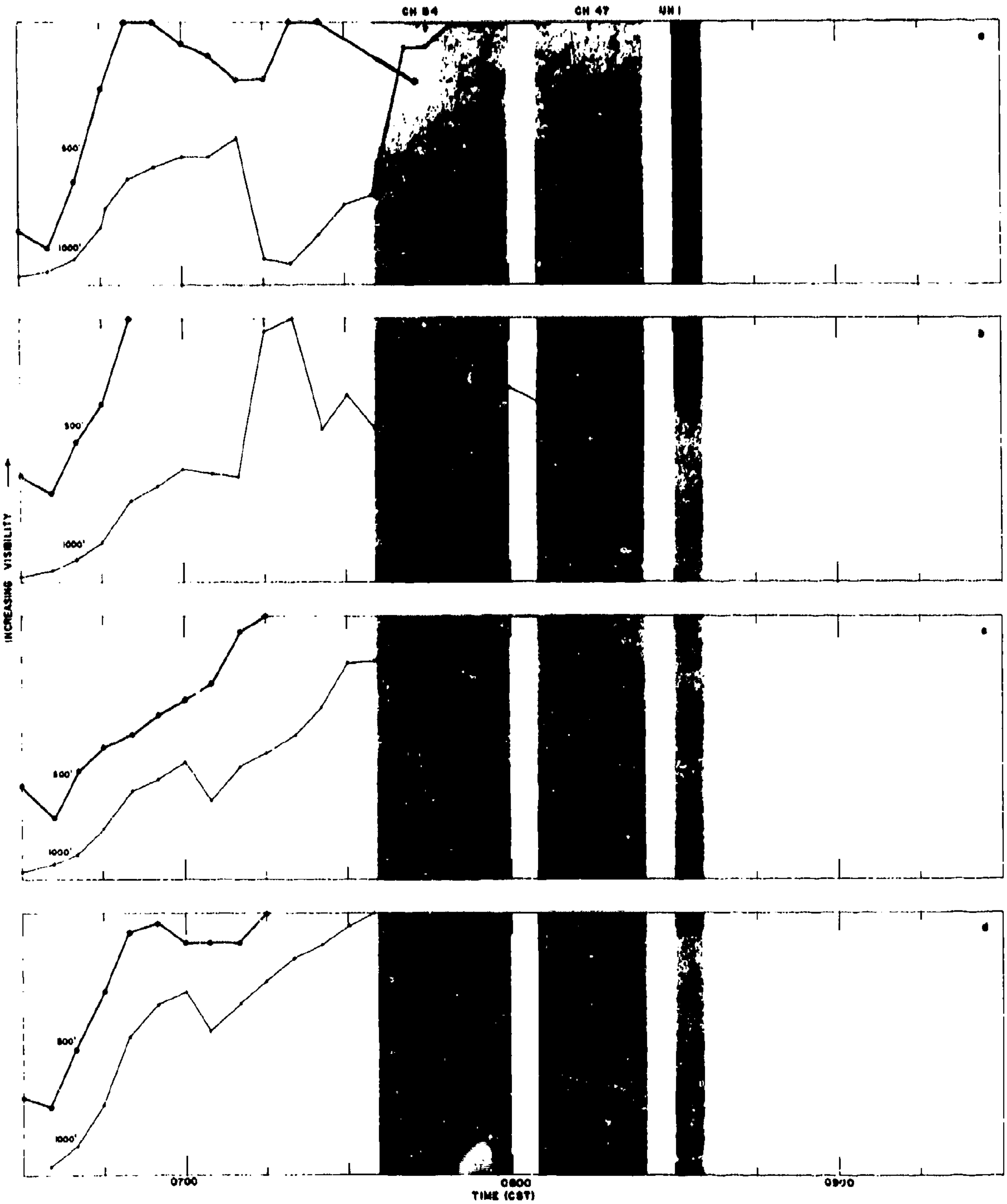



Figure 16. Horizontal Visibility Measurements, 18 Feb 1971.
A) East, B) West, C) North, D) South

## TABLE IV

### TERRAIN DIFFERENCES OF HORIZONTAL VISIBILITY MEASUREMENT SYSTEM

| | | |
|---|---|---|
| NORTH | - The distance on the near leg equals 500' of grassy turf and asphalt runway. 275' includes MOMET path*. | The distance on the far leg was 1000' on very wet ground and 50' on asphalt runway near wet, swampy areas. |
| EAST | - The distance on the near leg equals 500' on runway edge. 150' asphalt runway includes MOMET path* with the light path nearer ground level. | The distance on the far leg was 900' on the cultivated field crossing an asphalt runway at 50', and an asphalt road, light traffic at 500' out and the path was 300' from houses. |
| SOUTH | - The distance on the near leg equals 500' on runway edge; 150' asphalt runway. | The distance on the far leg was 1000' on grassy turf and an asphalt runway for 50' |
| WEST | - The distance on the near leg equals 500' on the runway edge. 200' asphalt runway includes MOMET path*. | The distance on the far leg was 900' on grassy turf and asphalt runway for 75' in edge of forest creek to 500' west. |

* The travel path of the jeep with the met instrumentation.

On 17 February, the ground-based camera was activated at T-1 hour. The data (Figure 15) show a maximum fog intensity at 0545 hours CST. A second maximum occurred at 0610 hours, 3 minutes after the CH-54 arrived at 1230 feet MSL and may have been the result of the fog being downwashed into the area. The fog then appeared to dissipate fairly linearly, with some striking dips occurring at the times of the lowest levels reached by the CH-54. Data from the light sources in the north, east, and south directions indicate that the fog had completely dissipated by about 0710 hours CST.

Again, on 18 February, the ground-based camera was activated at T-1 hour, 15 minutes prior to the arrival of the CH-54. According to the data (Figure 16), the fog was at a maximum intensity at the time the camera was activated and began to dissipate shortly thereafter.

## MICROPHYSICAL MEASUREMENTS

The study of particulate chemistry is a means of better understanding fog evolution and, hence, artificial dispersion. Temporal changes of fog chemistry help in the determination of which dissipation technique is best suited for a given place, or fog, or time, or combinations thereof. A recent study has indicated the abundance of sulfate-containing condensation nuclei at selected locations [4]. Direct observations [5] of sulfate variation in atmospheric particulates during periods of moisture (rain, fog, haze, or high relative humidity) indicated a direct correspondence between the variation of sulfate and relative humidity. Fogwash I permitted the testing of the hypotheses that sulfate content increases with moisture increase, that sulfates act as condensation nuclei constituents, and that the number of particles containing sulfate are increased during fog. Selected data are presented in Table V and Figure 17.

Thermal Diffusion Chamber. This device for measuring low levels of condensation nuclei concentrations consists of four principal components: a thermal diffusion chamber, a collimated light source, a photo-recording system, and a conditioning chamber.

Condensation Nuclei Counter. The counter used to measure high levels of nuclei concentrations was a commercially available General Electric Condensation Nuclei Counter.

Single-Stage Impactor. Fog drop size distribution in the target area was sampled before, during, and after a foggy period to determine drop size changes and number of drops. A Kumai [6,7] hand-held, single-stage im-

TABLE V

Change of sulfate content and total particle concentration in air as a result of fog

| Date (1971) | Sampling Times (Hrs CST) | Andersen Samples (Stages) | $SO_4$ Particles % | No. Total Particles ($cm^{-3}$) |
|---|---|---|---|---|
| 16 Feb | 1100 to 1115 (morning prior to fog) | 4 | 6.3 | 0.6 |
| | | 5 | 44.2 | 3.4 |
| | | 6 | 79.5 | 19.7 |
| 16 Feb | 2320 to 2343 (immediately prior to fog) | 4 | 29.1 | 0.08 |
| | | 5 | 25 | 0.1 |
| | | 6 | 26 | 8.61 |
| 17 Feb | 0933 to 0948 (immediately after fog) | 4 | 25.4 | 0.8 |
| | | 5 | 53.2 | 2.5 |
| | | 6 | 91.2 | 74 |

NOTE: Fog began 2330 hours 16 February 71, dispersed 0730 hours 17 February 71.

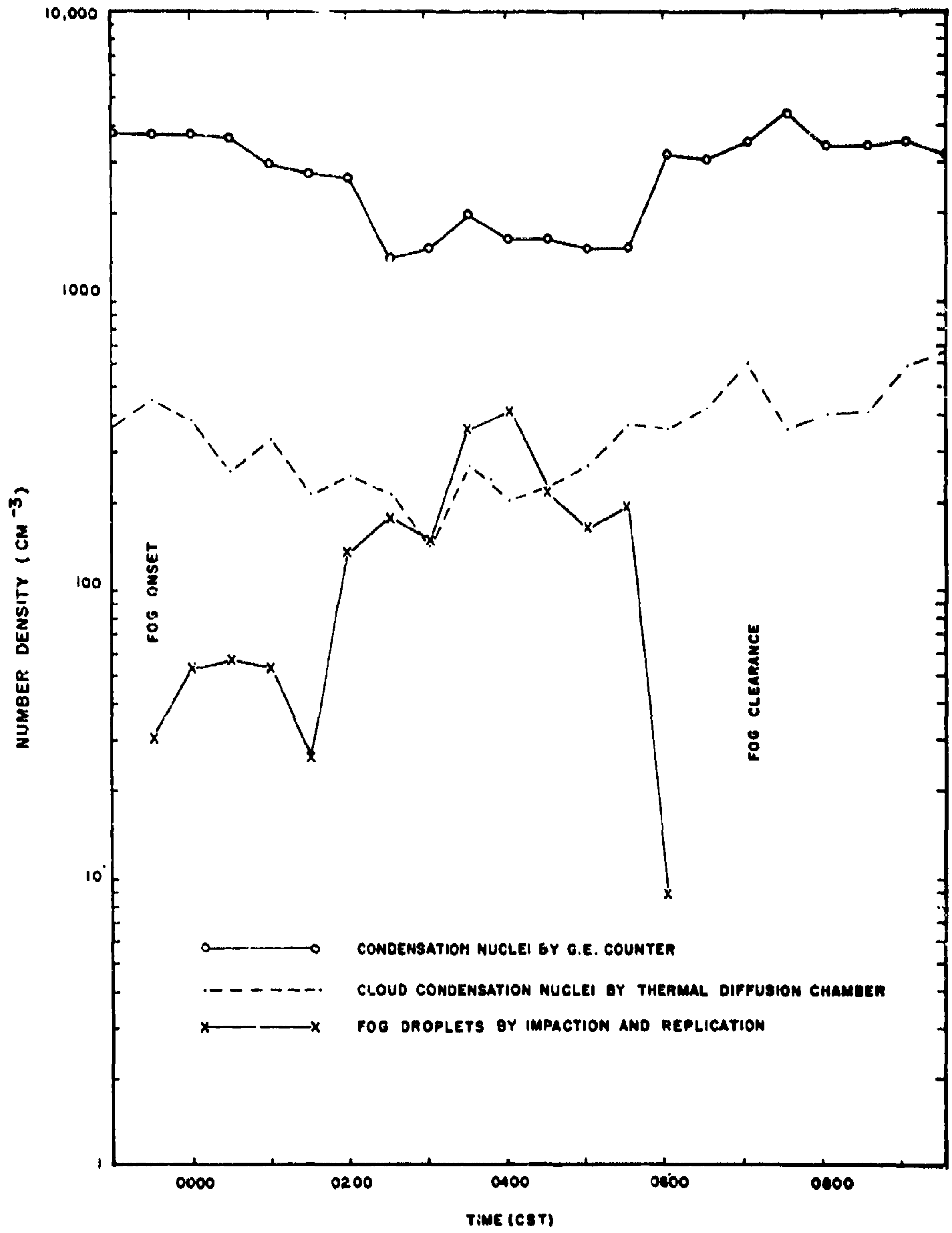



Figure 17. Unaffected Fog Area Condensation Nuclei and Droplet Concentrations.

pactor was used to sample a 50 cc volume of foggy air for a one-second time period at 30-minute intervals. Sampler efficiency is above 83% for droplets as small as 0.9 μ and increases to 100% for droplets greater than 7.0 μ.

The stage or impactor surface was a gelatin-coated, 10mm diameter circular glass disc. The disc was placed in the impactor shortly before the sample was to be taken; unfortunately, the slide was exposed to the fog whenever the slide box was opened and before the cover was placed on the impactor. Large drops in the fog preferentially fell on the slide during these exposed periods and, thus, have weighted the distribution toward larger sizes.

To account for droplet spreading on impaction on the gelatin [8], the drop sizes were multiplied by a factor of 0.6. Data revealed that the mode drop sizes of approximately 18 μ radius were larger than the typical radiation fog, the mode of which is usually about 7 or 8 μ. Fog drop size data are presented in Table VI and permit the analysis of drop size and number changes resulting from helicopter downwash.

Andersen Sampler. A 6-stage Andersen Sampler [9] was used to measure the number of sulfate particles and total number of fog particulates in the undisturbed area (Figure 1, MCPL). The last three stages (4, 5, and 6) were utilized as collecting sites; particulate radii associated with stages 4, 5, and 6 are, respectively: greater than 1.0 μ, 0.4 to 1.5 μ, and 0.2 to 0.4 μ. Samples taken before and after the fog of 16-17 February indicated a buildup of sulfate percentage and total particulates after the fog. (See Table VII.)

Prior to the fog, one hundred and five daytime samples, each of which contained particles collected from approximately 15 cubic feet of air, were obtained.* A direct variation of particulate number with relative humidity was noted at the MCPL, indicating that an increase in particle number is linked to increasing relative humidity, as was noted earlier [4].

An inverse variation of particulate number with temperature was observed and suggested that solar heating expanded the lower level air mass which resulted in reducing the number of particles per sampled volume. Convective transport of the warmed air probably carried the particulates upward, with a resultant decrease in sampled particles.

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*Collected for 15 minutes each hour beginning at 0900 hours and ending at 1500 hours from 3 through 7 February.

TABLE VI

Fog Droplet Radii at Target Area, 17 February 1971

| Time (hrs CST) | Droplet Number ($cm^{-3}$) | Droplet Radius ($\mu$) | Observer's Remarks |
|---|---|---|---|
| 0400 | 6 | 18 | Foggy |
| 0430 | 4 | 18 | Foggy |
| 0600 | 6 | 18 | Foggy |
| 0630 | 8 | 18 | CH54 overhead. Fog thinning. |
| 0700 | 9 | 12 | Wind stronger; fog thicker. CH47 overhead. |
| 0730 | .2 | 12 | Fog dispersing naturally. UH-1's overhead. |
| 0800 | .2 | 17 | Fog dispersing naturally. |

TABLE VII

Particle counts and selected meteorological measurements from Mobile Cloud Physics Laboratory, 17 February 1971.

| Time (hrs CST) | CCN* ($cm^{-3}$) | G.E. CN ($cm^{-3}$) | Droplets ($cm^{-3}$) | Wind Direction (Degrees) | Wind Speed (Meters/Sec) | Temp (°C) | R.H. (%) |
|---|---|---|---|---|---|---|---|
| 2300 | 340 | 3400 | | 130 | 0.2 | | |
| 2330 | 410 | 3400 | 30 | 280 | 0.3 | | |
| 0000 | 370 | 3400 | 52 | 252 | 0.4 | | |
| 0030 | 250 | 3300 | 56 | 320 | 0.6 | 5.6 | 100 |
| 0100 | 320 | 2700 | 53 | 320 | 0.8 | 5.0 | 100 |
| 0130 | 210 | 2500 | 26 | 307 | 0.4 | 5.0 | 100 |
| 0200 | 240 | 2400 | 131 | 305 | 0.6 | 3.9 | 100 |
| 0230 | 210 | 1300 | 170 | 130 | 0.2 | 5.0 | 100 |
| 0300 | 140 | 1400 | 145 | 103 | 0.7 | 4.7 | 100 |
| 0330 | 260 | 1800 | 341 | 0 | 0.7 | 4.3 | 100 |
| 0400 | 200 | 1500 | 392 | 10 | 0.7 | 4.2 | 100 |
| 0430 | 220 | 1500 | 210 | 0 | 1.2 | 4.1 | 100 |
| 0500 | 260 | 1400 | 157 | 0 | 1.1 | 4.1 | 95 |
| 0530 | 360 | 1400 | 188 | 0 | 1.3 | 4.4 | 93 |
| 0600 | 350 | 2900 | 9 | 0 | 1.4 | 4.2 | 92 |
| 0630 | 410 | 2800 | | 0 | 1.2 | 3.9 | 87 |
| 0700 | 680 | 3200 | | 0 | 1.6 | 4.4 | 65 |
| 0730 | 350 | 4000 | | 0 | 1.6 | 5.7 | 60 |
| 0800 | 390 | 3100 | | 0 | 2.6 | 7.2 | 78 |
| 0830 | 400 | 3100 | | 0 | 1.1 | | |
| 0900 | 570 | 3200 | | 0 | 1.7 | | |
| 0930 | 640 | 2900 | | 65 | 0.7 | 14.4 | 80 |

*The CCN data were taken at 0.98% supersaturation.

Eighty-seven samples taken over a continuous 29-hour period (0500 hrs, 11 Feb to 1000 hrs, 12 Feb) at the MCPL site indicated an increase in average particulate number beginning after 1500 hours.

## SUMMARY

Microphysical measurements of a fog's life cycle were acquired and will aid in numerical modeling. These data indicate that particulate number varies as relative humidity and inversely as temperature and that sulfate particles increase with increased relative humidity. Further microphysical experiments and life cycle measurements should be conducted.

Also, testing and refinement of helicopter downwash techniques should be conducted.

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## APPENDIX A

## PROGRAM PARTICIPANTS

| Personnel | Function | Parent Organization |
|---|---|---|
| E. A. Blomerth, Jr. | Project Director | AMTA, ASL |
| CPT Joe Harrelson | Ft. Rucker Project Officers | DDL&P Army Aviation School |
| CW4 Harry Lemonte, Jr. | Ft. Rucker Assoc. " " | " " |
| CW3 Robert Golden | " " " " " | " " |
| CW3 J. E. Wojteczko | Military OIC | AMTA, ASL |
| Walter S. Nordquist, Jr. | Scientific Advisor | " " |
| Max H. Hamlin | Operations Director | " " |
| Emmet Pybus, et al. | Themis 129 Participants | O. S. U. |
| Keith C. Farnsworth | Technician | AMTA, ASL |
| Richard C. Sojka | " | " " |
| SSG H. Boghosian | " | " " |
| SP5 C. J. Carlos | " | " " |
| Robert S. Bonner | Scientific Staff | " " |
| David H. Dickson | " | " " |
| William H. Hatch | " | " " |
| Radon B. Loveland | " | " " |
| Richard D. H. Low | " | " " |
| Gayle S. Rinehart | " | " " |
| Huran A. Marmon | Met Technician | Met Supp. Act Ft. Huachuca |
| SSG Robert T. Ware | NCOIC (Met team leader) | MSA |
| SP5 Russel M. Parnes | Met Team | " |
| SP5 John F. Sarmiento | " | " |
| SP5 Paul E. Diezman | " | " |
| PFC Donald L. Nichols | " | " |
| SP6 Leo Pleasant | Photographer | NR - K WSMR |
| CW3 M. D. Murry - AC | CH54B - Fog 1 | Army Aviation School |
| CW2 G. W. Brooks - P | " " | " " " |
| SP6 N. L. Johnson - CC | " " | " " " |
| CPT C. J. Farrell - AC | CH47C - Fog 2 | " " " |
| CW2 L. J. Gillies - P | " " | " " " |
| SSG J. M. Roden - CC | " " | " " " |
| 1Lt D. W. Nimblett - AC | UH-1D - Fog 3A | " " " |
| CW2 R. D. Brixey - P | " " | " " " |
| CPT S. E. Young - AC | " Fog 3B | " " " |
| CW2 R. L. Fussell Jr. - P | " " | " " " |
| CPT P. J. Ahneman - P | U-6 - Fog 4 | " " " |
| CPT M. E. Butler - P | " " | " " " |
| CPT C. W. Reed - P | " " | " " " |
| CW3 H. G. Dickson - P | " " | " " " |

NOTE: Aircraft Commander - AC
Pilot - P
Crew Chief - CC
Officer in Charge - OIC
Non-Commissioned Officer in Charge - NCOIC

APPENDIX B

CH54A INFLIGHT DATA/PROJECT FOGWASH I
FOG I

Number: 71-2
Date: 17 February 1971
Time: 0544 CST

Start: 0602
Fog Run I Time 51 min.
Finish: 0653 CST

Initial Gross Weight: 32,500
Alt Setting: 30.28
Fuel Flow: 3000
% Torque: 36
Air Temp: +14°C
Exhaust Temp: 410
440

Roll/Pitch: S&L
Frd Speed: 0
Altitude: 1230 100' Altitude to 600' MSL 5 min ea
Heading: 310 - 325
Rel Position: Over Target
Fog Appearance: Thin and occasionally broken.

Fog Changes: Fog cleared below A/C all the way to ground, visibility was good - fog appeared to build on outer perimeter of airfield.

Gen Obs and Comments: Marker balloons were placed too close to target. Cluster balloons appeared to be right distance.

Time CST - Altitude-MSL-Indicated

| | |
|---|---|
| 0607 | 1230 |
| 0622 | 1000 |
| 0627 | 900 |
| 0632 | 800 |
| 0637 | 700 |
| 0642 | 600 |
| 0647 | Depart for Hanchey AAF |

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APPENDIX B

PROJECT FOGWASH I
CH47C - FOG 2 - INFLIGHT DATA

Number: 71-2
Date: 17 February 1971
Time: 0630 CST

Start: 0653 CST
Fog Run: 2 Time: 21 min
Finish: 0714 CST

Initial Gross Weight: 29,000 lbs
Alt Setting: 30.31
Fuel Flow: 2250 lbs per hour
% Torque: 600 lbs
Air Temp: 14°C
Exhaust Temp: $475^1$ $470^2$
Roll/Pitch: 3°RR(wind) Pitch-Neutral
Frd Speed: 0
Altitude: 1200 Indicated *sec back
Heading: 315
Rel Position: Target
Fog Appearance: @0705 hrs fog tops 400'MSL - @ 0709 hrs fog tops 300'-350'MSL

Gen Obs and Comments:

Time CST - Altitude-MSL-Indicated

| | |
|---|---|
| 0653 | 1000 |
| 0658 | 800 |
| 0703 | 600 |
| 0708 | 400 |
| 0714 | Depart area |

APPENDIX B

PROJECT FOGWASH I
UH-1D INFLIGHT DATA
FOG 3A

Number: 71-2
Date: 17 February 1971
Time: 0700 hrs CST

Start: 0720 CST
Fog Run: 3 Time: 20 min
Finish: 0735 CST

Initial Gross Weight: 7127 lbs
Alt Setting: 30.12
Fuel Flow: 520 lbs per hour
% Torque: 31
Air Temp: +16°C
Exhaust Temp: 560°C
Roll/Pitch: Straight and level
Frd Speed: 0
Altitude: 800, 600, 400' MSL
Heading: 306
Rel Position: Over target
Fog Appearance: Thin - Layer

Fog Changes: Fog had large opening with large swirls on outside of opening.

Gen Obs and Comments:

Time CST - Altitude-MSL-Indicated

| | |
|---|---|
| 0718 | 800 |
| 0724 | 600 |
| 0730 | 400 |
| 0735 | Depart area |

APPENDIX B

PROJECT FOGWASH I
UH-ID INFLIGHT DATA
FOG 3B

Number: 71-2
Date: 17 February 1971
Time: 0730

Start: 0720 CST
Fog Run: 3 Time:
Finish: 0735 CST

Initial Gross Weight: 7154 lbs
Alt Setting: 30.12
Fuel Flow: 500 lbs/hr HOVER
% Torque: 28 lbs
Air Temp: +16°C
Exhaust Temp: 500 E.G.T.
Roll/Pitch: st and level
Frd Speed: 0
Altitude: 800', 600', 400' MSL
Heading: 310°
Rel Position: Over target
Fog Appearance: Ridges with valleys and peaks moving from Northwest to Southeast.

Fog Changes: Large holes were blown behind hovering aircraft.

General Obs and Comments:

Time CST - Altitude-MSL-Indicated

| | |
|---|---|
| 0718 | 800 |
| 0724 | 600 |
| 0730 | 400 |
| 0735 | Depart area |

## APPENDIX B

### CH54B INFLIGHT DATA/PROJECT FOGWASH I
### FOG I

Number: 71-3
Date: 18 February 71
Time: 0714 CST

Start: 0735 CST
Fog Run: I Time: 33 min
Finish: 0808 CST

Initial Gross Weight: 3200
Alt Setting: 30.31
Fuel Flow: 3000
% Torque: 32
Air Temp: 15°C
Exhaust Temp: 470°C
Roll/Pitch: S&L
Altitude: 1100 MSL
Heading: 360°
Rel Position: Over target
Fog Appearance: Patchy - mainly in low areas. Appears to be a localized fog. Approximately 4 miles E of Skelly we encountered fog bank - tops 500 MSL (Met Report tops 720 MSL 0719 hr.)

Fog Changes: Good hole VER - landed with no closing from above. NOTE: Atmos appeared polluted - fog was light tan in color - after ops a haze from ground level to 1000 MSL was observed to be wide spread & tanish brown in color.

Gen Obs and Comments: Cannot tell difference with and without lens on high intensity light. Camera on 0732 hrs CST 2000 MSL and Off 0802 below 400 MSL

| Time CST | Altitude-MSL-Indicated |
|---|---|
| 0735 | 1100 |
| 0745 | 900 |
| 0750 | 700 |
| 0755 | 500 |
| 0808 | Landed in target area |

## APPENDIX B

### CH47C INFLIGHT DATA/PROJECT FOGWASH I
### FOG 2

Number: 71-3
Date: 18 February 71
Time: 0730 CST

Start: 0806
Fog Run: 2 Time: 19 min
Finish: 0825 CST

Initial Gross Weight: 2800
Alt Setting: 30.29
Fuel Flow: 2040
% Torque: 600
Air Temp: 14°C
Exhaust Temp: 480°[1]
480°[2]
Roll/Pitch: S&L
Frd Speed: 0
Altitude: 1200', 800', 600'
Heading: 315
Rel Position: Target
Fog Appearance: Strip 100 yards wide 7 miles on Heading 270 starting from Target Point After CH-54 Hrd finished - hovering.

Fog Changes: Looks more like thin haze layer.

Gen Obs and Comments:

Time - CST - Altitude-MSL-Indicated

| | |
|---|---|
| 0806 | 1100 |
| 0811 | 900 |
| 0816 | 700 |
| 0821 | 500 |
| 0825 | Landed in target area |

APPENDIX B

UH-ID INFLIGHT DATA/PROJECT FOGWASH I
FOG 3A

Number: 71-3
Date: 18 February 71
Time: 0745 CST

Start: 0828
Fog Run: 3 Time: 9 min
Finish: 0832

Initial Gross Weight: 7470
Alt Setting: 29.13
Fuel Flow: 540
% Torque: 30
Air Temp: 12
Exhaust Temp: 510
Roll/Pitch: S&L
Frd Speed: 20 Kts IAS
Altitude: 200
Heading: 36L Returned 18 R
Rel Position: Over Target
Fog Appearance: Thin ground fog

Fog Changes: Fog had dissipated by the time we approached on station.

## APPENDIX B

### UH-1D INFLIGHT DATA/PROJECT FOGWASH I
### FOG 3B

Number: 71-3
Date: 18 February 71
Time: 0745 CST

Start: 0828
Fog Run: 3 Time: 9 min
Finish: 0832

Initial Gross Weight: 6984
Alt Setting: 29.13
Fuel Flow: 500
% Torque: N/A (29-31)
Air Temp: 12
Exhaust Temp: 565°C
Roll/Pitch:
Frd Speed: 05 Knots
Altitude: 400 MSL
Headings: 360 & 180
Rel Position: Over target
Fog Appearance: Fog had dissipated by the time we had moved on station. One little cloud bank with tops at 400 MSL.

Fog Changes: After passing through from South to North, a Swath above twice the size of Rotor Dia. was cut.

Gen Obs and Comments:

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