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BY

BARBARA SPARKMAN

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ABSTRACT

A Nimbus Medium Resolution Infrared Radiometer (MRIR) flown on the NASA Convair 990 aircraft experienced a shift in calibration of its three infrared channels such that measurements became increasingly too low with increasing aircraft altitude, to the plane's maximum altitude of 42,000 ft. Using the Radiometers built-in check-of-calibration cavity (the housing, with temperature monitored separately by means of an imbedded thermistor), and assuming that the entire calibration is shifted by the increment of effective radiance indicated by the check-of-calibration, the degraded measurements can be corrected. Tests were made of the validity of this approach, and good agreement was obtained with theoretically computed temperatures after accounting for radiative transfer through the atmosphere.

CONTENTS

A METHOD TO CORRECT THE CALIBRATION SHIFT OBSERVED IN A NIMBUS MEDIUM RESOLUTION INFRARED RADIOMETER ON THE NASA CONVAIR 990 AIRCRAFT

INTRODUCTION

A Nimbus Medium Resolution Infrared Radiometer (MRIR), (Serial No. F-3), flown on the NASA Convair 990 aircraft, experienced a shift in calibration of its three infrared channels such that temperatures indicated became increasingly too low with increasing aircraft altitudes. Observing an ocean surface of 15°C, the MRIR read 15°C at 500 ft, 7°C at 16,000 ft., and -11°C at 40,000 ft.

A similar shift has been observed in data from the MRIR aboard the Nimbus II satellite. This was noted during brief periods while the satellite was entering or leaving the Earth's shadow, and sunlight momentarily struck the radiometer optics, warming the mirrors. Since the radiometer is calibrated with all parts of the radiometer held at 25°C, and the incoming signal is chopped after passing the optics, any change in the optics' temperature affects the incoming signal. Energy is added to the incoming signal, and the temperature reported by the radiometer changes accordingly. Output from the MRIR is a DC signal in volts, with voltage inversely proportional to sensed energy. Thus, when the Nimbus II MRIR optics are warmed by sunlight, energy is added to the incoming signal, and the output voltage drops. Aboard the Convair 990, the voltage increased with altitude more than would be expected from changes in energy due to atmospheric effects on the upward stream of radiation from the surface.

Radiation arriving at the MRIR, shown in Fig. 1, first strikes the scan mirror which is placed at an angle of 45° to its rotating axis. Five cassagrainian telescopes are mounted parallel to and grouped around this axis, facing the scan mirror. As the mirror rotates it reflects an incoming signal from the object it observes into the telescopes. Rotation of the scan mirror brings a terrestrial target into view for a large portion of the cycle followed by the calibration housing which is held at a constant temperature. Each of the five telescopes, or five channels as they are called, has thermistor bolometers and filters for a specific wave length. Channel 1 is sensitive to the 6.7 micron water vapor absorption region, channel 2 to the 10 - 11 micron atmospheric window region, and channel 4 to the 5 - 30 micron region. Channels 3 and 5 are sensitive to visible radiation (.55 - .85 microns and (.2 - 4. microns) respectively.

Just before reaching the filters, the incoming signal is chopped so that the thermistor alternately "sees" the target signal and the chopper. The chopper temperature is nominally 25°C, and any temperature changes are compensated for in the offset voltage for each channel. In order to identify the position of the scan mirror during each scan, a synchronization pulse of -4.5 volts is added to the signal slightly before the mirror views the housing. This sync pulse automatically shuts off when the scan mirror looks directly into the housing. Thus when the sync pulse is on, the output voltage is equal to the difference between the offset voltage, and the sum of the target signal voltage and the sync pulse voltage.

Since the 6.7 micron channel (channel 1) is sensitive to a much narrower spectral region than the other channels, and the temperatures measured in this region are generally lower than those of the other two IR channels, there is much less incoming target energy than there is for the other channels. It is therefore necessary to have a larger gain on the channel 1 output voltage. In order to keep the channel 1 output voltage on the same 0 to -6 volt scale as that of the other 4 channels, the offset voltage (V_f) is cut during the sync pulse to .15 of the normal offset voltage level. Because of its higher gain, channel 1 saturates at -3°C. It is therefore necessary to read the housing (~25°C) when the sync pulse is on and the offset voltage is cut to 0.15 V_f. Channels 2 and 4 are designed to measure warm earth temperatures. The housing remains well within this range so it can be read right after the sync pulse shuts off.

DERIVATION OF CORRECTION EQUATIONS

To eliminate the error voltage observed in the airborne MRIR signal, and so obtain the correct output voltage, the following sequence of events was employed: First, state the output voltage equations for the MRIR as the sum of all acting influences; solve for the voltage error; solve for the corrected output voltage; and compare the target temperature that this voltage indicates with one found theoretically. This derivation is valid of the assumption is made that the voltage added to the radiometer output signal is constant during one revolution of the scan mirror, while it views both the target and the radiometer housing. Since the housing temperature is monitored by thermistors, the correct radiometer output for the period when the housing is viewed is known. The output, as obtained however, includes an error signal. Subtracting these two quantities gives the error signal for one particular scan, which can then be applied as a correction to the output voltage obtained while the radiometer views a terrestrial target.

Fig. 2 shows a diagram of the input voltages of the MRIR when it is observing: Case I, the target, and Case II, the housing. Case III applies only to channel 1 when the MRIR is observing the housing. Cases I and II have the same voltage balance equations. For Case III the offset voltage is attenuated to .15 V_f and a synchronization pulse (V_{sync}) is added, as noted.

From each Case two equations can be derived: the laboratory calibration case with optics at 25°C, and the inflight case where the voltage error was added to the signal. Primes are used to designate the inflight case. The synchronization pulse is -4.5 volts in each case.

Case I. Target calibration case.

$$V_{RADT} = V_T + V_f \tag{1}$$

Target inflight case.

$$V'_{RADT} = V_T + V'_E + V'_f \tag{2}$$

Case II. Housing calibration case.

$$V_{RADH} = V_H + V_f$$

Since the housing signal voltage is proportional to the difference in temperature between the chopper and housing; and since the chopper and housing are the same temperature during calibration, $V_H = 0$.

$$\therefore V_{RADH} = V_f \tag{3}$$

Housing inflight case, Ch. 2 and Ch. 4.

$$V'_{RADH} = V'_E + V'_f \tag{4}$$

Case III. Housing calibration case, Ch. 1

$$V_{RADH} = V_H + 0.15\ V_f + V_{SYNC}$$

Again in the laboratory calibration, $V_H = 0$. Therefore, we have,

$$V_{RADH} = 0.15\ V_f + V_{SYNC} \tag{5}$$

Housing inflight case, Ch. 1.

$$V_{RADH} = V'_E + 0.15\ V'_f + V_{SYNC} \tag{6}$$

By combining these equations, one can solve for the true target voltage, (V_{RADT}), in the following manner:

For channels 2 and 4, subtracting Eq. 3 from Eq. 4 and solving for the error voltage V'_E, we have

$$V'_E = V'_{RADH} - V_{RADH} + V_f - V'_f \tag{7}$$

Solving Eq. 2 for V_T yields

$$V_T = V'_{RADT} - V'_E - V_f$$

Substituting V_T into Eq. 1 yields

$$V_{RADT} = V'_{RADT} - V'_E - V'_f + V_f \tag{8}$$

Finally, substituting Eq. (7) into (8) to eliminate V'_E, we have

$$V_{RADT} = V'_{RADT} + [V_{RADH} - V'_{RADH}] \tag{9}$$

For channel one the same procedure is followed using Eqs. 5 and 6, which gives

$$V_{RADT} = V'_{RADT} + [V_{RADH} + 0.85\ V_f] - [V'_{RADH} + 0.85\ V'_f] \tag{10}$$

For practical use, these equations can be rewritten in terms of everyday language for convenience in interpretation.

$$V_{\text{Corrected Voltage}} = V^{\text{Target}}_{\text{Output}} + \left[V^{\text{Housing}}_{\text{Calibration}} - V^{\text{Housing}}_{\text{Output}}\right] \tag{11}$$

$$V_{\text{Corrected Voltage}} = V^{\text{Target}}_{\text{Output}} + \left[V^{\text{Housing}}_{\text{Calibration}} + 0.85\ V^{\text{Offset}}_{\text{Calibration}}\right] - \left[V^{\text{Housing}}_{\text{Output}} + 0.85\ V^{\text{Offset}}_{\text{Output}}\right] \tag{12}$$

The second and third terms of each equation are simply the radiometer outputs when the radiometer is viewing the target and the housing respectively. The fourth term, $V^{Housing}_{Calibration}$ is found by noting the true housing temperature as monitored by thermistors, called Housing 1 and Housing 2, and converting this temperature to the corresponding voltage measured in the laboratory calibration. In doing this, one assumes no gradient between the thermistors and the housing surfaces. Each thermistor is placed in a hole drilled through the housing, and as close to the surface as possible. Wind tunnel tests showed that the unprotected scan mirror stopped rotating at wind speeds of 30 knots. (In the aircraft the MRIR was protected by a fairing). Using 30 knots as a maximum wind speed, Conrath[1] calculated that the gradient between the surface and the thermistor could not be more than 0.5°C.

The offset voltages V_f in Eq. 10 and 12, are controlled by the chopper temperature. The voltage from the detector is proportional to the difference between the effective radiation emitted by the target and that emitted by the chopper. To compensate for the variation in chopper radiation from the designed value the offset voltage V_f is algebraically added to the signal. The chopper temperature is thermistor monitored by two housekeeping channels, Chop 1 and Chop 2. By applying these two temperatures to a radiometer output vs. temperature curve, and averaging voltages, one finds the V^{Offset}.

Since output voltage is linearly proportional to effective radiance ($\overline{N}$), these equations can be converted by $\overline{N} = mv + b$ to:

$$\overline{N}_{Corrected\ Target} = \overline{N}^{Target}_{Output} + \left[\overline{N}^{Housing}_{Calibration} - \overline{N}^{Housing}_{Output}\right] \tag{13}$$

$$\overline{N}_{Corrected\ Target} = \overline{N}^{Target}_{Output} + \left[\overline{N}^{Housing}_{Calibration} + 0.85\ \overline{N}^{Offset}_{Calibration}\right] - \left[\overline{N}^{Housing}_{Output} + 0.85\ \overline{N}^{Offset}_{Output}\right] \tag{14}$$

A METHOD TO CHECK CORRECTION EQUATIONS

To check this method of data correction, airborne MRIR inferred radiation temperatures were compared to temperatures found by the radiation transfer program for a spherical atmosphere by Wark, Yamamoto, and Lienisch.[2,3] Using radiosonde data and the MRIR effective spectral response functions, ϕ_ν , with this program the vertical outgoing effective radiance at designated levels was computed with the equation:

$$\bar{N} = \sum_j \left[B_\nu (T_t)\phi_\nu \, [\Delta\nu]\right]_j + \sum_{i=0}^{200} \left[\sum_j \left[\phi_\nu \tau_\nu \left[\frac{\partial B_\nu (T)}{\partial T}\right] [\Delta\nu]\right]_j [\Delta T]\right]_i \quad (15)$$

The atmosphere is divided into 200 layers, where $\bar{\nu}$ is the center of the spectral interval $\Delta\nu$, T is temperature, T_t is the temperature at the top atmospheric layer, B is the Planck intensity, and $\tau_{\nu i}$ is the transmission for the top layer to a given level. For the interval in which the H_2O and CO_2 (or O_3) bands overlap, $\tau_{\nu i}$ is taken to be the product of the transmissions of the separate gases.

Results of both MRIR and radiosonde inferred temperatures are presented in the following section.

DATA COMPARISONS

To test this method of calibration, data taken during aircraft vertical cross-section manuevers were used. A vertical crossection, shown in Fig. 3 is ideal for testing this method because the MRIR observes a homogeneous target (viz, the ocean surface) from different altitudes. It is reasonable to assume that the MRIR was observing isothermal ocean surface temperatures, although the horizonal distance of the crossection is 50 to 80 miles. The sea surface temperatures used were obtained from nearby ships.

Radiosonde data, (Tables 1 and 2), were not as readily obtainable as ocean surface temperatures. In fact most of the radiosondes were flown hundreds of miles away from the aircraft and, in some cases, in different weather conditions, as can be seen from Fig. 4 through 9. Despite the wide spacing of correlation data, there is very good agreement (with in 3°C), at all vertical profile levels between MRIR corrected temperatures and the theoretically computed temperatures which the MRIR should measure (indicated by radiative transfer solutions using the radiosonde data). Tables 3 through 20 list these comparisons. Discrepancies, as in flights 30 and 31, of 10°C maximum, can be explained by weather conditions. During flight 30 (See Fig. 5), the aircraft was located on the edge of a cold front while the radiosonde was flown in a high pressure area. The vertical profile of

Flight 31 (See Fig. 6) was flown over a solid stratocumulus deck at 3,000 ft. There the MRIR measured the energy transferred through the atmosphere from the cloud tops. The radiosonde data indicated no clouds, and the radiative transfer program does not take clouds into consideration. Since the cloud was about 5°C colder than the ocean surface, one would expect the MRIR to read colder temperatures than the radiosonde indicated, and it did.

PHYSICAL EXPLANATION OF CALIBRATION SHIFT

Bandeen and Goldberg[4] derived an equation to solve for the mirror temperatures needed to account for the voltage error observed in the Nimbus II and airborne MRIR. Fig. 10 shows the path radiation takes through the MRIR optics. The incremental difference between externally-viewed radiation and radiation from the chopper, ΔN_λ, which gives rise to the output voltage, may be expressed by

$$\Delta N_\lambda = \partial N_\lambda r_\lambda^m r_\lambda^p r_\lambda^s f_\lambda + \partial \epsilon_\lambda^m B_\lambda^m r_\lambda^p r_\lambda^s f_\lambda + \beta B_\lambda^b r_\lambda^p r_\lambda^s f_\lambda + \epsilon_\lambda^p B_\lambda^p r_\lambda^s f_\lambda + \epsilon_\lambda^s B_\lambda^s f_\lambda - [B_\lambda^c f_\lambda + \text{OFFSET}] \quad (16)$$

where: m = rotating mirror

p = primary mirror

s = secondary mirror

b = spider holding the secondary mirror

c = chopper

f = filter transmissivity

B_λ = spectral Planck intensity from internal radiometer components

N_λ = spectral radiance viewed by radiometer

α = 87% = portion of field of view occupied by target or housing

β = 13% = portion of field of view occupied by spider

ϵ = emissivity

and:

$\alpha N_\lambda r^m_\lambda r^p_\lambda r^s_\lambda f_\lambda$ = Radiance viewed by the radiometer which travels through the optical system to the detector.

$\alpha \epsilon^m_\lambda B^m_\lambda r^p_\lambda r^s_\lambda f_\lambda$ = Energy which is emitted by the rotating mirror, (m), and travels through the rest of the optical system to the detector.

$\beta B^b_\lambda r^p_\lambda r^s_\lambda f_\lambda$ = Energy which is emitted by the spider, (b), and travels through the rest of the optical system to the detector.

$\epsilon^p_\lambda B^p_\lambda r^s_\lambda f_\lambda$ = Energy which is emitted by the primary mirror, (p), and travels through the rest of the optical system to the detector.

$\epsilon^s_\lambda B^s_\lambda f_\lambda$ = Energy which is emitted by the secondary mirror, (s), and travels through the remaining portion of the optical system to the detector.

$[B^c_\lambda f_\lambda + \text{Offset}]$ = Energy which is emitted by the chopper, (c), and travels through the remaining optics to the detector; and the offset energy which makes the quantity in brackets a constant; that is, the offset is added to the energy emitted by the chopper to maintain the the effective chopper radiation at a designated level.

Letting:

$$[B^c_\lambda f_\lambda + \text{OFFSET}] = K, \quad N_\lambda f_\lambda = \hat{N}$$

and omitting λ, by assuming that functions are averaged over the wavelength intervals which a particular channel responds, ΔN becomes the difference between externally-viewed radiation and the radiation from the chopper. We have

$$\Delta N = [\partial \hat{N} r^m r^p r^s + \alpha \epsilon^m \hat{B}^m r^p r^s + \beta \hat{B}^b r^p r^s + \epsilon^p \hat{B}^p r^s + \epsilon^s \hat{B}^s] - K \qquad (17)$$

By letting:

$$r^m = r^p = r^s = r$$

$$\epsilon^m = \epsilon^p = \epsilon^s = \epsilon = 1 - r$$

$$\hat{B}^m = \hat{B}^b = \hat{B}^p = \hat{B}^s = \hat{B}$$

Equation (17) becomes:

$$[\Delta N + K] = \hat{N}\,(\alpha\, r^3) + \hat{B}\,[\partial\, \epsilon\, r^2 + \beta\, r^2 + \epsilon\, r + \epsilon]$$

Substituting $(1 - r)$ for ϵ and simplifying, we have:

$$\overline{N} = [\Delta N + K] = \hat{N}\,(\partial\, r^3) + \hat{B}\,(1 - \partial\, r^3) \tag{18}$$

To apply this equation to the airborne radiometer one can write two such equations: One for the output voltage observed on the flight, the true target temperature, and unknown optics temperature; another for the same output voltage and its corresponding calibrated target temperature with optics at the calibration temperature, (25°C).

$$V_{Output} \propto [\Delta N + K]_{Output} = \hat{N}_2\,(\alpha\, r^3) + \hat{B}_2\,(1 - \alpha\, r^3)$$

$$V_{True} \propto [\Delta N + K]_{True} = \hat{N}_1\,(\alpha\, r^3) + \hat{B}_1\,(1 - \alpha\, r^3)$$

Combining these equations and solving for B_2, the Plank intensity from internal radiometer components during flight:

$$\hat{B}_2 = \hat{B}_1 + \frac{.87\, r^3}{1 - .87\, r^3}\,(\hat{N}_1 - \hat{N}_2) \tag{19}$$

The reflectivity of the mirrors, r, was measured in the laboratory to be 96%.

Solution of Eq. 19 with Nimbus II data shows that the temperature increase of MRIR optics can account for the added energy.[5]

Data from Ch. 2, Flight No. 35 was used to solve Eq. 19. Results are presented in Table 21. The resultant optics temperatures (T_0) needed to account for the energy decrease observed at high altitudes are much too cold, (i.e., colder than the ambient air).

CONCLUSIONS

The good agreement between the MRIR empirically corrected temperatures and the theoretically derived temperatures based on radiosonde data show that this method of correction yields accurate temperatures from MRIR output voltages.

It must therefore be concluded that although the shift in signal is linear with energy and can be eliminated by use of Eqs. 11 and 12; and 13 and 14, mirror temperatures alone cannot account for it. Investigation is currently underway by the radiometer manufacturer to seek a possible explanation for the voltage error in terms of the functions of the various electronic compensating networks within the MRIR.

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TABLE 1
RADIOSONDE DATA

FLIGHT 14 JACKSONVILLE, FLA

TOP ALTITUDE	PRESSURE	H_2O MASS	O_3 MASS	RADIOSONDE AIR TEMP.	AIR TEMP. TAKEN FROM COCKPIT
100'	1019 mb	0.048 prec/cm	0.00011 gm/cm^2	+21.7°C	+ 18°C
8K'	766	2.154	0.00694	+11.7	+11
16K'	558	2.712	0.01400	- 2.7	- 4
24K'	422	2.807	0.02170	-16.7	-20
32K'	298	2.845	0.03468	-36.2	-39
40K'	203	2.853	0.05221	-56.1	-58

FLIGHT 30 "NOVEMBER"

8K'	765 mb	1.530 prec/cm	0.00683 gm/cm^2	+11.7°C	+ 7°C
16K'	550	2.222	0.01413	- 3.2	-10
24K'	415	2.426	0.02177	-17.0	-21
32K'	311	2.489	0.03269	-33.0	-38
40K'	203	2.507	0.05258	-57.0	-60

FLIGHT 31 OAKLAND, CAL.
RADIOSONDE NO. I

8K'	759 mb	1.588 prec/cm	0.00688 gm/cm^2	+ 3.2°C	+ 7°C
16K'	552	2.112	0.01391	-11.6	- 7
24K'	413	2.342	0.02178	-22.5	-21
32K'	311	2.445	0.03249	-38.0	-41
40K'	199	2.503	0.05310	-56.3	-58

FLIGHT 31 "NOVEMBER"
RADIOSONDE NO. II

8K'	767 mb	1.695 prec/cm	0.00686 gm/cm^2	+11.8°C	+ 7°C
16K'	559	2.630	0.01392	- 1.0	- 7
24K'	416	2.935	0.02201	-15.8	-21
32K'	311	3.006	0.03304	-32.8	-41
40K'	204	3.032	0.05274	-57.0	-58

FLIGHT 35 "NOVEMBER"
RADIOSONDE NO. I

500'	1005 mb	0.066 prec/cm	0.00022 gm/cm^2	13.0°C	13°C
8K'	770	1.026	0.00656	13.0	12
16K'	575	1.552	0.01319	- 2.0	- 5
24K'	415	1.717	0.02223	-20.0	-21
32K'	295	1.755	0.03479	-38.0	-41
39K'	215	1.763	0.04960	-55.5	-51

TABLE 2
RADIOSONDE DATA

FLIGHT 35 OAKLAND CAL.
RADIOSONDE NO. II

TOP ALTITUDE	PRESSURE	H_2O MASS	O_3 MASS	RADIOSONDE AIR TEMP	AIR TEMP TAKEN FROM COCKPIT
500'	999 mb	0.123 prec/cm	0.00040 gm/cm^2	+23.3°C	13°C
8K'	771	1.356	0.00656	15.7	12
16K'	555	1.772	0.01389	- 1.9	- 5
24K'	415	1.885	0.02182	-20.0	-21
32K'	310	1.915	0.03284	-37.5	-41
39K'	203	1.922	0.05255	-57.8	-51

FLIGHT 36 OAKLAND, CAL
RADIOSONDE NO. I

TOP ALTITUDE	PRESSURE	H_2O MASS	O_3 MASS	RADIOSONDE AIR TEMP	AIR TEMP TAKEN FROM COCKPIT
500'	998 mb	0.189 prec/cm	0.00043 gm/cm^2	29.1°C	14°C
8K'	764	1.798	0.00675	16.8	17
16K'	559	2.181	0.01371	- 3.6	- 3
24K'	412	2.275	0.02203	-22.4	-22
32K'	308	2.300	0.03294	-39.4	-41
40K'	203	2.313	0.05229	-55.7	-57

FLIGHT 36 "NOVEMBER"
RADIOSONDE NO. II

TOP ALTITUDE	PRESSURE	H_2O MASS	O_3 MASS	RADIOSONDE AIR TEMP	AIR TEMP TAKEN FROM COCKPIT
500'	1005 mb	0.078 prec/cm	0.00022 gm/cm^2	17.0°C	14°C
8K'	770	1.504	0.00656	12.7	17
16K'	575	1.904	0.01319	- 2.6	- 3
24K'	415	2.042	0.02223	-19.0	-22
32K'	295	2.082	0.03479	-46.5	-41
40K'	205	2.096	0.05141	-57.7	-57

FLIGHT 41 "NOVEMBER"

TOP ALTITUDE	PRESSURE	H_2O MASS	O_3 MASS	RADIOSONDE AIR TEMP	AIR TEMP TAKEN FROM COCKPIT
2.5K'	940	0.449 prec/cm	0.00197 gm/cm^2	19.0°C	18°C
8K'	770	1.130	0.00656	11.7	13
16K'	575	1.547	0.01299	0.0	- 2
24K'	415	1.712	0.02223	-15.0	-20
32K'	295	1.753	0.03479	-34.2	-39

TABLE 3
MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 14 CHANNEL 1
TARGET TEMPERATURE = 23.0°C

$$V_{RADT} = V'_{RADT} - V'_{RADH} + V_{RADH} + 0.85\,(V_f - V'_f)$$

TIME	ALT. (FT.)	V'_{RADT}	V'_{RADH}	V_{HSG}	V_{RADH}	V_f	V_{CHOP}	V'_f	V_{RADT}	$\bar{N}_{RADT}$	T_{RADT}	I RAD. TEMP	II RAD. TEMP.	AIR TEMP.
19:27	16K'	-0.33	-4.32	-1.81	-3.81	4.39	-1.76	4.48	0.10	0.84	- 3.3	- 2.1		- 4
		-0.62	-4.52	-1.83			-1.79		0.01	0.83	- 3.7			
19:36	24K'	-1.81	-5.18	-1.78	-3.80	4.39	-1.76	4.48	-0.51	0.71	- 9.1	-13.2		-20
		-2.12	-5.49	-1.83			-1.76		-0.51	0.71	- 9.1			
19:47	32K'	-3.09	-5.64	-1.81	-3.82	4.39	-1.76	4.53	-1.39	0.52	-18.8	-23.3		-39
		-3.45	-6.06	-1.87			-1.74		-1.33	0.53	-18.3			
20:12	40K'	-3.55	-5.99	-1.80	-3.82	4.39	-1.77	4.53	-1.50	0.50	-19.8	-31.4		-58
		-4.12	-6.32	-1.86			-1.71		-1.74	0.44	-23.6			

ALT.	WEATHER CONDITIONS
100'	HAZE, CLEAR TO OCEAN, WHITE CAPS BELOW
8K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
16K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
24K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
32K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
40K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW

KEY TO SYMBOLS

- V'_{RADT} = OUTPUT VOLTAGE OF RADIOMETER TARGET
- V'_{RADH} = OUTPUT VOLTAGE OF RADIOMETER MEASURING HOUSING
- V_{HSG} = VOLTAGE FROM SIGNAL FOR HSG 1&2
- V_{RADH} = OUTPUT VOLTAGE WHICH WOULD CORRESPOND TO SAME TEMPERATURE AS V_{HSG}
- V_f = OFFSET VOLTAGE FROM SIGNAL CORRESPONDING TO A CHOPPER TEMPERATURE OF 25°C IN THE CALBRATION
- V_{CHOP} = VOLTAGE FROM SIGNAL FOR CHOP 1&2
- V'_f = OFFSET VOLTAGE CORRESPONDING TO SAME TEMPERATURE AS V_{CHOP}
- V_{RADT} = CORRECTED OUTPUT VOLTAGE OF TARGET
- $\bar{N}_{RADT}$ = ENERGY CORRESPONDING TO SAME ABOVE, watts/m^2/ster.
- T_{RADT} = CORRECTED TEMPERATURE OF TARGET, °C
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM, THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM °C

TABLE 4

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 14 CHANNEL 2
TARGET TEMPERATURE = 23.0°C

$\bar{N}^{T}_{TARGET} = \bar{N}^{H}_{HSG} - \bar{N}^{H}_{OUTPUT} + \bar{N}^{T}_{OUTPUT}$

TIME	ALT. (FT.)	T^{H}_{HSG}	$\bar{N}^{H}_{HSG}$	T^{H}_{OUTPUT}	$\bar{N}^{H}_{OUTPUT}$	T^{T}_{OUTPUT}	$\bar{N}^{T}_{OUTPUT}$	$\bar{N}^{T}_{TARGET}$	T^{T}_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
19:00	100'	26.35	8.20	27.8	8.35	24.0	7.80	7.65	22.5	24.0		18
19:18	8K'	26.05	8.18	26.0	8.10	22.2	7.62	7.70	22.7	22.3		11
19:27	16K'	24.75	8.00	19.0	7.30	13.0	6.64	7.34	19.1	21.0		-4
19:36	24K'	25.25	8.02	14.0	6.76	8.4	6.18	7.44	20.0	20.6		-20
19:47	32K'	24.25	7.88	7.5	6.04	2.0	5.50	7.34	19.1	19.8		-39
20:12	40K'	24.65	7.96	0.5	5.32	-5.7	4.74	7.38	19.5	19.0		-58

ALT.	WEATHER CONDITIONS
100'	HAZE, CLEAR TO OCEAN, WHITE CAPS BELOW
8K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
16K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
24K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
32K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
40K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW

KEY TO SYMBOLS

T^{H}_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2

$\bar{N}^{H}_{HSG}$ = ENERGY CORRESPONDING TO ABOVE

T^{H}_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER

$\bar{N}^{H}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.

T^{T}_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER

$\bar{N}^{T}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE

T^{T}_{TARGET} = CORRECTED TEMPERATURE OF TARGET

$\bar{N}^{T}_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM

AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 5
MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 14 CHANNEL 4
TARGET TEMPERATURE = 23.0°C

$\bar{N}^T_{TARGET} = \bar{N}^H_{HSG} - \bar{N}^H_{OUTPUT} + \bar{N}^T_{OUTPUT}$

TIME	ALT. (FT.)	T^H_{HSG}	$\bar{N}^H_{HSG}$	T^H_{OUTPUT}	$\bar{N}^H_{OUTPUT}$	T^T_{OUTPUT}	$\bar{N}^T_{OUTPUT}$	$\bar{N}^T_{TARGET}$	T^T_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
19:00	100'	26.35	51.0	26.0	51.0	21.2	47.5	47.5	23.0	20.0		18
19:18	8K'	26.05	51.0	24.0	49.0	13.2	42.0	44.0	18.2	16.8		11
19:27	16K'	24.75	50.0	17.0	44.5	0.8	35.5	41.0	12.2	10.7		-4
19:36	24K'	25.25	50.5	12.2	41.5	-6.0	32.0	41.0	8.3	6.9		-20
19:47	32K'	24.25	49.5	4.2	37.0	-19.0	26.0	38.5	4.5	2.8		-39
20:12	40K'	24.65	50.0	-3.0	33.5	-32.0	20.5	37.0	2.0	0.4		-58

ALT.	WEATHER CONDITIONS
100'	HAZE, CLEAR TO OCEAN, WHITE CAPS BELOW
8K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
16K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
24K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
32K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW
40K'	HAZE, FRACTUS STRATOCUMULUS AT 4K' BELOW

KEY TO SYMBOLS

T^H_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2

$\bar{N}^H_{HSG}$ = ENERGY CORRESPONDING TO ABOVE

T^H_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER

$\bar{N}^H_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.

T^T_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER

$\bar{N}^T_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE

T^T_{TARGET} = CORRECTED TEMPERATURE OF TARGET

$\bar{N}^T_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM

AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 6

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 30 CHANNEL 1

TARGET TEMPERATURE = 17.4°C

$V_{RADT} = V'_{RADT} - V'_{RADH} + V_{RADH} + 0.85 (V_f - V'_f)$

TIME	ALT. (FT.)	V'_{RADT}	V'_{RADH}	V_{HSG}	V_{RADH}	V_f	V_{CHOP}	V'_f	V_{RADT}	$\bar{N}_{RADT}$	T_{RADT}	I RAD. TEMP	II RAD. TEMP.	AIR TEMP.
09:04	16K'	-1.20	-4.78	-1.83	-3.82	4.39	-1.86	4.39	-0.24	0.77	- 6.3	- 2.9		-10
		-1.46	-5.02	-1.83			-1.80		-0.26	0.77	- 6.3			
09:12	24K'	-2.57	-5.26	-1.79	-3.79	4.39	-1.86	4.39	-1.10	0.58	-15.5	-14.2		-21
		-2.89	-5.57	-1.78			-1.79		-1.11	0.58	-15.5			
09:23	32K'	-4.14	-5.89	-1.84	-3.82	4.39	-1.86	4.44	-2.11	0.36	-29.4	-22.9		-38
		-4.46	-6.19	-1.85			-1.76		-2.13	0.36	-29.4			
09:45	40K'	-4.96	-6.36	-1.82	-3.81	4.39	-1.85	4.48	-2.49	0.28	-36.4	-33.0		-60
		-5.19	-6.39	-1.82			-1.72		-2.69	0.24	-40.5			

ALT.	WEATHER CONDITIONS
3K'	ABOVE STRATUS CLOUDS – TOP AT 2.9K
8K'	PATCHES OF BROKEN STRATUS CLOUD LAYER AT 6.5K (FOUR LEVELS OF CLOUDS)
16K'	SAME CLOUDS. SCATTERED CIRRUS AT 18K; BOTTOM OF VERY THIN LAYER AT 19.5K'. AT 20K THERE MAY BE ICE CRYSTALS
24K'	SAME CLOUDS; THERE ARE CLOUDS AT 26-28K
32K'	ICE CRYSTALS: PLANE IN THIN CIRRUS
40K'	ABOVE ALL CLOUDS

KEY TO SYMBOLS

- V'_{RADT} = OUTPUT VOLTAGE OF RADIOMETER TARGET
- V'_{RADH} = OUTPUT VOLTAGE OF RADIOMETER MEASURING HOUSING
- V_{HSG} = VOLTAGE FROM SIGNAL FOR HSG 1&2
- V_{RADH} = OUTPUT VOLTAGE WHICH WOULD CORRESPOND TO SAME TEMPERATURE AS V_{HSG}
- V_f = OFFSET VOLTAGE FROM SIGNAL CORRESPONDING TO A CHOPPER TEMPERATURE OF 25°C IN THE CALBRATION
- V_{CHOP} = VOLTAGE FROM SIGNAL FOR CHOP 1&2
- V'_f = OFFSET VOLTAGE CORRESPONDING TO SAME TEMPERATURE AS V_{CHOP}
- V_{RADT} = CORRECTED OUTPUT VOLTAGE OF TARGET
- $\bar{N}_{RADT}$ = ENERGY CORRESPONDING TO SAME ABOVE, watts/m^2/ster.
- T_{RADT} = CORRECTED TEMPERATURE OF TARGET, °C
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM, THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM °C

TABLE 7
MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT #30 CHANNEL 2
TARGET TEMPERATURE = 17.4°C

$\bar{N}^T_{TARGET} = \bar{N}^H_{HSG} - \bar{N}^H_{OUTPUT} + \bar{N}^T_{OUTPUT}$

TIME	ALT. (FT.)	T^H_{HSG}	$\bar{N}^H_{HSG}$	T^H_{OUTPUT}	$\bar{N}^H_{OUTPUT}$	T^T_{OUTPUT}	$\bar{N}^T_{OUTPUT}$	$\bar{N}^T_{TARGET}$	T^T_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
08:47	3K'	26.10	8.18	24.0	7.80	8.50	6.20	6.58	12.0			10
08:55	8K'	25.80	8.10	23.6	7.80	5.00	5.80	6.10	7.8	16.7		7
09:04	16K'	24.75	8.00	15.7	6.96	-1.80	5.06	6.10	7.8	15.5		-10
09:12	24K'	25.05	8.00	12.0	6.52	-9.10	4.42	5.90	5.8	15.0		-21
09:23	32K'	24.45	7.90	5.5	5.86	-26.00	3.10	5.14	-1.4	14.7		-38
09:45	40K'	24.75	8.00	-3.0	5.00	-41.20	2.14	5.14	-1.4	13.3		-60

ALT.	WEATHER CONDITIONS
3K'	ABOVE STRATUS CLOUDS – TOP AT 2.9K
8K'	PATCHES OF BROKEN STRATUS CLOUD LAYER AT 6.5K (FOUR LEVELS OF CLOUDS)
16K'	SAME CLOUDS. SCATTERED CIRRUS AT 18K; BOTTOM OF VERY THIN LAYER AT 19.5K'. AT 20K THERE MAY BE ICE CRYSTALS
24K'	SAME CLOUDS; THERE ARE CLOUDS AT 26-28K
32K'	ICE CRYSTALS: PLANE IN THIN CIRRUS
40K'	ABOVE ALL CLOUDS

KEY TO SYMBOLS

- T^H_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2
- $\bar{N}^H_{HSG}$ = ENERGY CORRESPONDING TO ABOVE
- T^H_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER
- $\bar{N}^H_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.
- T^T_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER
- $\bar{N}^T_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE
- T^T_{TARGET} = CORRECTED TEMPERATURE OF TARGET
- $\bar{N}^T_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM
- AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 8
MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT #30 CHANNEL 4
TARGET TEMPERATURE = 17.4°C

$\bar{N}^{T}_{TARGET} = \bar{N}^{H}_{HSG} - \bar{N}^{H}_{OUTPUT} + \bar{N}^{T}_{OUTPUT}$

TIME	ALT. (FT.)	T^{H}_{HSG}	$\bar{N}^{H}_{HSG}$	T^{H}_{OUTPUT}	$\bar{N}^{H}_{OUTPUT}$	T^{T}_{OUTPUT}	$\bar{N}^{T}_{OUTPUT}$	$\bar{N}^{T}_{TARGET}$	T^{T}_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
08:47	3K'	26.10	51.0	22.2	48.0	8.2	39.5	42.5	13.5			10
08:55	8K'	25.80	50.5	21.2	47.5	4.5	37.5	40.5	10.0	15.0		7
09:04	16K'	24.75	50.0	13.8	42.5	-8.0	31.0	38.5	6.3	8.5		-10
09:12	24K'	25.05	50.0	10.5	40.5	-19.5	25.5	35.0	-0.2	4.3		-21
09:23	32K'	24.45	49.5	3.5	37.0	-42.0	17.0	29.5	-11.5	0.8		-38
09:45	40K'	24.75	50.0	-5.0	32.5	-63.5	11.0	28.5	-13.2	-2.8		-60

ALT.	WEATHER CONDITIONS
3K'	ABOVE STRATUS CLOUDS – TOP AT 2.9K
8K'	PATCHES OF BROKEN STRATUS CLOUD LAYER AT 6.5K (FOUR LEVELS OF CLOUDS)
16K'	SAME CLOUDS. SCATTERED CIRRUS AT 18K; BOTTOM OF VERY THIN LAYER AT 19.5K' AT 20K THERE MAY BE ICE CRYSTALS
24K'	SAME CLOUDS; THERE ARE CLOUDS AT 26-28K
32K'	ICE CRYSTALS: PLANE IN THIN CIRRUS
40K'	ABOVE ALL CLOUDS

KEY TO SYMBOLS

T^{H}_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2

$\bar{N}^{H}_{HSG}$ = ENERGY CORRESPONDING TO ABOVE

T^{H}_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER

$\bar{N}^{H}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.

T^{T}_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER

$\bar{N}^{T}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE

T^{T}_{TARGET} = CORRECTED TEMPERATURE OF TARGET

$\bar{N}^{T}_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM

AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 9

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT# 31 CHANNEL 1

TARGET TEMPERATURE = 15.2°C

$V_{RADT} = V'_{RADT} - V'_{RADH} + V_{RADH} + 0.85 (V_f - V'_f)$

TIME	ALT. (FT.)	V'_{RADT}	V'_{RADH}	V_{HSG}	V_{RADH}	V_f	V_{CHOP}	V'_f	V_{RADT}	$\bar{N}_{RADT}$	T_{RADT}	I RAD. TEMP	II RAD. TEMP.	AIR TEMP.
07:43	16K'	-0.78	-4.57	-1.76	-3.78	4.39	-1.85	4.34	0.05	0.83	-3.9	-11.1	-0.6	-7
		-0.36	-4.15	-1.75			-1.81		0.05	0.83	-3.9			
07:54	24K'	-2.79	-5.49	-1.79	-3.80	4.39	-1.85	4.39	-1.10	0.58	-15.5	-20.3	-13.9	-21
		-2.23	-5.02	-1.80			-1.79		-1.01	0.60	-14.5			
08:05	32K'	-4.06	-5.91	-1.82	-3.82	4.39	-1.85	4.44	-2.01	0.38	-27.2	-32.2	-24.8	-41
		-3.75	-5.50	-1.84			-1.75		-2.11	0.36	-29.4			
08:25	40K'	-4.75	-6.45	-1.82	-3.81	4.39	-1.85	4.62	-2.31	0.32	-32.6	-43.2	-34.7	-58
		-4.43	-6.14	-1.82			-1.72		-2.30	0.32	-32.6			

ALT.	WEATHER CONDITIONS
3.5K'	OVER SOLID STRATOCUMULUS; CLOUD TOPS AT 3.5K'
8K'	OVER SOLID STRATOCUMULUS
16K'	OVER SOLID STRATOCUMULUS; PLANE IS PROBABLY IN SOME THIN CLOUDS AT 15.5K'
24K'	OVER SOLID STRATOCUMULUS
32K'	OVER SOLID STRATOCUMULUS
40K'	OVER SOLID STRATOCUMULUS; PLANE IN SOME VERY THIN CIRRUS

KEY TO SYMBOLS

- V'_{RADT} = OUTPUT VOLTAGE OF RADIOMETER TARGET
- V'_{RADH} = OUTPUT VOLTAGE OF RADIOMETER MEASURING HOUSING
- V_{HSG} = VOLTAGE FROM SIGNAL FOR HSG 1 & 2
- V_{RADH} = OUTPUT VOLTAGE WHICH WOULD CORRESPOND TO SAME TEMPERATURE AS V_{HSG}
- V_f = OFFSET VOLTAGE FROM SIGNAL CORRESPONDING TO A CHOPPER TEMPERATURE OF 25°C IN THE CALBRATION
- V_{CHOP} = VOLTAGE FROM SIGNAL FOR CHOP 1 & 2
- V'_f = OFFSET VOLTAGE CORRESPONDING TO SAME TEMPERATURE AS V_{CHOP}
- V_{RADT} = CORRECTED OUTPUT VOLTAGE OF TARGET
- $\bar{N}_{RADT}$ = ENERGY CORRESPONDING TO SAME ABOVE, watts/m^2/ster.
- T_{RADT} = CORRECTED TEMPERATURE OF TARGET, °C
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM, THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM °C

TABLE 10
MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 31 CHANNEL 2
TARGET TEMPERATURE = 15.2°C

$$\bar{N}^{T}_{TARGET} = \bar{N}^{H}_{HSG} - \bar{N}^{H}_{OUTPUT} + \bar{N}^{T}_{OUTPUT}$$

TIME	ALT. (FT.)	T^{H}_{HSG}	$\bar{N}^{H}_{HSG}$	T^{H}_{OUTPUT}	$\bar{N}^{H}_{OUTPUT}$	T^{T}_{OUTPUT}	$\bar{N}^{T}_{OUTPUT}$	$\bar{N}^{T}_{TARGET}$	T^{T}_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
07:24	3.5K'	26.15	8.15	24.5	7.95	7.5	6.06	6.26	9.2			10
07:33	8K'	26.20	8.15	24.5	7.95	4.5	5.80	6.00	7.0	13.7	14.8	7
07:43	16K'	25.80	8.10	19.5	7.35	-0.5	5.22	5.87	5.5	13.0	13.7	-7
07:54	24K'	24.95	7.98	15.2	6.90	-7.5	4.59	5.67	3.6	11.9	13.1	-21
08:05	32K'	24.55	7.95	9.0	6.23	-12.0	4.20	5.92	6.3	11.2	12.8	-41
08:25	40K'	24.85	7.97	1.0	5.38	-22.0	3.40	5.99	6.8	10.2	11.4	-58

ALT.	WEATHER CONDITIONS
3.5K'	OVER SOLID STRATOCUMULUS; CLOUD TOPS AT 3.5K'
8K'	OVER SOLID STRATOCUMULUS
16K'	OVER SOLID STRATOCUMULUS; PLANE IS PROBABLY IN SOME THIN CLOUDS AT 15.5K'
24K'	OVER SOLID STRATOCUMULUS
32K'	OVER SOLID STRATOCUMULUS
40K'	OVER SOLID STRATOCUMULUS; PLANE IN SOME VERY THIN CIRRUS

KEY TO SYMBOLS

T^{H}_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2

$\bar{N}^{H}_{HSG}$ = ENERGY CORRESPONDING TO ABOVE

T^{H}_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER

$\bar{N}^{H}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.

T^{T}_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER

$\bar{N}^{T}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE

T^{T}_{TARGET} = CORRECTED TEMPERATURE OF TARGET

$\bar{N}^{T}_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM

AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 11
MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT #31 CHANNEL 4
TARGET TEMPERATURE = 15.2°C

$\bar{N}^T_{TARGET} = \bar{N}^H_{HSG} - \bar{N}^H_{OUTPUT} + \bar{N}^T_{OUTPUT}$

TIME	ALT. (FT.)	T^H_{HSG}	$\bar{N}^H_{HSG}$	T^H_{OUTPUT}	$\bar{N}^H_{OUTPUT}$	T^T_{OUTPUT}	$\bar{N}^T_{OUTPUT}$	$\bar{N}^T_{TARGET}$	T^T_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
07:24	3.5K'	26.15	51.0	24.0	49.0	8.2	39.5	41.5	11.8			10
07:33	8K'	26.20	51.0	24.0	49.0	6.2	38.5	40.5	10.0	10.6	14.3	7
07:43	16K'	25.80	50.5	19.2	46.0	-3.0	33.5	37.0	3.5	4.1	8.5	-7
07:54	24K'	24.95	50.0	13.5	42.5	-16.0	27.0	34.5	-1.2	-0.2	3.5	-21
08:05	32K'	24.55	50.0	6.5	38.5	-27.5	22.5	33.5	-3.2	-4.1	-0.5	-41
08:25	40K'	24.85	50.0	-2.0	34.0	-38.0	18.5	34.5	-1.2	-7.5	-4.0	-58

ALT.	WEATHER CONDITIONS
3.5K'	OVER SOLID STRATOCUMULUS; CLOUD TOPS AT 3.5K'
8K'	OVER SOLID STRATOCUMULUS
16K'	OVER SOLID STRATOCUMULUS; PLANE IS PROBABLY IN SOME THIN CLOUDS AT 15.5K'
24K'	OVER SOLID STRATOCUMULUS
32K'	OVER SOLID STRATOCUMULUS
40K'	OVER SOLID STRATOCUMULUS; PLANE IN SOME VERY THIN CIRRUS

KEY TO SYMBOLS

T^H_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1&2

$\bar{N}^H_{HSG}$ = ENERGY CORRESPONDING TO ABOVE

T^H_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER

$\bar{N}^H_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.

T^T_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER

$\bar{N}^T_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE

T^T_{TARGET} = CORRECTED TEMPERATURE OF TARGET

$\bar{N}^T_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM

AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 12

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT #35 CHANNEL 1

TARGET TEMPERATURE = 15.2°C

$$V_{RADT} = V'_{RADT} - V'_{RADH} + V_{RADH} + 0.85\,(V_f - V'_f)$$

TIME	ALT. (FT.)	V'_{RADT}	V'_{RADH}	V_{HSG}	V_{RADH}	V_f	V_{CHOP}	V'_f	V_{RADT}	$\bar{N}_{RADT}$	T_{RADT}	I RAD. TEMP	II RAD. TEMP.	AIR TEMP.
21:44	16K'	-0.39	-4.63	-1.77	-3.79	4.39	-1.81	4.48	0.37	0.90	-0.8	-1.4	-0.5	-5
		-0.64	-4.99	-1.78			-1.76		0.48	0.93	+0.3			
21:57	24K'	-2.51	-5.36	-1.79	-3.80	4.39	-1.82	4.48	-1.03	0.60	-14.5	-15.0	-15.0	-21
		-2.87	-5.72	-1.83			-1.74		-1.03	0.60	-14.5			
22:10	32K'	-3.60	-5.79	-1.81	-3.82	4.39	-1.81	4.53	-1.75	0.44	-23.6	-25.7	-24.2	-41
		-3.92	-6.06	-1.86			-1.71		-1.80	0.43	-24.3			

ALT.	WEATHER CONDITIONS
500'	CLEAR BELOW TO OCEAN, STRATOCUMULUS ABOVE; TOP AT 2K', BOTTOM AT 1.5K'
8K'	
16K'	
24K'	
32K'	CLEAR OCEAN AND 1% FRACTO-STRATOCUMULUS BELOW
39K'	CLEAR OCEAN

KEY TO SYMBOLS

- V'_{RADT} = OUTPUT VOLTAGE OF RADIOMETER TARGET
- V'_{RADH} = OUTPUT VOLTAGE OF RADIOMETER MEASURING HOUSING
- V_{HSG} = VOLTAGE FROM SIGNAL FOR HSG 1 & 2
- V_{RADH} = OUTPUT VOLTAGE WHICH WOULD CORRESPOND TO SAME TEMPERATURE AS V_{HSG}
- V_f = OFFSET VOLTAGE FROM SIGNAL CORRESPONDING TO A CHOPPER TEMPERATURE OF 25°C IN THE CALBRATION
- V_{CHOP} = VOLTAGE FROM SIGNAL FOR CHOP 1 & 2
- V'_f = OFFSET VOLTAGE CORRESPONDING TO SAME TEMPERATURE AS V_{CHOP}
- V_{RADT} = CORRECTED OUTPUT VOLTAGE OF TARGET
- $\bar{N}_{RADT}$ = ENERGY CORRESPONDING TO SAME ABOVE, watts/m^2/ster.
- T_{RADT} = CORRECTED TEMPERATURE OF TARGET, °C
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM, THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM °C

TABLE 13
MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 35 CHANNEL 2
TARGET TEMPERATURE = 15.2°C

$\bar{N}^{T}_{TARGET} = \bar{N}^{H}_{HSG} - \bar{N}^{H}_{OUTPUT} + \bar{N}^{T}_{OUTPUT}$

TIME	ALT. (FT.)	T^{H}_{HSG}	$\bar{N}^{H}_{HSG}$	T^{H}_{OUTPUT}	$\bar{N}^{H}_{OUTPUT}$	T^{T}_{OUTPUT}	$\bar{N}^{T}_{OUTPUT}$	$\bar{N}^{T}_{TARGET}$	T^{T}_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
21:00	500'	25.90	8.1	25.7	8.10	15.2	6.90	6.90	15.0	15.5	15.0	13
21:18	8K'	26.10	8.1	25.7	8.10	15.2	6.90	6.90	15.0	14.6	15.5	12
21:44	16K'	25.10	8.1	19.7	7.40	7.2	6.00	6.70	13.1	13.7	15.1	-5
21:57	24K'	24.85	7.9	13.2	6.70	1.3	5.40	6.60	12.5	13.5	14.8	-21
22:10	32K'	24.75	7.9	7.2	6.00	-5.4	4.78	6.68	13.0	13.0	14.5	-41
22:23	39K'	24.70	7.9	3.2	5.62	-11.3	4.19	6.47	12.0	12.0	13.1	-51

ALT.	WEATHER CONDITIONS
500'	CLEAR BELOW TO OCEAN, STRATOCUMULUS ABOVE; TOP AT 2K', BOTTOM AT 1.5K'
8K'	
16K'	
24K'	
32K'	CLEAR OCEAN AND 1% FRACTO-STRATOCUMULUS BELOW
39K'	CLEAR OCEAN

KEY TO SYMBOLS

T^{H}_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2

$\bar{N}^{H}_{HSG}$ = ENERGY CORRESPONDING TO ABOVE

T^{H}_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER

$\bar{N}^{H}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.

T^{T}_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER

$\bar{N}^{T}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE

T^{T}_{TARGET} = CORRECTED TEMPERATURE OF TARGET

$\bar{N}^{T}_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM

AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 14

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 35 CHANNEL 4

TARGET TEMPERATURE = 15.2°C

$$\bar{N}^T_{TARGET} = \bar{N}^H_{HSG} - \bar{N}^H_{OUTPUT} + \bar{N}^T_{OUTPUT}$$

TIME	ALT. (FT.)	T^H_{HSG}	$\bar{N}^H_{HSG}$	T^H_{OUTPUT}	$\bar{N}^H_{OUTPUT}$	T^T_{OUTPUT}	$\bar{N}^T_{OUTPUT}$	$\bar{N}^T_{TARGET}$	T^T_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
21:00	500'	25.90	51	23.5	49.0	13.5	42.5	44.5	16.8	15.5	18.6	13
21:18	8K'	26.10	51	25.2	50.0	13.5	42.5	43.5	15.3	15.0	17.1	12
21:44	16K'	25.10	50	17.0	44.5	-1.0	34.5	40.0	9.0	9.4	10.8	-5
21:57	24K'	24.85	50	12.0	41.5	-14.0	28.0	36.5	2.5	3.7	5.5	-21
22:10	32K'	24.75	50	4.0	37.5	-26.0	23.0	35.5	0.8	0.0	2.3	-41
22:23	39K'	24.70	50	0.0	35.0	-35.0	19.5	34.5	-1.2	-2.2	-0.8	-51

ALT.	WEATHER CONDITIONS
500'	CLEAR BELOW TO OCEAN, STRATOCUMULUS ABOVE; TOP AT 2K', BOTTOM AT 1.5K'
8K'	
16K'	
24K'	
32K'	CLEAR OCEAN AND 1% FRACTO-STRATOCUMULUS BELOW
39K'	CLEAR OCEAN

KEY TO SYMBOLS

- T^H_{HSG} = TEMPERATURE OF HOUSING MEASURED BY **HSG 1&2**
- $\bar{N}^H_{HSG}$ = ENERGY CORRESPONDING TO ABOVE
- T^H_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER
- $\bar{N}^H_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.
- T^T_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER
- $\bar{N}^T_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE
- T^T_{TARGET} = CORRECTED TEMPERATURE OF TARGET
- $\bar{N}^T_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM
- AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 15

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 36 CHANNEL 1

TARGET TEMPERATURE = 15.7°C

$V_{RADH} = V'_{RADT} - V'_{RADH} + V_{RADH} + 0.85\,(V_f - V'_f)$

TIME	ALT. (FT.)	V'_{RADT}	V'_{RADH}	V_{HSG}	V_{RADH}	V_f	V_{CHOP}	V'_f	V_{RADT}	$\bar{N}_{RADT}$	T_{RADT}	I RAD. TEMP	II RAD. TEMP.	AIR TEMP.
23:22	16K'	-0.26	-4.76	-1.78	-3.80	4.39	-1.82	4.44	0.66	0.97	1.8	-2.1	-1.9	-3
		-0.62	-5.10	-1.83			-1.77		0.64	0.96	1.5			
23:49	24K'	-2.40	-5.73	-1.78	-3.81	4.39	-1.81	4.39	-0.48	0.72	-8.8	-16.0	-15.0	-22
		-2.81	-6.22	-1.88			-1.73		-0.40	0.74	-7.9			
00:16	32K'	-3.75	-6.26	-1.76	-3.80	4.39	-1.81	4.39	-1.29	0.54	-17.8	-24.7	-29.4	-41
		-4.04	-6.48	-1.84			-1.70		-1.36	0.53	-18.2			

ALT.	WEATHER CONDITIONS
500'	CLEAR BELOW
8K'	CLEAR BELOW
16K'	CLEAR BELOW
24K'	CLEAR BELOW
32K'	CLEAR BELOW
40K'	STRATOCUMULUS DECK AT ~8K'

KEY TO SYMBOLS

- V'_{RADT} = OUTPUT VOLTAGE OF RADIOMETER TARGET
- V'_{RADH} = OUTPUT VOLTAGE OF RADIOMETER MEASURING HOUSING
- V_{HSG} = VOLTAGE FROM SIGNAL FOR HSG 1&2
- V_{RADH} = OUTPUT VOLTAGE WHICH WOULD CORRESPOND TO SAME TEMPERATURE AS V_{HSG}
- V_f = OFFSET VOLTAGE FROM SIGNAL CORRESPONDING TO A CHOPPER TEMPERATURE OF 25°C IN THE CALBRATION
- V_{CHOP} = VOLTAGE FROM SIGNAL FOR CHOP 1&2
- V'_f = OFFSET VOLTAGE CORRESPONDING TO SAME TEMPERATURE AS V_{CHOP}
- V_{RADT} = CORRECTED OUTPUT VOLTAGE OF TARGET
- $\bar{N}_{RADT}$ = ENERGY CORRESPONDING TO SAME ABOVE, watts/m^2/ster.
- T_{RADT} = CORRECTED TEMPERATURE OF TARGET, °C
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM, THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM °C

TABLE 16

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 36 CHANNEL 2
TARGET TEMPERATURE = 15.7°C

$$\bar{N}^T_{TARGET} = \bar{N}^H_{HSG} - \bar{N}^H_{OUTPUT} + \bar{N}^T_{OUTPUT}$$

TIME	ALT. (FT.)	T^H_{HSG}	$\bar{N}^H_{HSG}$	T^H_{OUTPUT}	$\bar{N}^H_{OUTPUT}$	T^T_{OUTPUT}	$\bar{N}^T_{OUTPUT}$	$\bar{N}^T_{TARGET}$	T^T_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
22:34	500'	29.2	8.60	23.5	7.78	10.0	6.35	7.18	17.8	16.0	15.5	14
				22.2	7.60	5.4	5.82	6.82	14.8			
22:49	8K'	27.3	8.30	28.0	8.40	13.5	6.70	6.60	12.5	17.5	15.3	17
				24.5	7.92	10.0	6.35	6.73	13.8			
23:22	16K'	25.4	8.15	21.5	7.60	8.5	6.18	6.68	13.8	17.0	15.0	-3
				18.0	7.22	6.5	5.97	6.90	15.3			
23:49	24K'	25.2	8.10	13.5	6.72	-1.0	5.16	6.54	12.2	16.5	14.6	-22
				8.3	6.18	-8.4	4.50	6.42	10.8			
00:16	32K'	25.3	8.10	1.0	5.40	-18.1	3.68	6.38	10.3	15.8	13.5	-41
				5.0	5.80	-9.5	4.36	6.66	13.3			
00:49	40K'	25.3	8.10	-1.9	5.10	-19.4	3.55	6.55	12.0	15.5	12.5	-57
				3.0	5.60	-13.6	4.08	6.58	12.2			

ALT.	WEATHER CONDITIONS
500'	CLEAR BELOW
8K'	CLEAR BELOW
16K'	CLEAR BELOW
24K'	CLEAR BELOW
32K'	CLEAR BELOW
40K'	STRATOCUMULUS DECK AT ~8K'

KEY TO SYMBOLS

- T^H_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2
- $\bar{N}^H_{HSG}$ = ENERGY CORRESPONDING TO ABOVE
- T^H_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER
- $\bar{N}^H_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.
- T^T_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER
- $\bar{N}^T_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE
- T^T_{TARGET} = CORRECTED TEMPERATURE OF TARGET
- $\bar{N}^T_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM
- AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 17

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT #36 CHANNEL 4

TARGET TEMPERATURE = 15.7°C

$\bar{N}^T_{TARGET} = \bar{N}^H_{HSG} - \bar{N}^H_{OUTPUT} + \bar{N}^T_{OUTPUT}$

TIME	ALT. (FT.)	T^H_{HSG}	$\bar{N}^H_{HSG}$	T^H_{OUTPUT}	$\bar{N}^H_{OUTPUT}$	T^T_{OUTPUT}	$\bar{N}^T_{OUTPUT}$	$\bar{N}^T_{TARGET}$	T^T_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
22:34	500'	29.2	53.0	21.2	47.5	9.0	40.0	45.5	18.5	+21.2	16.8	14
				20.0	46.5	7.0	39.0	45.5	18.5			
22:49	8K'	27.3	52.0	27.0	51.0	15.3	43.5	44.5	17.0	+18.7	15.5	17
				25.2	50.0	13.5	42.5	44.5	17.0			
23:22	16K'	25.4	50.0	17.0	44.5	-0.2	35.0	40.5	10.0	+12.0	9.8	-3
				16.0	44.0	-1.0	34.5	40.5	10.0			
23:49	24K'	25.2	50.5	9.0	40.0	-12.2	29.0	39.5	8.0	+6.2	4.8	-22
				7.5	39.0	-14.0	28.0	39.5	8.0			
00:16	32K'	25.3	50.0	1.2	35.5	-26.5	22.5	37.0	3.5	+3.0	-0.6	-41
				-0.5	34.5	-28.5	22.0	37.5	4.5			
00:49	40K'	25.3	50.0	-2.3	34.0	-33.5	20.0	36.0	2.0	+0.6	-2.9	-57
				-4.0	33.0	-37.5	18.5	35.5	1.0			

ALT.	WEATHER CONDITIONS
500'	CLEAR BELOW
8K'	CLEAR BELOW
16K'	CLEAR BELOW
24K'	CLEAR BELOW
32K'	CLEAR BELOW
40K'	STRATOCUMULUS DECK AT ~8K'

KEY TO SYMBOLS

T^H_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2

$\bar{N}^H_{HSG}$ = ENERGY CORRESPONDING TO ABOVE

T^H_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER

$\bar{N}^H_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.

T^T_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER

$\bar{N}^T_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE

T^T_{TARGET} = CORRECTED TEMPERATURE OF TARGET

$\bar{N}^T_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM

AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 18

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 41 CHANNEL 1

TARGET TEMPERATURE = 11.7°C

$$V_{RADH} = V'_{RADT} - V'_{RADH} + V_{RADH} + 0.85\,(V_f - V'_f)$$

TIME	ALT. (FT.)	V'_{RADT}	V'_{RADH}	V_{HSG}	V_{RADH}	V_f	V_{CHOP}	V'_f	V_{RADT}	$\bar{N}_{RADT}$	T_{RADT}	I RAD. TEMP	II RAD. TEMP.	AIR TEMP.
19:39	16K'	-0.07	-4.16	-1.76	-3.77	4.39	-1.81	4.48	0.24	0.88	-1.8	1.0		-2
		-0.27	-4.52	-1.73			-1.77		0.40	0.91	-0.5			
20:10	24K'	-2.47	-5.30	-1.76	-3.79	4.39	-1.81	4.48	-1.04	0.60	-14.5	-12.0		-20
		-2.84	-5.69	-1.79			-1.74		-1.02	0.60	-14.5			
20:39	32K'	-4.10	-6.11	-1.76	-3.78	4.39	-1.81	4.48	-1.85	0.42	-25.0	-22.0		-39
		-4.43	-6.33	-1.78			-1.71		-1.96	0.40	-26.3			
21:17	40K'	-4.42	-6.38	-1.81	-3.80	4.39	-1.81	4.48	-1.92	0.40	-26.3			-57
		-4.75	-6.39	-1.80			-1.70		-2.24	0.33	-31.8			

ALT.	WEATHER CONDITIONS
2.5K'	CLEAR BELOW
8K'	CLEAR BELOW
16K'	CLEAR BELOW
24K'	CLEAR BELOW
32K'	CLEAR BELOW
40K'	BROKEN STRATOCUMULUS BELOW

KEY TO SYMBOLS

V'_{RADT} = OUTPUT VOLTAGE OF RADIOMETER TARGET

V'_{RADH} = OUTPUT VOLTAGE OF RADIOMETER MEASURING HOUSING

V_{HSG} = VOLTAGE FROM SIGNAL FOR HSG 1&2

V_{RADH} = OUTPUT VOLTAGE WHICH WOULD CORRESPOND TO SAME TEMPERATURE AS V_{HSG}

V_f = OFFSET VOLTAGE FROM SIGNAL CORRESPONDING TO A CHOPPER TEMPERATURE OF 25°C IN THE CALBRATION

V_{CHOP} = VOLTAGE FROM SIGNAL FOR CHOP 1&2

V'_f = OFFSET VOLTAGE CORRESPONDING TO SAME TEMPERATURE AS V_{CHOP}

V_{RADT} = CORRECTED OUTPUT VOLTAGE OF TARGET

$\bar{N}_{RADT}$ = ENERGY CORRESPONDING TO SAME ABOVE, watts/m^2/ster.

T_{RADT} = CORRECTED TEMPERATURE OF TARGET, °C

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM, THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM °C

TABLE 19

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT #41 CHANNEL 2

TARGET TEMPERATURE = 11.7°C

$$\bar{N}^{T}_{TARGET} = \bar{N}^{H}_{HSG} - \bar{N}^{H}_{OUTPUT} + \bar{N}^{T}_{OUTPUT}$$

TIME	ALT. (FT.)	T^{H}_{HSG}	$\bar{N}^{H}_{HSG}$	T^{H}_{OUTPUT}	$\bar{N}^{H}_{OUTPUT}$	T^{T}_{OUTPUT}	$\bar{N}^{T}_{OUTPUT}$	$\bar{N}^{T}_{TARGET}$	T^{T}_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
18:46	2.5K'	27.35	8.24	28.50	8.48	16.5	7.00	6.76	13.8	11.5		18
19:12	8K'	25.80	8.18	25.45	8.08	11.0	6.45	6.55	12.0	11.6		13
19:39	16K'	26.00	8.22	20.20	7.40	5.0	5.80	6.52	11.9	11.3		-2
20:10	24K'	25.55	8.08	14.00	6.75	-2.2	5.08	6.41	10.3	11.1		-20
20:39	32K'	25.25	8.05	6.00	5.90	-11.3	4.27	6.42	10.5	10.7		-39
21:17	40K'	25.10	7.90	0.00	5.30	-17.5	3.75	6.35	9.8			-57

ALT.	WEATHER CONDITIONS
2.5K'	CLEAR BELOW
8K'	CLEAR BELOW
16K'	CLEAR BELOW
24K'	CLEAR BELOW
32K'	CLEAR BELOW
40K'	BROKEN STRATOCUMULUS BELOW

KEY TO SYMBOLS

- T^{H}_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2
- $\bar{N}^{H}_{HSG}$ = ENERGY CORRESPONDING TO ABOVE
- T^{H}_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER
- $\bar{N}^{H}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.
- T^{T}_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER
- $\bar{N}^{T}_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE
- T^{T}_{TARGET} = CORRECTED TEMPERATURE OF TARGET
- $\bar{N}^{T}_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE
- RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM
- AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 20

MRIR MEASURED TARGET TEMPERATURES AND RADIATIVE TRANSFER PROGRAM TEMPERATURES

FLIGHT # 41 CHANNEL 4

TARGET TEMPERATURE = 11.7°C

$$\bar{N}^T_{TARGET} = \bar{N}^H_{HSG} - \bar{N}^H_{OUTPUT} + \bar{N}^T_{OUTPUT}$$

TIME	ALT. (FT.)	T^H_{HSG}	$\bar{N}^H_{HSG}$	T^H_{OUTPUT}	$\bar{N}^H_{OUTPUT}$	T^T_{OUTPUT}	$\bar{N}^T_{OUTPUT}$	$\bar{N}^T_{TARGET}$	T^T_{TARGET}	I RAD. TEMP.	II RAD. TEMP.	AIR TEMP.
18:44	2.5K'	27.35	51.5	28.3	52.5	14.3	43.0	42.0	13.0	16.1		18
18:46				27.6	52.0	13.3	42.5	42.0	13.0			
19:08	8K'	25.80	50.5	24.0	49.0	10.8	41.0	42.5	14.0	13.8		13
19:12				24.0	49.0	10.9	41.0	42.5	14.0			
19:35	16K'	26.00	50.5	17.8	45.0	1.0	35.5	41.0	11.0	8.9		-2
19:39				18.5	45.5	0.0	35.0	40.0	9.0			
20:06	24K'	25.55	50.5	9.7	40.0	-16.0	27.0	37.5	4.5	4.1		-20
20:10				9.7	40.0	-15.9	27.0	37.5	4.5			
20:36	32K'	25.25	50.0	[illegible]	36.0	-29.0	21.5	35.5	1.0	0.5		-39
20:39				[illegible]	[illegible]	-29.0	21.5	35.5	1.0			
21:13	40K'	[illegible]	50.0	-4.2	33.0	-40.0	17.5	34.5	-1.0			-57
21:17				-4.2	33.0	-34.0	20.0	37.5	4.5			

ALT.	WEATHER CONDITIONS
2.5K'	CLEAR BELOW
8K'	CLEAR BELOW
16K	CLEAR BELOW
24K'	CLEAR BELOW
32K'	CLEAR BELOW
40K'	BROKEN STRATOCUMULUS BELOW

KEY TO SYMBOLS

T^H_{HSG} = TEMPERATURE OF HOUSING MEASURED BY HSG 1 & 2

$\bar{N}^H_{HSG}$ = ENERGY CORRESPONDING TO ABOVE

T^H_{OUTPUT} = TEMPERATURE OF HOUSING MEASURED BY RADIOMETER

$\bar{N}^H_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE IN watts/m^2/ster.

T^T_{OUTPUT} = TEMPERATURE OF TARGET MEASURED BY RADIOMETER

$\bar{N}^T_{OUTPUT}$ = ENERGY CORRESPONDING TO ABOVE

T^T_{TARGET} = CORRECTED TEMPERATURE OF TARGET

$\bar{N}^T_{TARGET}$ = ENERGY CORRESPONDING TO ABOVE

RAD. TEMP. = RADIATIVE TEMPERATURE OBTAINED FROM THE RADIOSONDES AND RADIATIVE TRANSFER PROGRAM

AIR TEMP. = AIR TEMPERATURE OBTAINED FROM COCKPIT

TABLE 21
FLIGHT 35 CHANNEL 2

TIME	ALT	$\hat{N}_1$	T_{T1}°(C)	$\hat{N}_2$	T_{T2}(°C)	$\hat{B}_1$	T_C(°C)	$\hat{B}_2$	T (°C)	T_{AIR}(°C)
21:00	500'	6.90	15.0	6.90	15.0	8.0	25.0	8.00	25.0	13
21:18	8K'	6.90	15.0	6.90	15.0	↓	↓	8.00	25.0	12
21:44	16K'	6.00	7.0	6.70	13.1	↓	↓	5.68	3.6	-5
21:57	24K'	5.40	1.1	6.60	12.5	↓	↓	4.03	-13.7	-21
22:10	32K'	4.78	-5.6	6.68	13.0	↓	↓	1.71	-49.4	-41
22:23	40K'	4.19	-11.5	6.47	12.0	↓	↓	0.45	-89.3	-51

$$0 = 0.87\, r^3(\hat{N}_1 - \hat{N}_2) + (1 - 0.87\, r^3)(\hat{B}_1 - \hat{B}_2)$$

$$\hat{B}_2 = \hat{B}_1 + \frac{0.87\, r^3}{1 - 0.87\, r^3}(\hat{N}_1 - \hat{N}_2)$$

$r = 0.96$
$0.87\, r^3 = 0.77$
$1 - 0.87\, r^3 = 0.23$

SUBSCRIPT 1 REFERS TO CALIBRATION CASE
SCRIPT 2 REFERS TO FLIGHT CASE

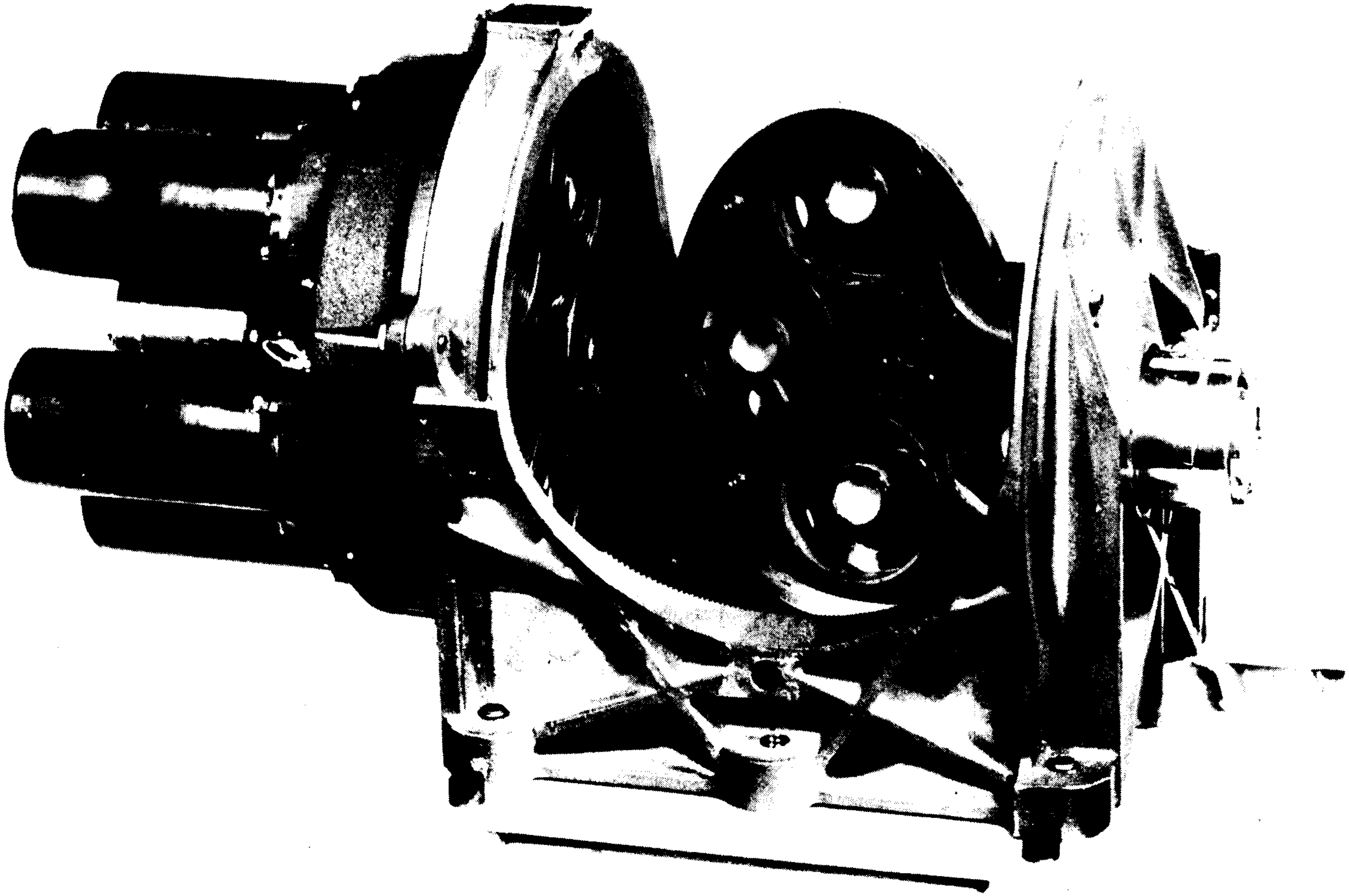
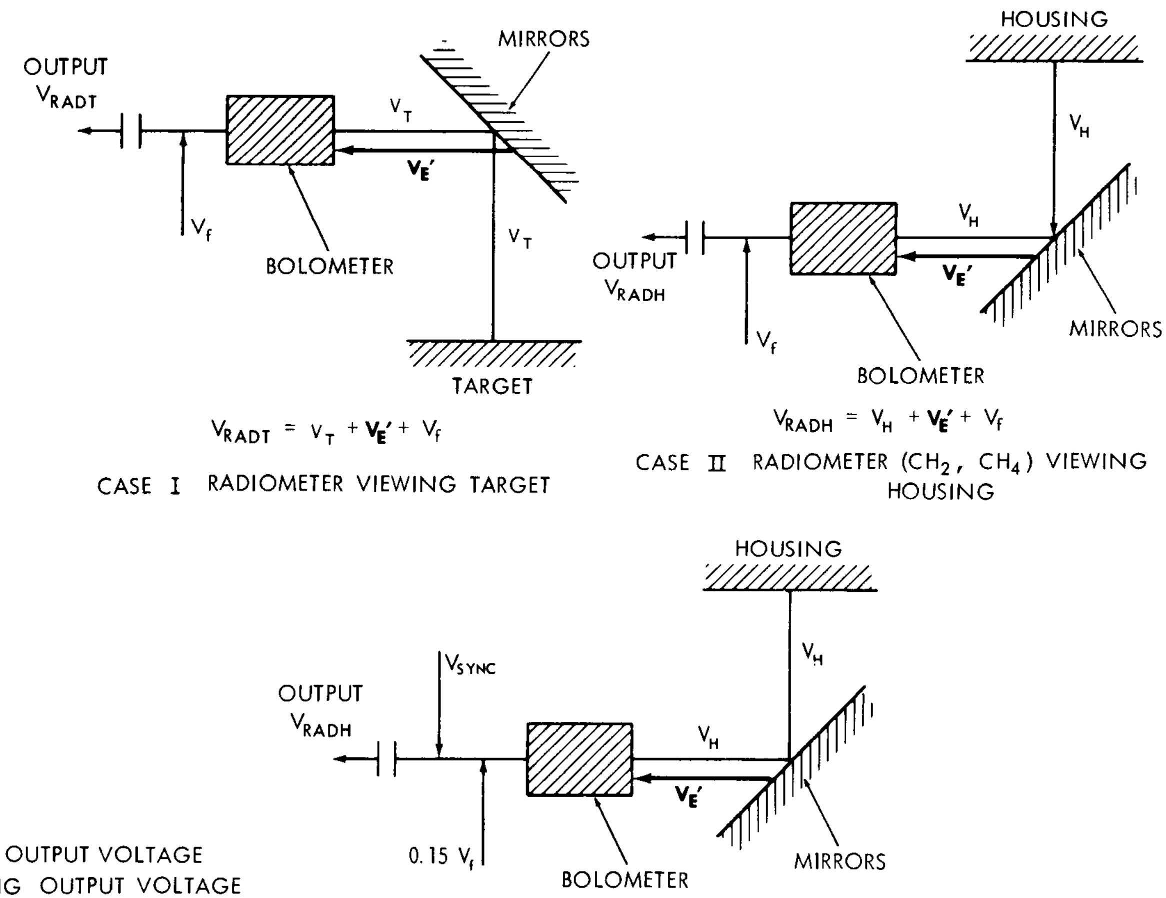


Figure 1—MRIR Radiometer.



$V_{RADT} = V_T + \mathbf{V_E'} + V_f$

CASE I RADIOMETER VIEWING TARGET

$V_{RADH} = V_H + \mathbf{V_E'} + V_f$

CASE II RADIOMETER (CH_2, CH_4) VIEWING HOUSING

$V_{RADH} = V_H + \mathbf{V_E'} + 0.151\,V_f + V_{SYNC}$

CASE III RADIOMETER (CH_1) VIEWING HOUSING

WHERE:

V_{RADT} = TARGET OUTPUT VOLTAGE
V_{RADH} = HOUSING OUTPUT VOLTAGE
V_T = TARGET SIGNAL VOLTAGE
V_H = HOUSING SIGNAL VOLTAGE
V_f = OFFSET VOLTAGE
V_{SYNC} = SYNCHRONIZATION VOLTAGE
V_E' = INFLIGHT ERROR VOLTAGE

Note that V_T, V_H, and V_E', are the voltage contributions resulting from radiation from the target, housing and "mirrors" respectively. The word "mirrors" here designates all optical components in the field of view of the detector.

Figure 2–Input Voltages Causing Inflight MRIR Output Voltage.

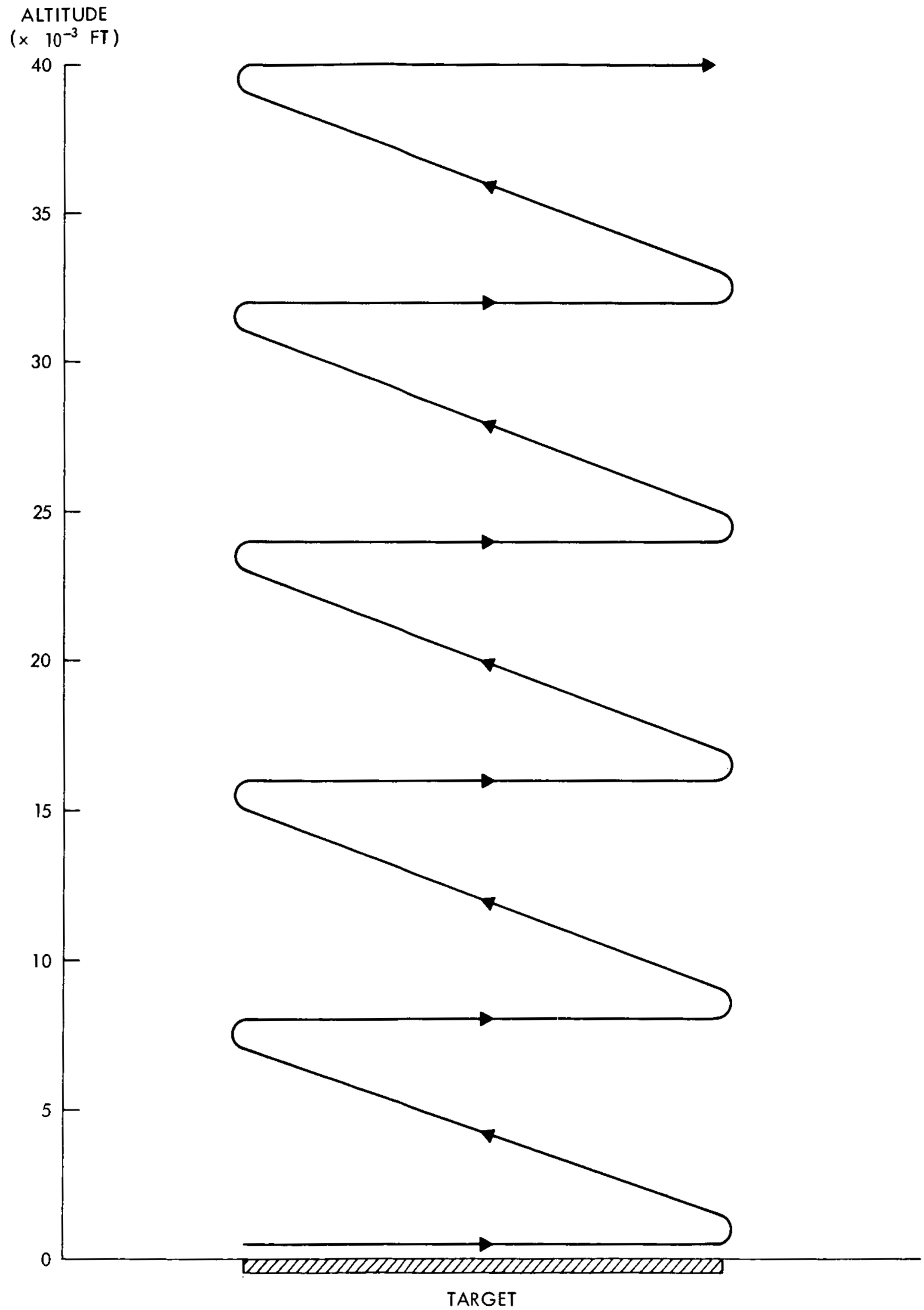


Figure 3–Diagram of a Vertical Cross-section.

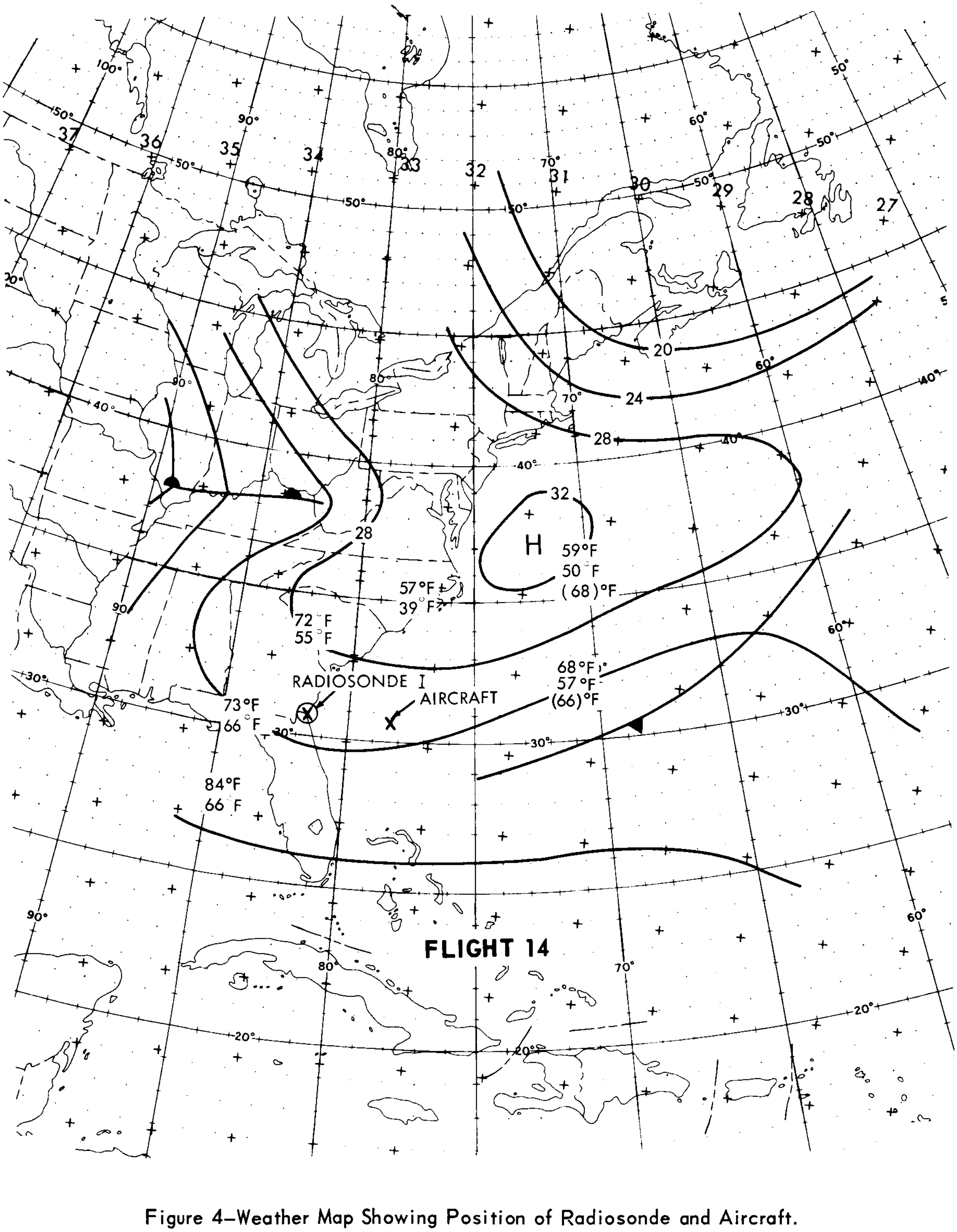


Figure 4—Weather Map Showing Position of Radiosonde and Aircraft.

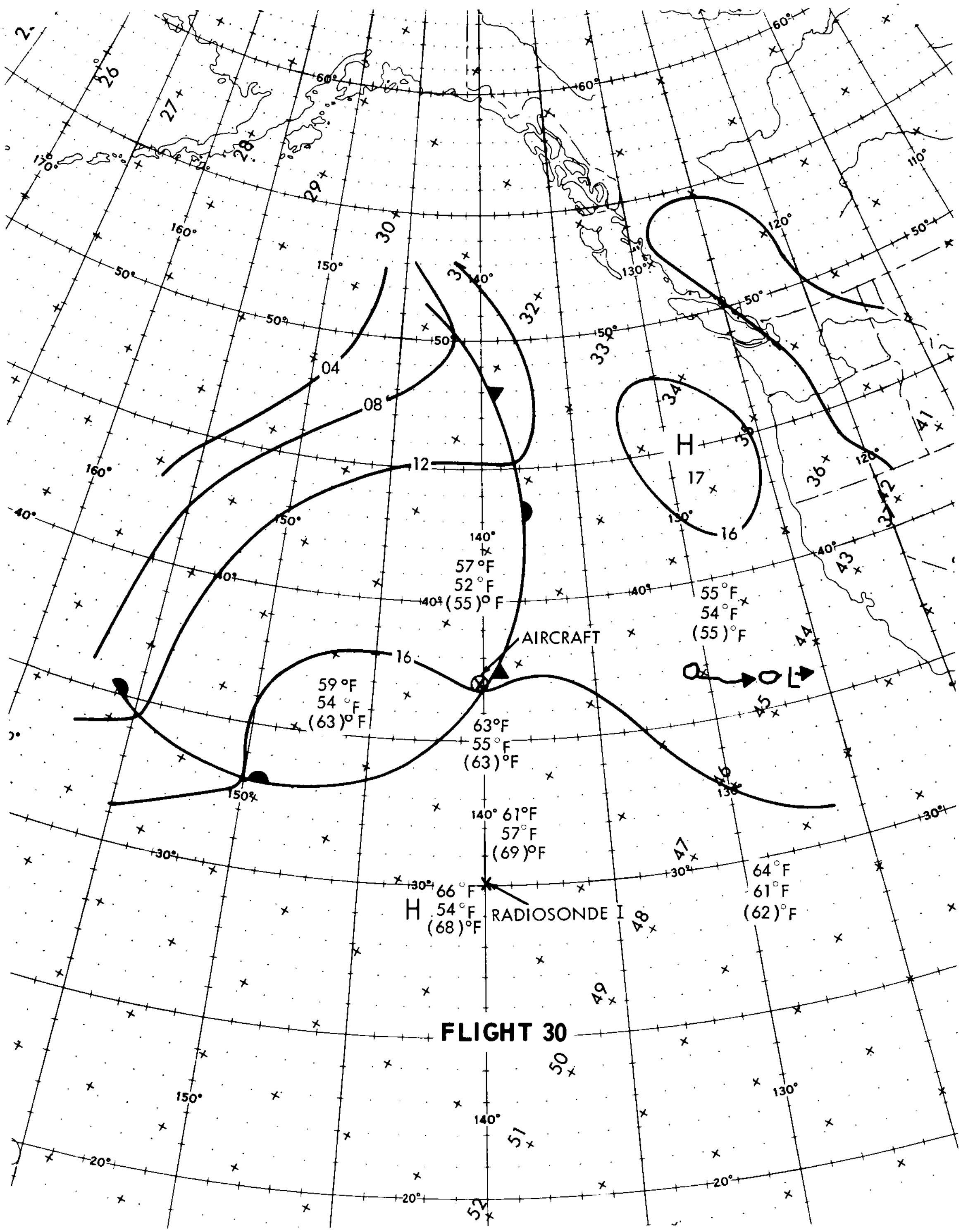


Figure 5–Weather Map Showing Position of Radiosonde and Aircraft.

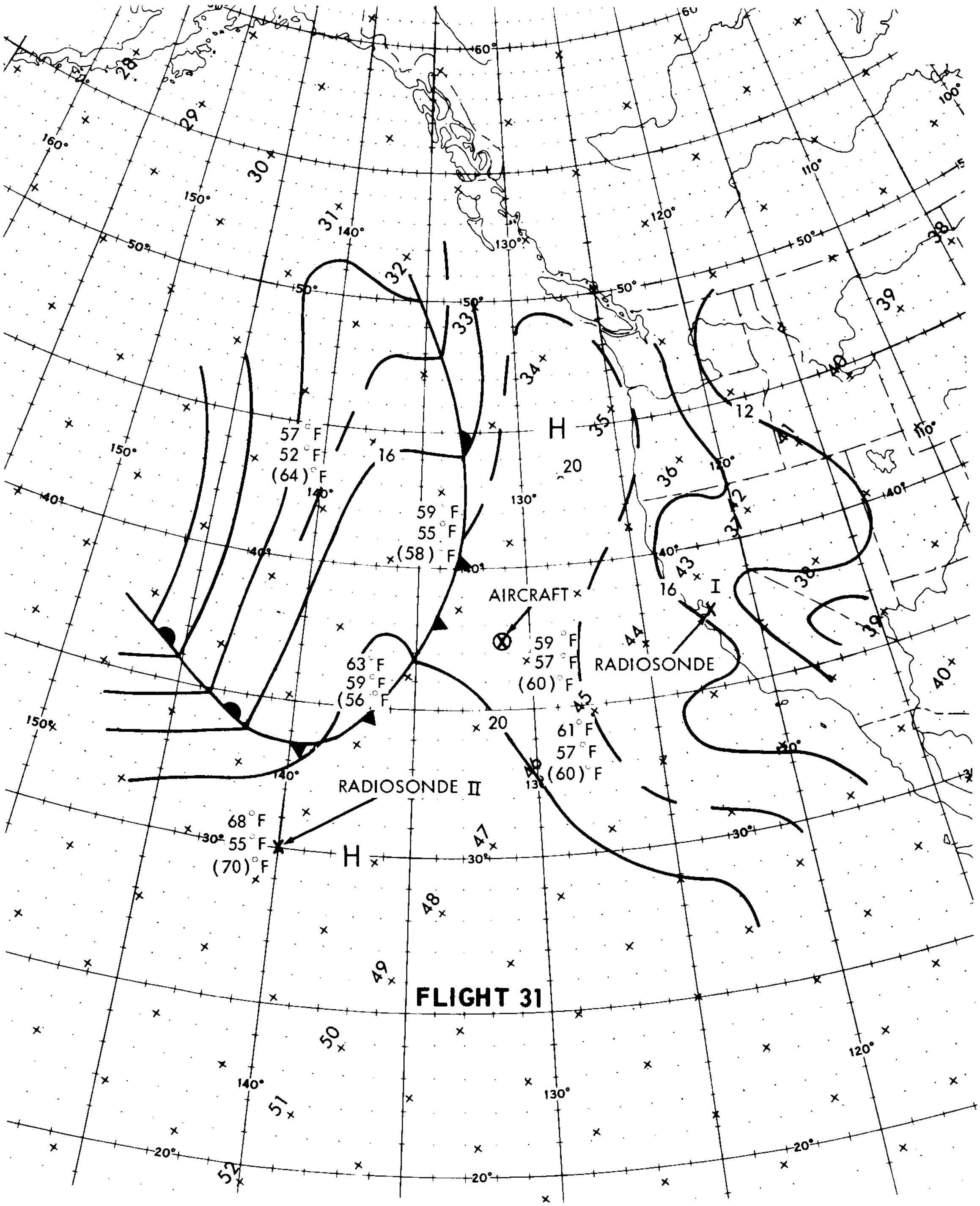


Figure 6—Weather Map Showing Position of Radiosonde and Aricraft.

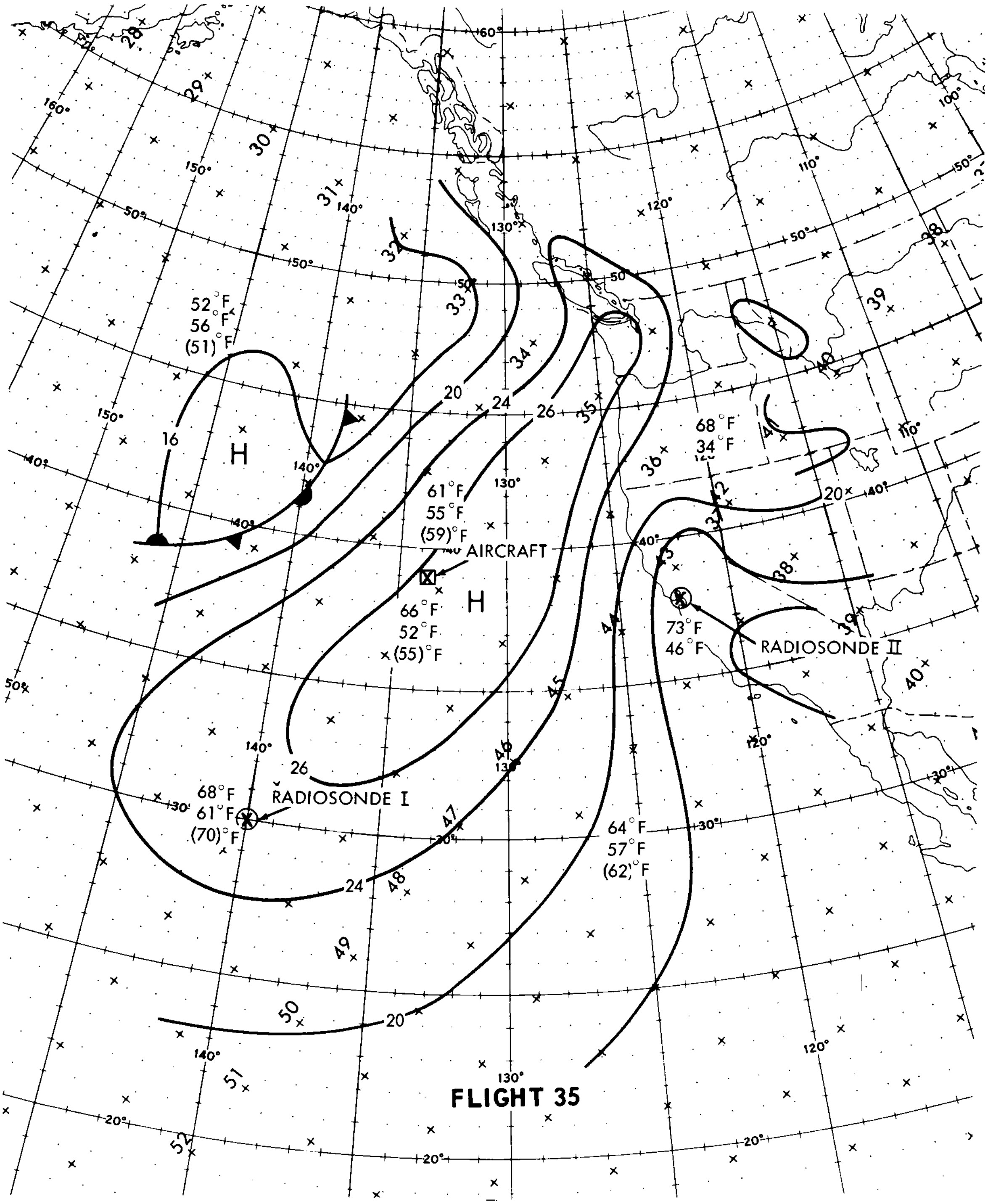


Figure 7—Weather Map Showing Position of Radiosonde and Aircraft.

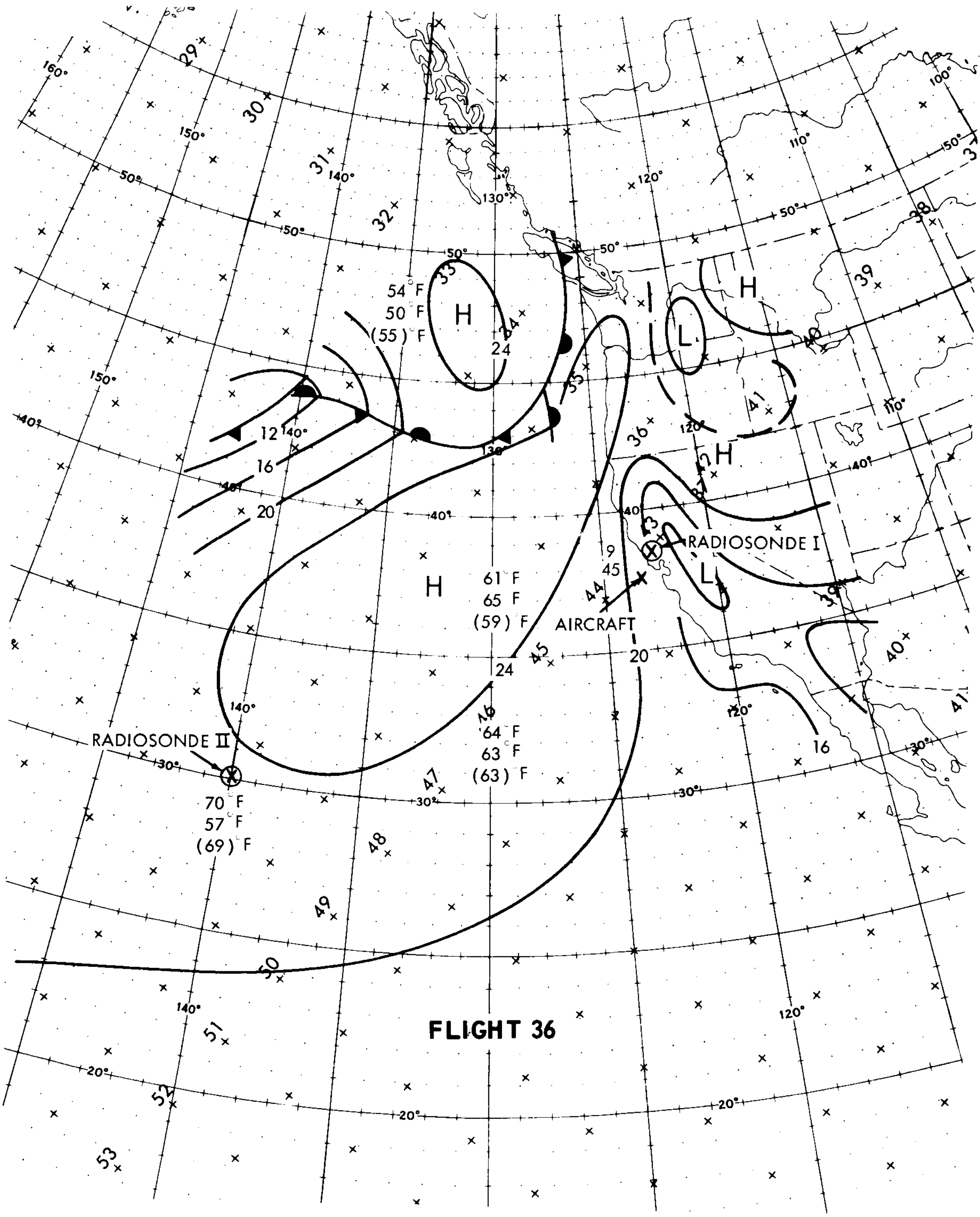


Figure 8–Weather Map Showing Position of Radiosonde and Aircraft.

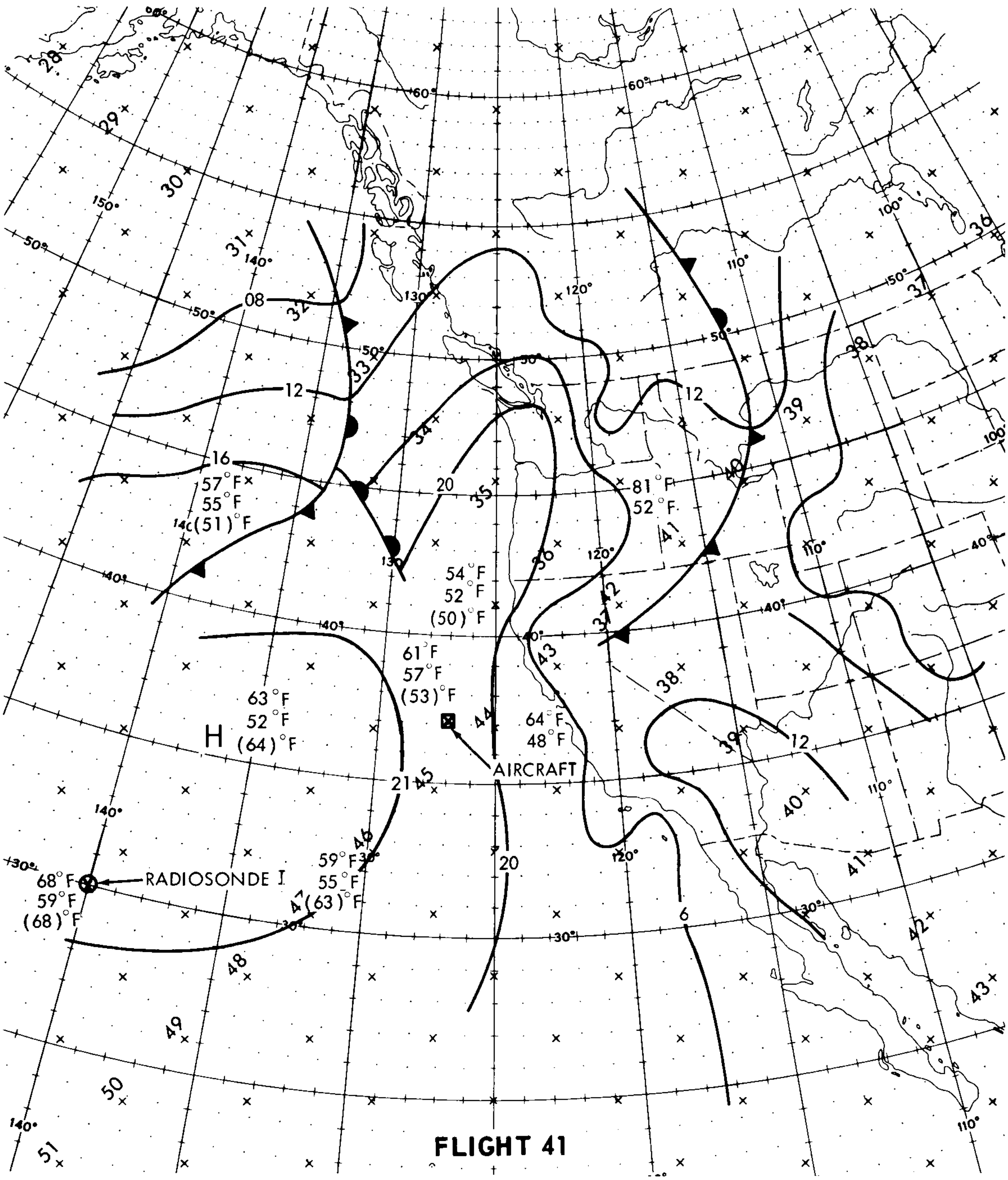


Figure 9—Weather Map Showing Position of Radiosonde and Aircraft.

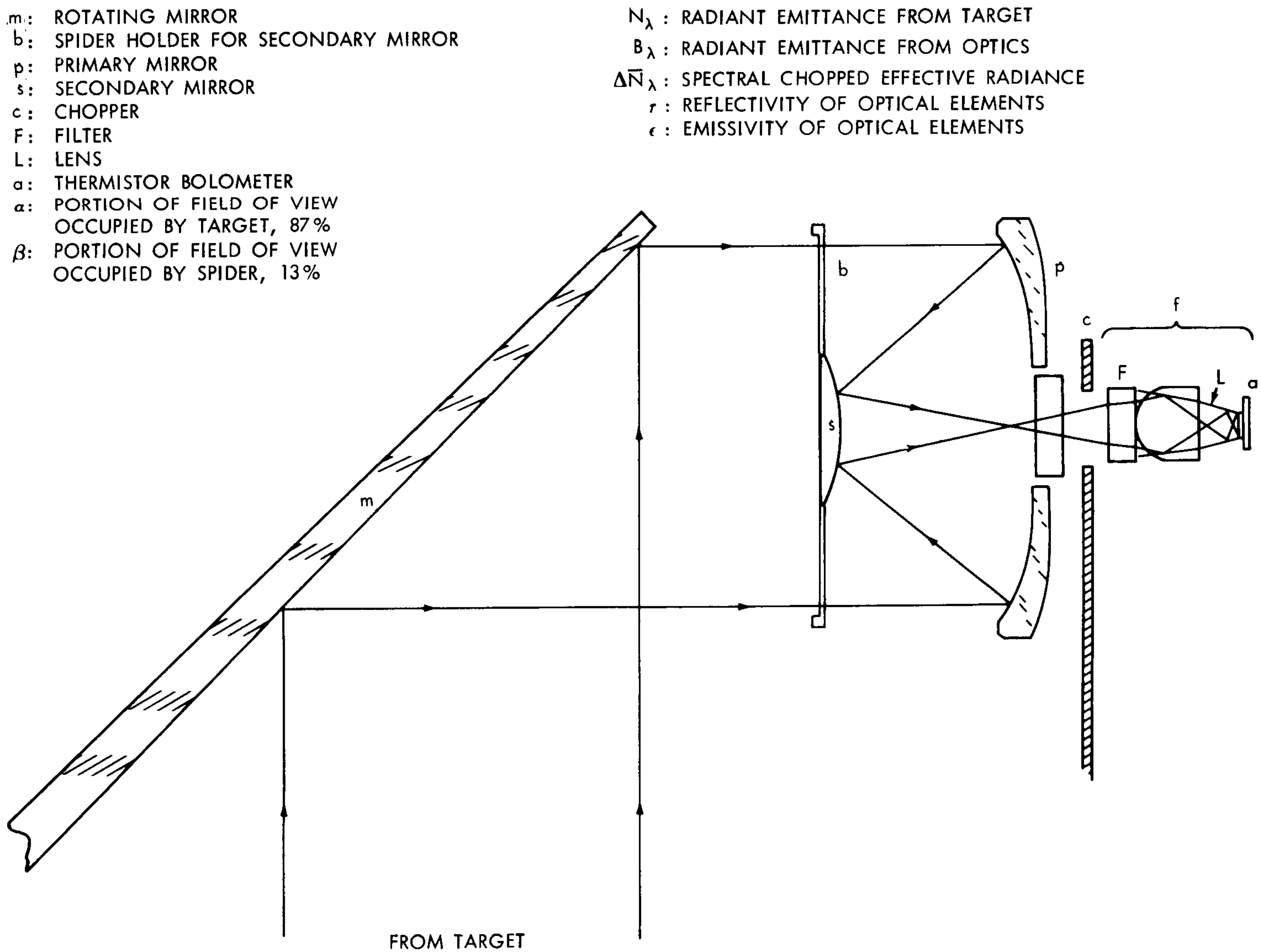


Figure 10–MRIR Optics.