THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
Department of Aerospace Engineering
High Altitude Engineering Laboratory

Quarterly Report

HIGH ALTITUDE RADIATION MEASUREMENTS

1 January, 1967 - 31 March, 1967

Fred L. Bartman

ORA Project 05863

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Abstract

This report is a summary of project activities during the period 1 January 1967 to 31 March 1967. Interferometer radiation data have been calculated at intervals throughout the day for the 8 May 1966 balloon flight. A study of the determination of atmospheric temperature structure from the interferometer data shows the effect of the initial guess upon the solution obtained. Calibration apparatus for FAT/free air temperature) thermister beads, laboratory testing of the IRIS interferometer, preparations for the next balloon flight and preparations for laboratory measurements of CO_2 transmission are described.

I Introduction

This is the 17th quarterly progress report on contract no. NASr-54(03), covering the period 1 January, 1967 to 31 March, 1967. The project effort during this time was divided among the following tasks:

1. Data Analysis and interpretation.
2. Calibration of FAT (Free Air Temperature) thermister beads.
3. Laboratory testing of the IRIS interferometer.
4. Preparations for the next balloon flight.
5. Laboratory measurements of CO_2 transmission.
6. Report writing.

At a meeting with Goddard Space Flight Center technical personnel on 5 January, 1967 it was decided that preparations for the balloon flight test of the Texas Instruments IRIS interferometer should have first priority and that report writing should have second priority (objectives 4 and 6 above).

II Data Analysis and Interpretation

A. Interferometer Radiation Data

Interferometer data at selected time intervals throughout the day of the 8 May 1966 balloon flight have been reduced to radiation spectra. This data will be published in a report "A Fourier Transform Spectrometer For the Measurement of Atmospheric Thermal Radiation", by L. W. Chaney, L. T. Loh and M. T. Surh (see section VII of this report).

Nine sets of radiation data are to be published. The times of the data sets (E. S. T.) are: 0830, 0910, 1006, 1109, 1234, 1331, 1412, 1448, 1511. Each data set covers the spectral range of 500-2000 $cm.^{-1}$ in 2 $cm.^{-1}$ steps. The error of the measurements (standard deviation) is estimated to be ± 0.5 ergs

sec^{-1} $cm.^{-2}$ or $^{-1}/cm.^{-1}$ for most of the spectrum. This uncertainty is exceeded in the spectral range 500-550 $cm.^{-1}$ because of a drop in instrument sensitivity, and in the spectral range 725-750 $cm.^{-1}$ because of errors introduced by vibrations on the balloon gondola.

A sample of the interferometer radiance data is given in table 1. The remainder of the data will be published in the report mentioned above. Aerial photographs showing the instrument field of view at each of the data time intervals also are shown in the report.

B. Determination of Atmospheric Temperature Structure From Radiation Data.

The "inversion" method employed by members of our laboratory to calculate the atmospheric temperature profile corresponding to a set of interferometer radiance data in the 15μ CO_2 band is the technique of calculating deviations from an "initial guess" temperature profile, expressing the solution as a matrix equation. The instabilities in the matrix inversion are suppressed using a truncated eigenvector expansion.

With this technique the solution obtained depends on the "initial guess" used as the starting point in the calculation. This result is indicated by the temperature profiles shown in figures 1-5. Figures 1 and 2 show the average radiosonde temperature curve for 8 May, 1966 along with three temperature curves which could be used as the "initial guess;" the May mean for 30°N, 80°W; the March mean for 30°N, 80°W and the U. S. Standard Atmosphere, 1962. Solutions obtained with these initial guesses are shown in figures 3-5. Results are reasonably good for the "May mean" and March mean" guesses and not quite as good for the U. S. Standard atmosphere. Note that the results obtained in each case show the influence of the initial guess.

These results have been presented in a paper given at the A.M. S. Conference on Physical Processes in theAtmosphere, March 20-20, 1967, Ann Arbor, Michigan (see section VII).

III Calibration of FAT (Free Air Temperature) Thermister Beads

A new set of 12 thermister beads has been assembled for use on the next balloon flight, and an attempt was made to calibrate these beads along with one head left from the last flight. The old bead is being recalibrated as a check on the accuracy of calibrations carried out before the last balloon flight. It is possible that recalibration may shed some light on the disagreement in balloon ascent measurements of air temperature on the 8 May 1966 balloon flight (see p 1, of quarterly report no. 05863-15-P).

The chamber in which the bead thermister is mounted for calibration is shown in figure 6. For calibration the chamber is inserted in a temperature controlled bath. Dry nitrogen is circulated through a coil in the in the bath, then through the coils around the chamber, through the inside of the chamber itself and out through the bath. Temperatures are measured by platinum resistance thermometers at 6 points within the chamber.

The previous calibration was made without circulating dry nitrogen. The chamber was placed in the temperature controlled bath and the thermister was cooled by radiation from the wall of the chamber. It is hoped that the flow of dry nitrogen will result in more uniform temperatures within the chamber and more accurate calibrations.

A drawing of the chamber, showing the bead in position for calibration is shown in figure 7, and a picture of the calibration apparatus, in figure 8.

The first attempt to calibrate the beads did not produce good results, because of an inaccurate digital voltmeter. The instrument has been returned to the factory for repairs.

IV Laboratory Testing of the IRIS Interferometer

Interferometer developments included work on the design of the new mirror drive system, the crystal control unit for the fixed mirror system, detector testing and study of the use of the 7032A^{o} neon line instead of the 5852 A^{o} of neon.

It has been necessary to re-design the new mirror drive system, because of the non-availability of Alnico 9 which had been selected as the magnet material. The re-design has been made using Alnico 6 as magnet material.

Final tests of the fixed mirror control system were made. This technique for fixed mirror adjustment has been abandoned because large voltages are required to obtain suitable mechanical displacements and because of high temperature coefficients of the crystal materials.

All of the bolometer detectors which have been repaired by Barnes Engineering were tested in the interferometer and the unit with best performance was selected for use on the next balloon flight.

A study of the sequencing and timing circuits which are used in the neon line reference channel was made to determine proper adjustments for use with the 0.7032 micron line which will be used in place of the 0.5852 micron line.

V Preparations for the Next Balloon Flight

A. Texas Instruments IRIS Instrument.

After a trip to Dallas in January to become familiar with the T. I. IRIS instrument, the mechanical appartus necessary for the balloon flight test of the IRIS instrument was designed and constructed.

The instrument will be operated in a manner similar to that in which the U. of M. IRIS instrument was flown in May 1966. It will be mounted on the bottom side of the main gondola platform on a cooling surface inside of a container insulated and shielded from the Sun's rays as necessary. A cold black body cooled to -60°C by liquid nitrogen will be mounted inside of the space-port of the instrument. A warm black body will slide back and forth over the earth port of the instrument container. Figure 9 shows the instrument cooling plate and container (shroud). Figure 10 shows these units assembled with earth port downward as it will be located on the balloon gondola. The warm and cold black bodies are shown in figures 11 and 12, respectively.

The instrument will be operated at a low temperature by initially freezing a suitable material in the cooling chamber. A search of the literature has uncovered three fluids which may be suitable for this purpose. These fluids and their freezing points are:

2, 4 - Pentanedione	-23.0°C.
benzoic acid butyl ester	-22.4°C.
methynapathalene	-22.0°C.

They are available from Eastman Kodak at a reasonable price. They will be studied further, and if suitable, will be tried in the cooling chamber.

Specifications were written for a 25 liter dewar flask to be used as a container for liquid nitrogen to cool the cold black body. Bids were received and a manufacturer selected, the Hofman-Paul Cryogenic Division. The internal heater assembly was fabricated and sent to the manufacturer for installation in the dewar.

Miscellaneous commercial electrical components for use with the T. I. IRIS were ordered.

Specifications for the electrical interface necessary for operation of the T. I. IRIS on the gondola were completed and design of this logic and command circuitry was begun.

B. U. of M. IRIS Instrument

The U. M. IRIS was installed on the gondola and initial system tests were run successfully.

The liquid nitrogen supply system for the U. M. IRIS was tested for total time of operation using the instruments cold black body with a simulated heat load. Five test runs were made, the maximum time of operation obtained was 17.5 hours.

C. The Filter Wedge Spectrometer

Conversations with Dr. Hovis indicated that the mechanical arrangement and electrical interface requirements for the F. W. instrument would be essentially the same as those used on the 8 May 1966 balloon flight.

A new frame for mounting the F. W. instrument on the gondola was constructed.

D. The MRIR Radiometer

The auxiliary mirror for obtaining sun calibration signals during the flight was constructed and assembled on the balloon gondola.

The MRIR instrument was also installed on the gondola and a preliminary test was run, using the new gondola programming unit.

E. Balloon Flight Planning and Systems Work

The new gondola programming unit was tested extensively to obtain experience with the unit and to provide an aging period before final testing. It was determined that the threshold detectors used to assure adequate rise time at the inputs to the timer and multiplexer were not operating properly at temperatures of 30^{o}C and above. They were replaced with new units which will operate properly at temperatures up to 55^{o}C.

Other electrical apparatus worked on include the Astrodata time code generator, the new H. P. 3955 tape recorder, the new battery charger for the silver-zinc batteries used on balloon flights, and the motor for the azimuth photocell scanner.

A trip was made to Holland, Michigan to observe testing of the new environmental test chamber. Tests were unsatisfactory due to a leak in a window seal.

Arrangements were made with H. J. Mastenbrook of NRL to make several flights of his frost point hygrometer on the day of our balloon flight to provide reliable water vapour distribution data to high altitudes. This data will be used for interpretation and analysis of the radiation data obtained on our balloon flight.

VI Laboratory Measurements of CO_2 Transmission

The work on laboratory measurements of CO_2 transmission has proceeded slowly. The Perkin-Elmer Model 13 spectrometer has been built into a dry box and has been adjusted to optimum working condition. However it appears that it will not be feasible to use this instrument for long path absorption measurements without a large expenditure of funds for special cells.

After some searching, Henry Reichle, who is doing his PhD thesis on these measurements has determined that he can borrow a pair of Perkin-Elmer 40 meter long path cells from Professor E. A. Boettner of the School of Public Health, and can also obtain the loan of a Perkin Elmer model 221 spectrophotometer from NASA Langley. It is expected that this equipment will arrive and be assembled during the next quarter.

VII Report Writing

This quarter has been singularly productive in reports published and papers presented.

A. Reports published:

1) Quarterly report 05863-13-P, High Altitude Radiation Measurements, 1 January, 1966 - 31 March, 1966. (This report is the first in a new format, departing from the letter type of report, containing more detailed technical information including illustrations, graphs and other graphic displays).

2) L. W. Chaney, Fundamentals of Fourier Transform Spectroscopy, The University of Michigan, Dept. of Aerospace Engineering, Technical Report No. 05863-10-T, February 1967.

3) F. L. Bartman, The Reflectance and Scattering of Solar Radiation by the Earth, The University of Michigan, Dept. of Aerospace Engineering, Technical Report No. 05863-11-T, February, 1967.

B. Papers Presented and Published

1) Chaney, L. W., S. R. Drayson, and C. Young, Fourier Transform Spectrometer Radiation Measurements and Temperature Inversion, Applied Optics, 6, No. 2, pp 347-349, February, 1967.

2) Bartman, F. L., Solar Reflection Patterns Measured by Radiometer on High Altitude Balloon Flights, presented at the American Meteorological Society Conference on Physical Processes in the Lower Atmosphere, March 20-22, 1967, Ann Arbor, Michigan.

3) Drayson, S. R. and Young, C., Determination of Meteorological Variables from Atmospheric Radiation Measurements, presented at the American Meteorological Society Conference on Physical Processes in the Lower Atmosphere, March 20-22, 1967, Ann Arbor, Michigan.

4) Chaney, L. W., The Measurement of the Earth's Thermal Radiation by a Fourier Transform Spectrometer, presented at the American Meteorological Society Conference on Physical Processes in the Lower Atmosphere. March 20-22, 1967, Ann Arbor, Michigan.

VIII Future Work

During the next quarter, the project effort will include:

1. Data analysis and theoretical investigations.
2. Interferometer development.
3. Balloon Flight preparations
4. Laboratory measurements of CO_2 transmission
5. Report writing

1. Sample of Interferometer Radiance Data

SPECTRAL RADIANCE IN ERGS/SEC CM STR

TIME --IN EASTERN STANDARD TIME-- MAY 8, 1966

WAVE NO	08 30	09 10	10 06	11 09	12 34	13 31	14 12	14 48	15 11
500	105.0	107.3	105.8	105.9	106.3	102.9	106.9	102.8	106.0
502	100.8	103.3	102.8	102.2	104.3	100.9	103.5	102.7	103.2
504	100.8	102.9	101.4	102.0	104.1	99.6	103.1	102.0	101.9
506	101.2	103.0	101.5	102.9	102.9	99.9	103.9	101.3	101.2
508	101.7	103.6	103.4	103.6	103.6	101.7	104.8	99.8	102.3
510	104.3	107.1	106.5	104.9	106.3	103.5	106.5	99.8	105.8
512	106.1	109.4	107.2	105.6	111.8	104.0	107.6	100.6	107.6
514	105.3	108.1	106.2	104.2	111.1	104.2	107.4	102.0	107.0
516	101.9	102.9	101.8	100.3	106.2	101.8	104.5	101.7	103.8
518	99.7	99.7	98.9	97.8	103.1	99.6	103.0	100.3	101.0
520	103.7	103.8	102.7	100.7	106.3	102.8	106.7	102.3	104.2
522	107.6	108.2	106.4	104.2	110.0	105.8	109.0	103.7	107.4
524	105.4	107.0	106.6	104.5	109.0	105.6	108.9	104.3	107.2
526	104.0	105.9	106.2	104.2	107.3	104.4	108.2	104.5	105.4
528	108.3	109.8	109.4	107.9	109.7	105.8	109.6	105.6	107.2
530	113.1	115.2	117.8	114.9	118.5	114.7	111.5	114.2	112.8
532	113.5	117.5	118.1	115.8	119.9	115.1	114.1	114.9	114.0
534	110.9	112.3	111.4	114.0	117.4	113.0	111.4	113.2	111.3
536	109.2	110.8	109.1	110.0	114.0	107.2	110.9	109.3	107.9
538	110.8	112.2	110.5	113.5	114.7	111.0	111.1	109.8	109.6
540	111.4	112.8	113.3	113.7	117.9	113.9	117.2	110.7	110.1
542	110.6	111.9	110.9	109.8	113.4	113.7	112.6	110.6	108.7
544	107.3	109.3	109.1	108.3	109.7	108.8	110.8	107.6	107.3
546	103.9	105.9	105.5	105.5	107.1	106.9	108.5	105.7	105.5
548	104.1	107.1	105.9	106.0	108.2	107.0	108.6	106.5	106.4
550	107.4	110.9	108.5	109.2	111.4	109.1	110.2	107.8	108.7
552	108.9	113.2	114.6	113.0	117.3	114.2	111.8	114.3	111.0
554	110.2	114.1	113.7	113.2	114.6	114.4	111.0	114.4	110.4
556	112.3	115.3	115.0	114.5	118.2	114.9	113.4	114.6	109.9
558	114.0	119.8	120.2	120.8	121.1	119.9	118.3	119.8	113.9
560	114.9	120.1	121.3	121.5	121.6	120.8	119.2	119.9	114.9
562	114.4	114.8	118.0	114.9	119.2	118.5	116.8	115.0	114.4
564	111.7	112.0	111.9	110.2	114.6	114.1	110.8	110.6	109.9
566	108.7	109.0	108.6	108.5	110.7	109.8	109.9	107.7	109.5
568	105.5	105.0	105.4	105.7	107.6	107.4	107.6	106.5	106.2
570	107.0	106.8	106.8	107.3	109.2	108.8	107.9	107.9	106.5
572	109.7	110.3	109.3	109.8	111.2	110.9	110.0	111.5	108.8
574	109.2	109.9	108.8	110.0	111.9	110.5	110.2	109.6	109.4
576	106.5	107.7	107.7	107.7	110.0	108.4	108.9	108.6	108.3
578	104.8	107.0	107.5	105.9	109.1	107.6	108.2	107.9	107.5
580	103.4	106.2	106.1	104.8	108.4	106.9	107.2	107.4	106.2
582	103.0	105.7	104.7	104.9	108.1	106.3	106.2	107.4	105.6
584	104.5	106.6	105.8	106.0	108.4	107.0	106.1	108.0	105.8
586	104.8	105.8	105.9	105.8	107.0	107.1	104.4	106.7	104.7
588	100.6	101.5	100.8	101.3	101.8	102.1	99.8	102.0	100.6
590	95.2	96.8	95.9	95.4	96.3	96.5	95.9	97.2	96.1
592	93.7	95.1	95.2	93.5	95.1	95.3	95.2	95.6	95.1
594	93.7	93.9	95.1	93.4	95.4	94.6	94.5	95.0	94.5
596	92.0	91.9	93.2	92.5	94.7	92.5	92.6	93.3	92.9
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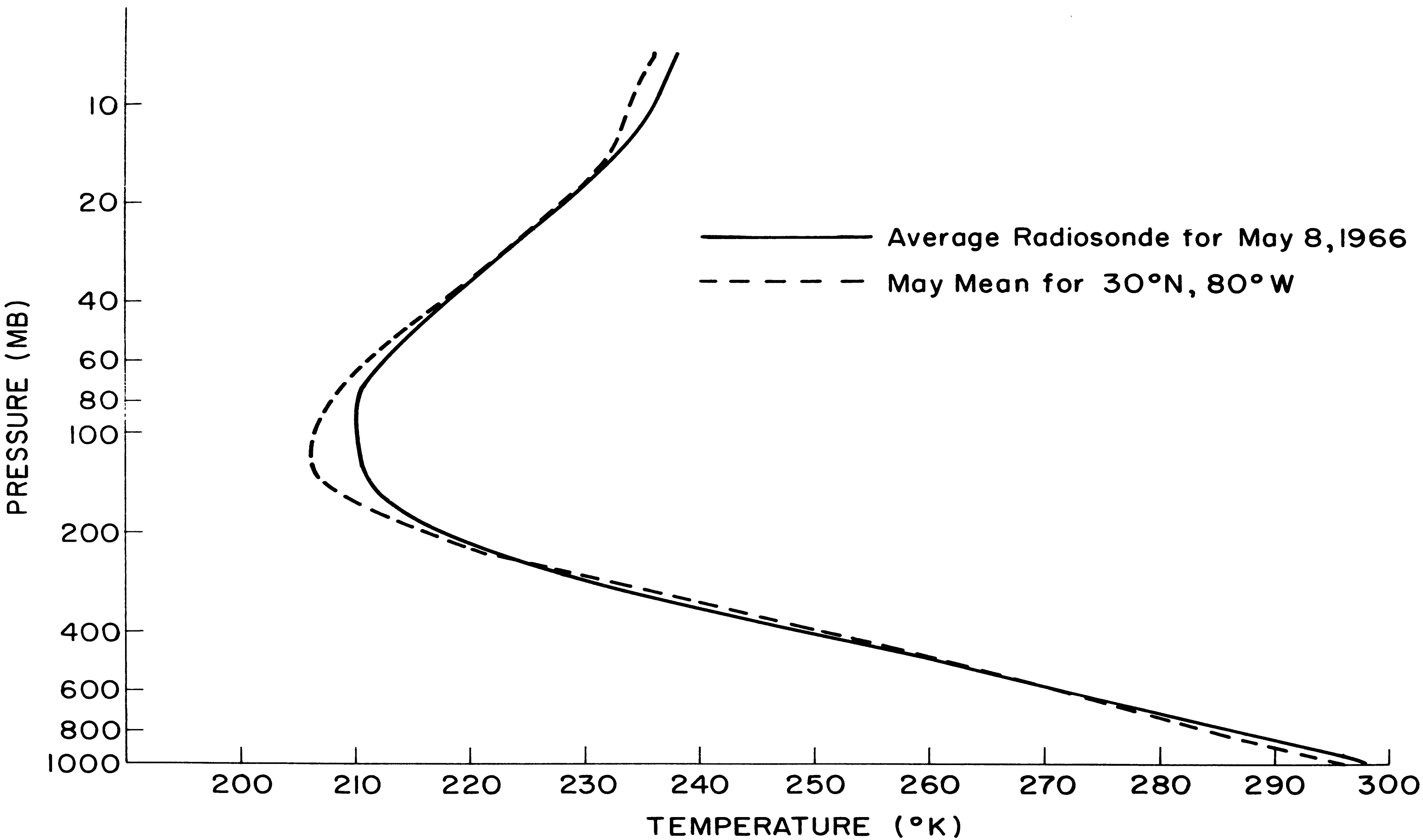
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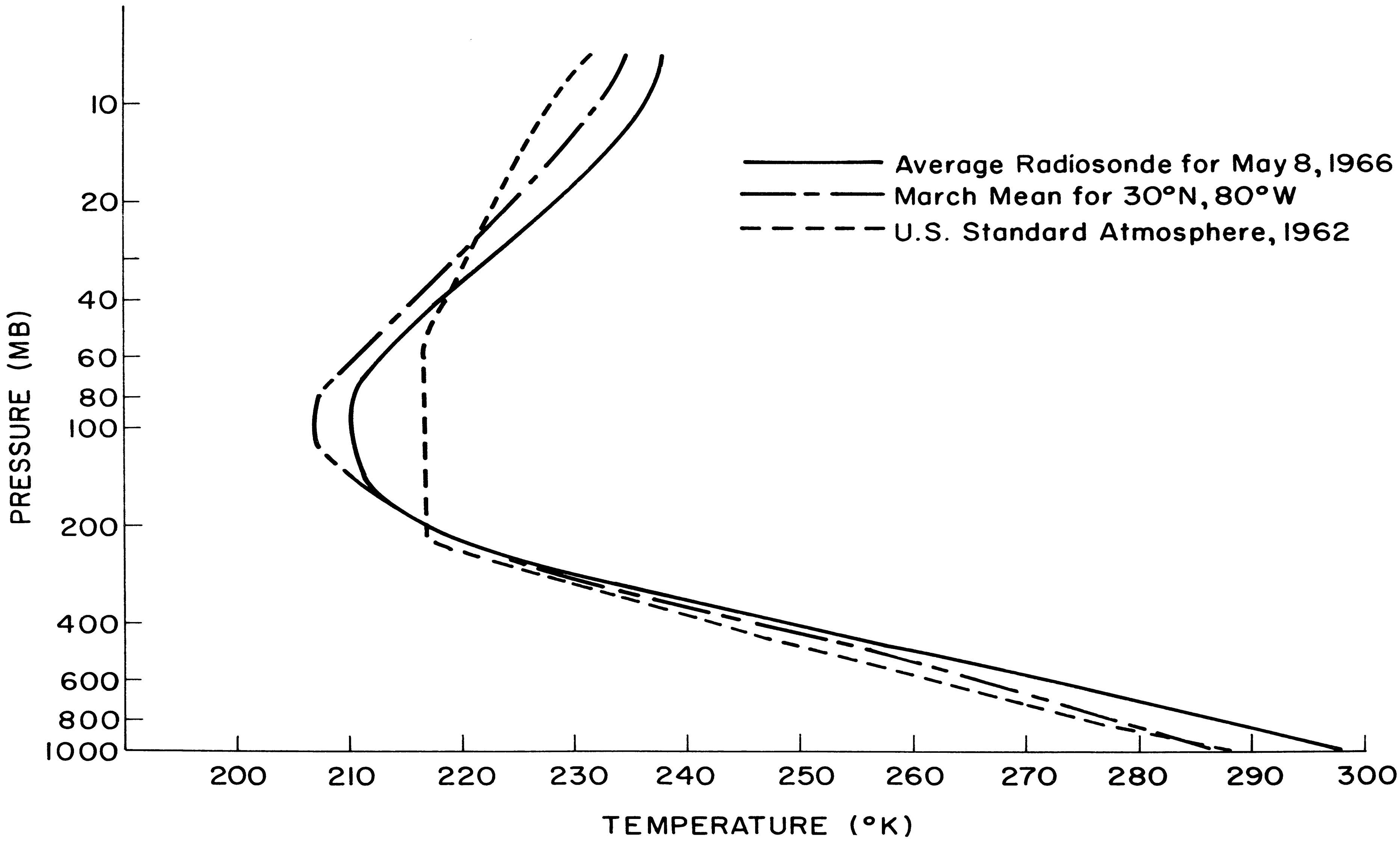
TEMPERATURE (°K)
Average Radiosonde for May 8, 1966
May Mean for 30°N, 80°W

Figure 1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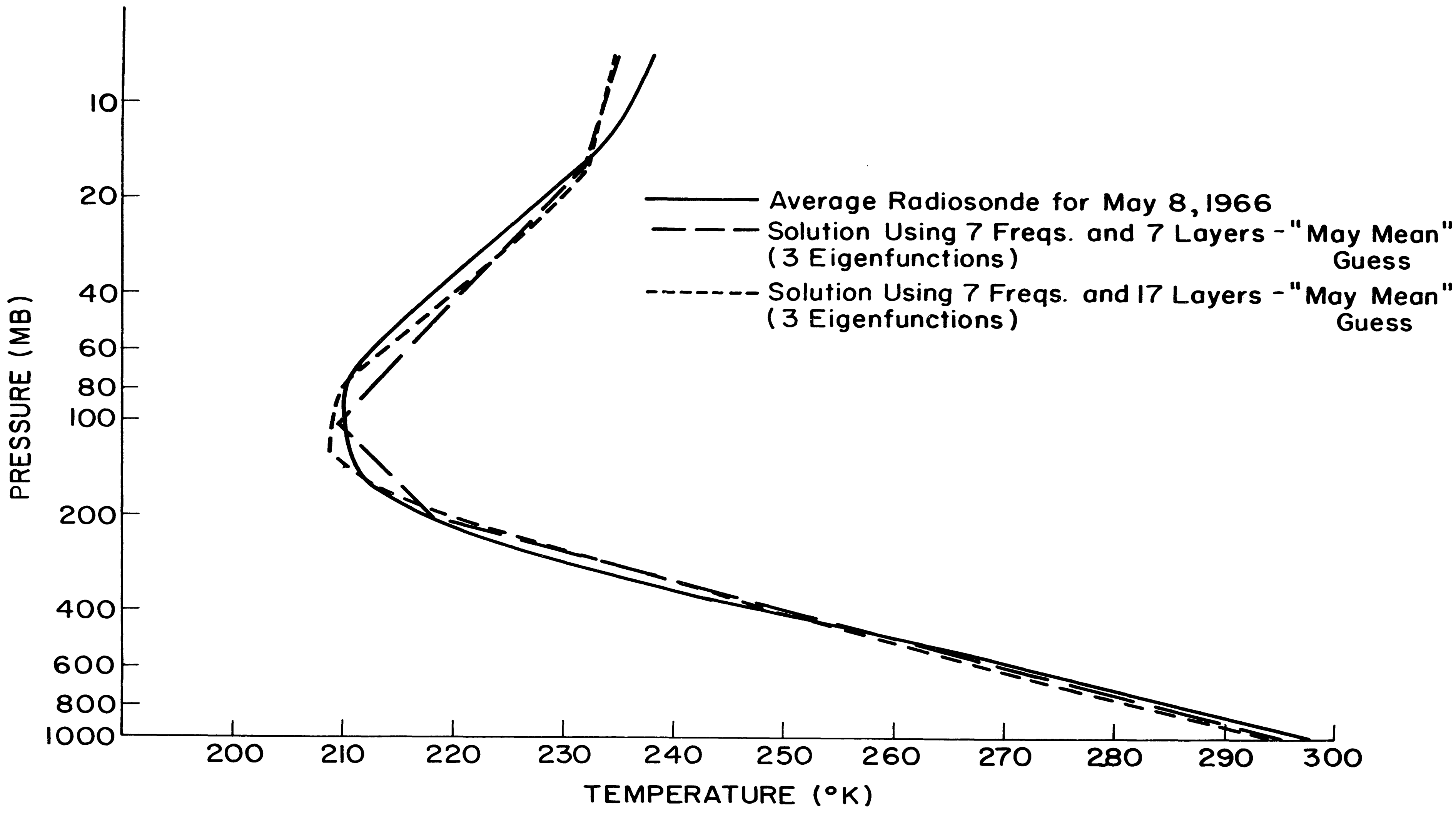
TEMPERATURE (°K)
Average Radiosonde for May 8, 1966
March Mean for 30°N, 80°W
U.S. Standard Atmosphere, 1962

Figure 2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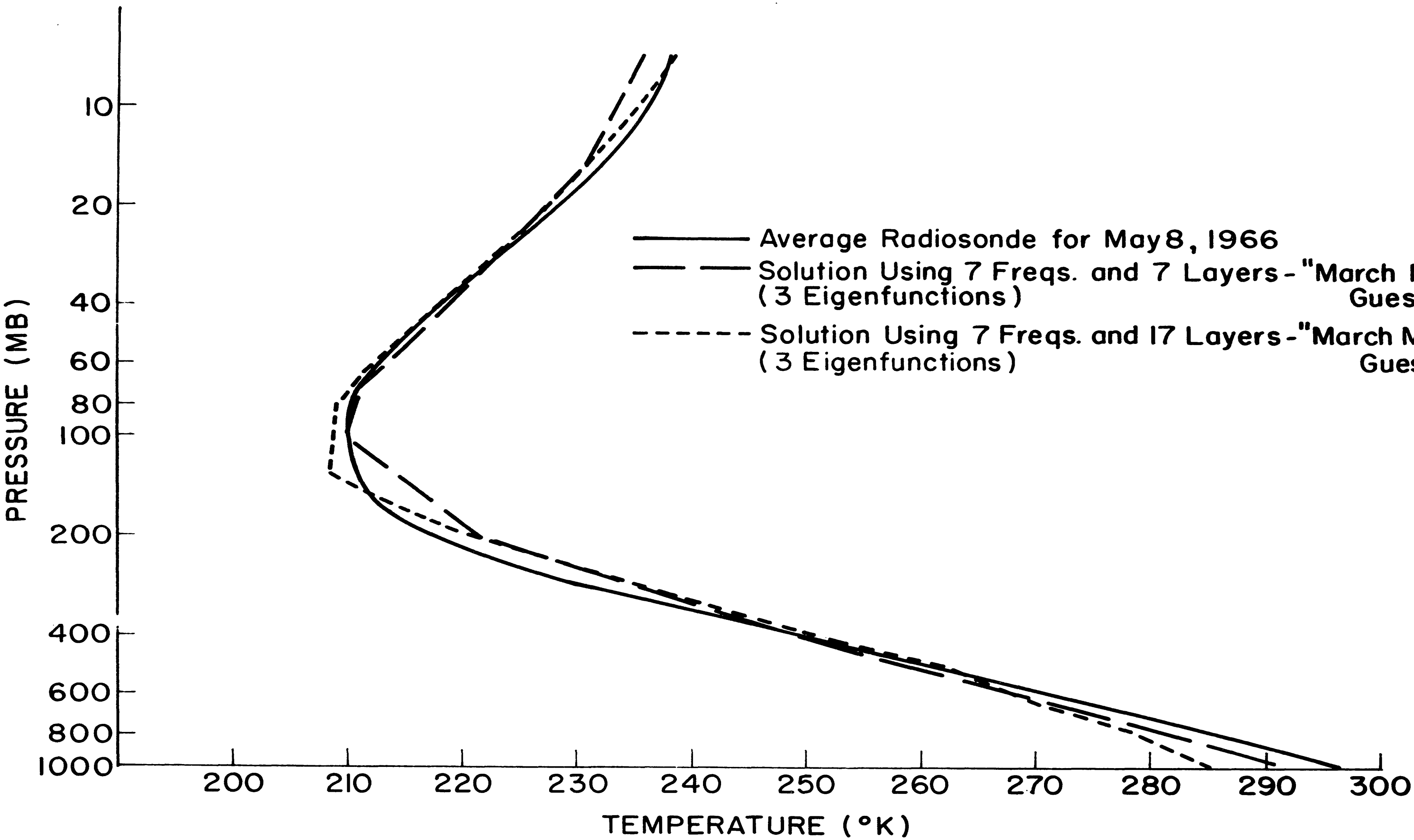
TEMPERATURE (°K)
Average Radiosonde for May 8, 1966
Solution Using 7 Freqs. and 7 Layers - "May Mean" Guess (3 Eigenfunctions)
Solution Using 7 Freqs. and 17 Layers - "May Mean" Guess (3 Eigenfunctions)

Figure 3



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PRESSURE (MB)
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TEMPERATURE (°K)
Average Radiosonde for May 8, 1966
Solution Using 7 Freqs. and 7 Layers - "March Mean" Guess (3 Eigenfunctions)
Solution Using 7 Freqs. and 17 Layers - "March Mean" Guess (3 Eigenfunctions)

Figure 4

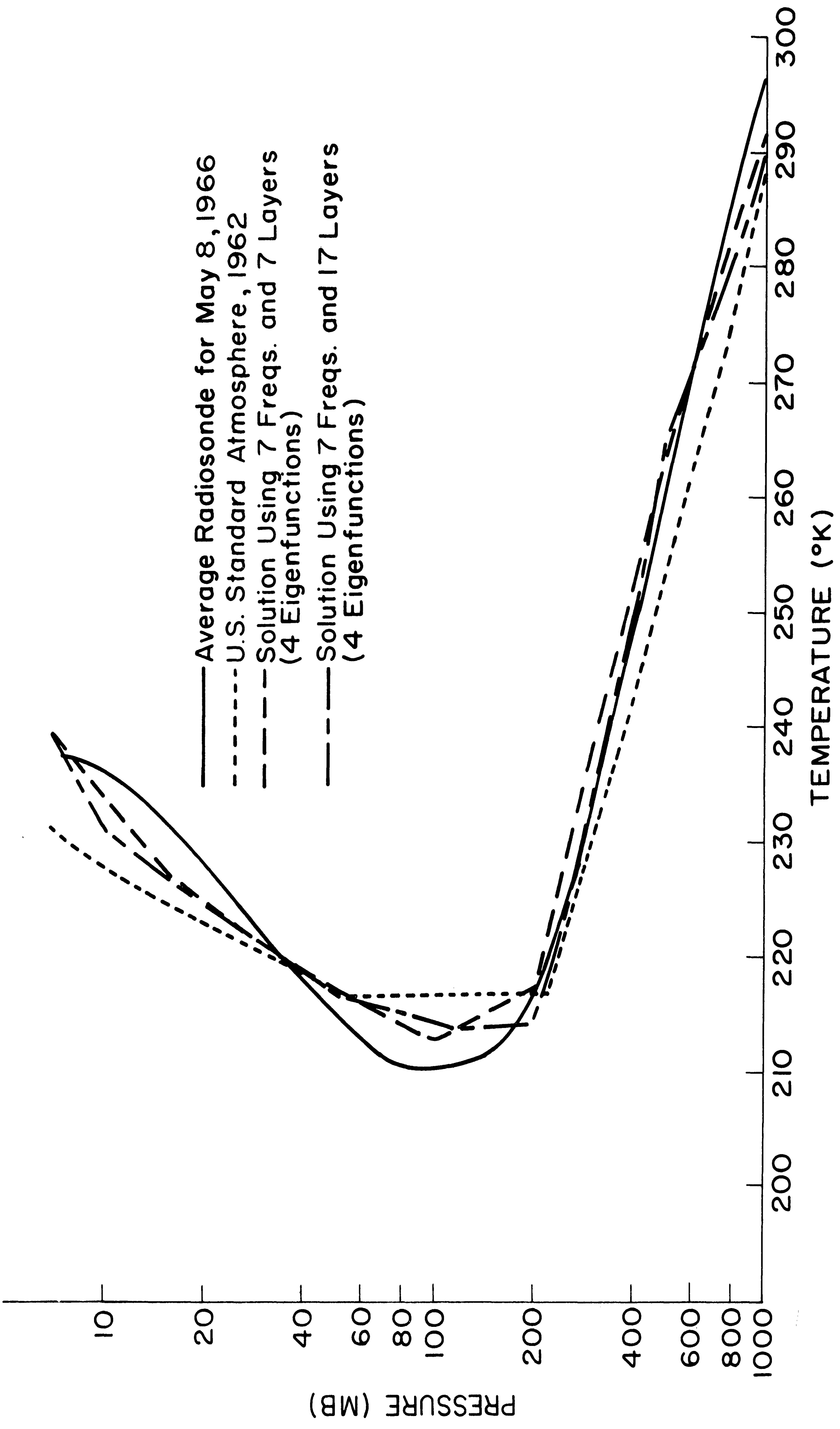
Average Radiosonde for May 8, 1966
U.S. Standard Atmosphere, 1962
Solution Using 7 Freqs. and 7 Layers (4 Eigenfunctions)
Solution Using 7 Freqs. and 17 Layers (4 Eigenfunctions)
TEMPERATURE (°K)
PRESSURE (MB)
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Figure 6

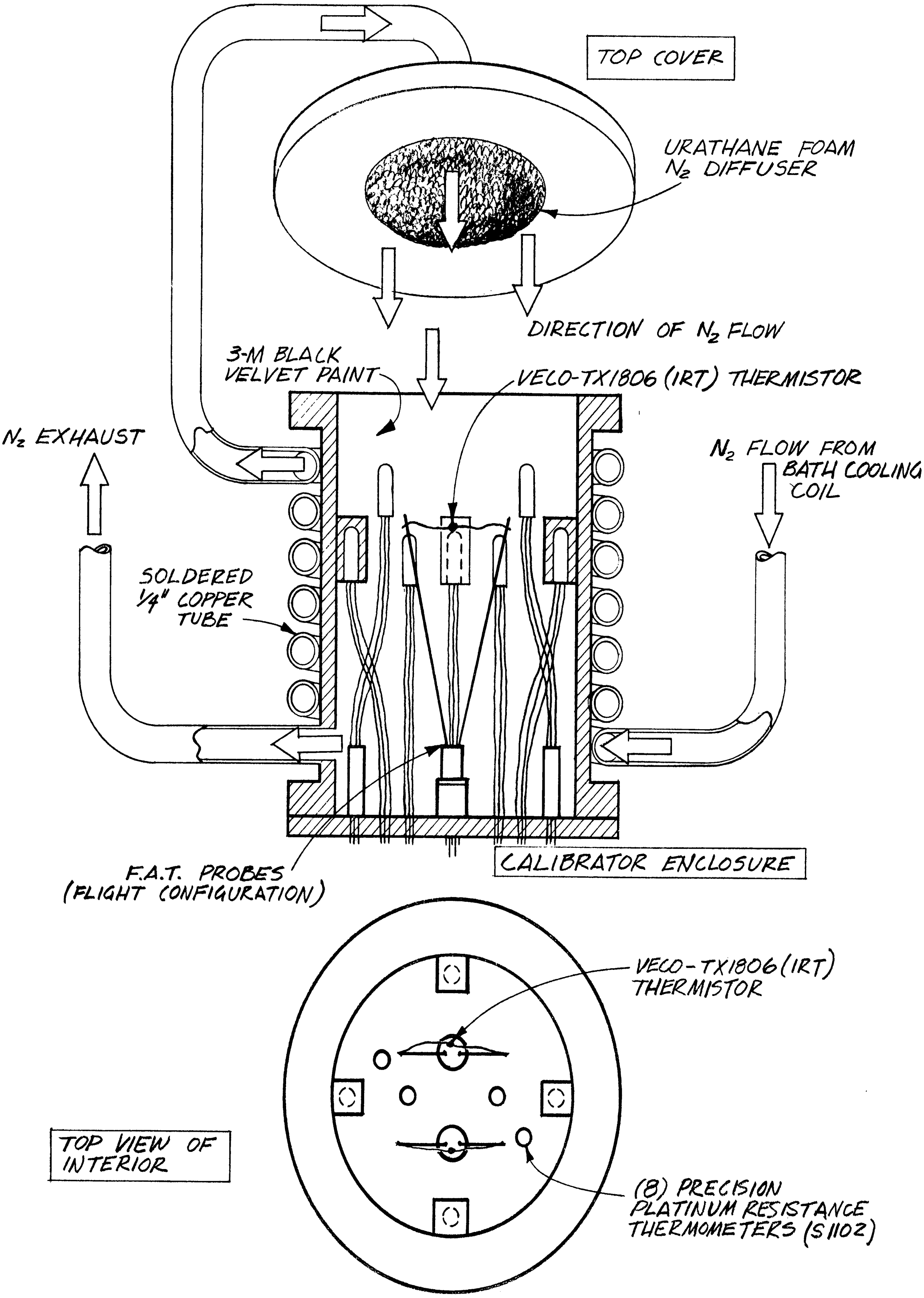

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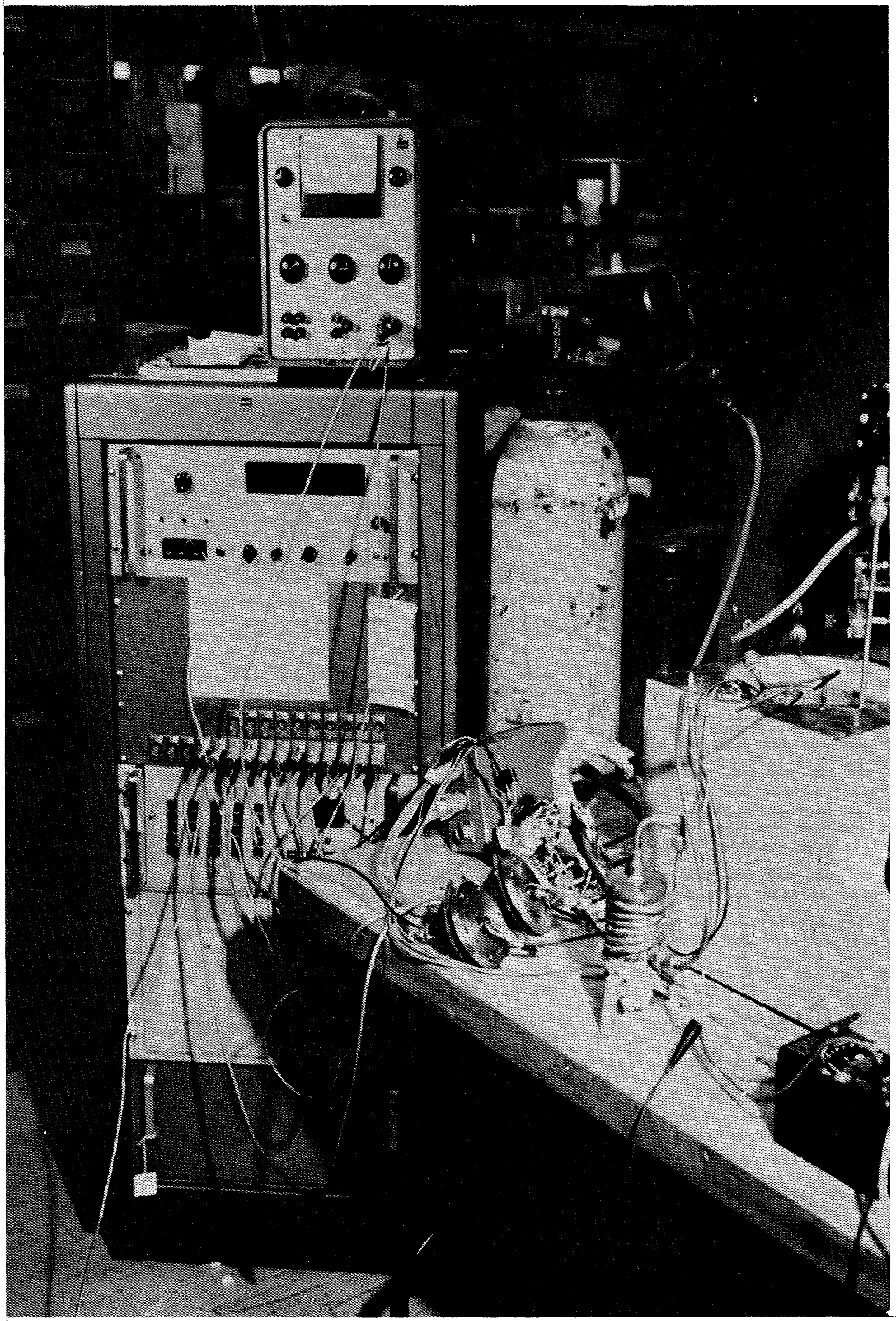
Figure 7



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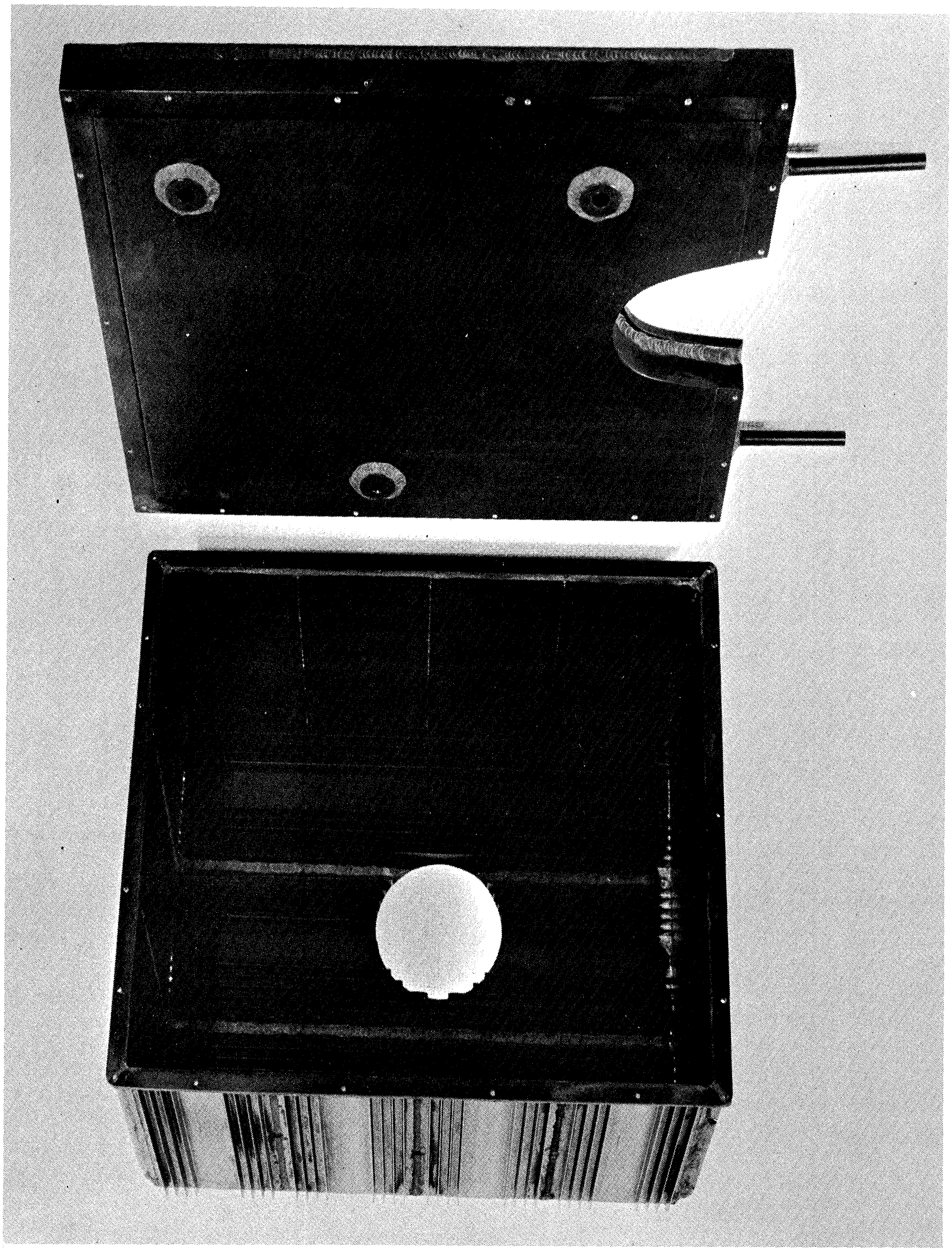

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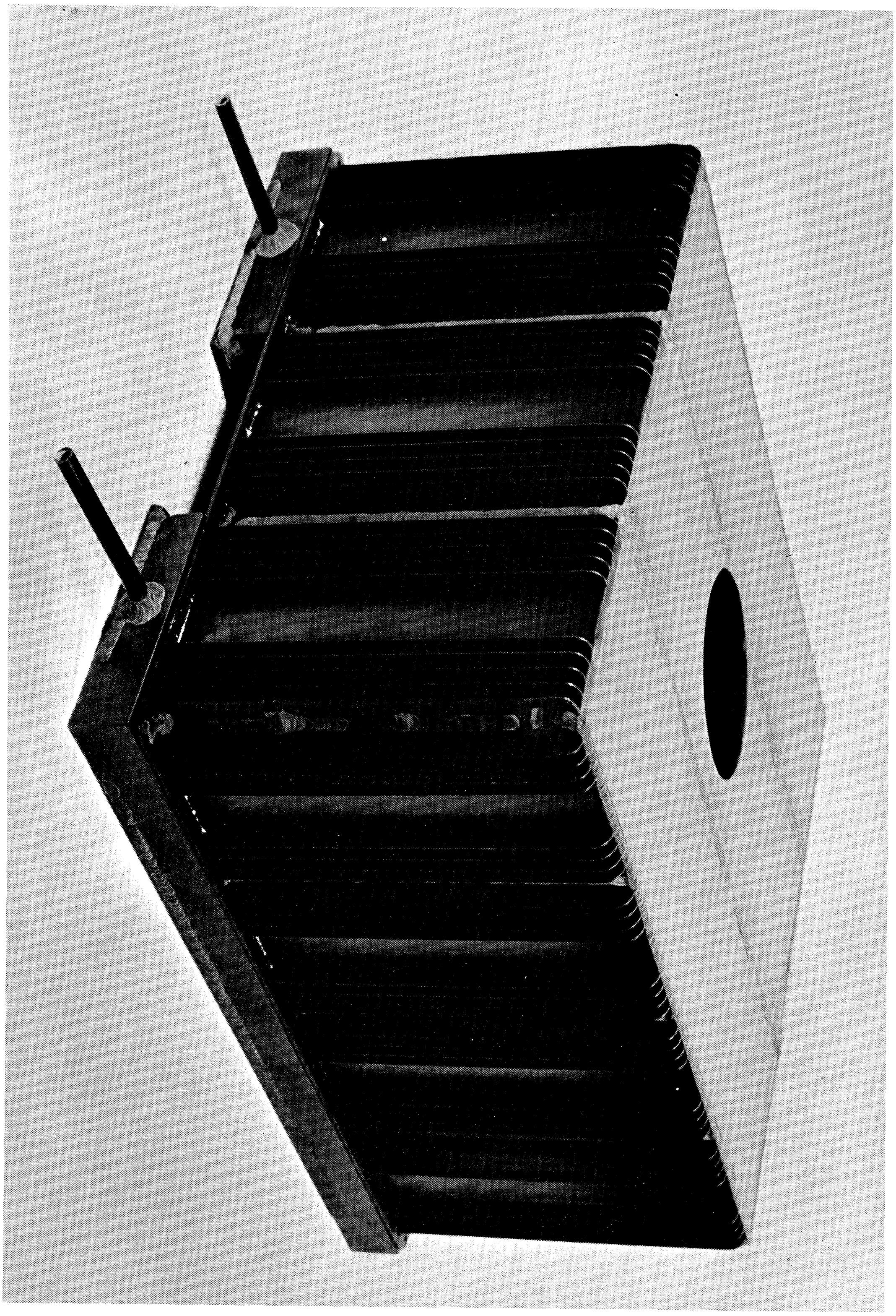

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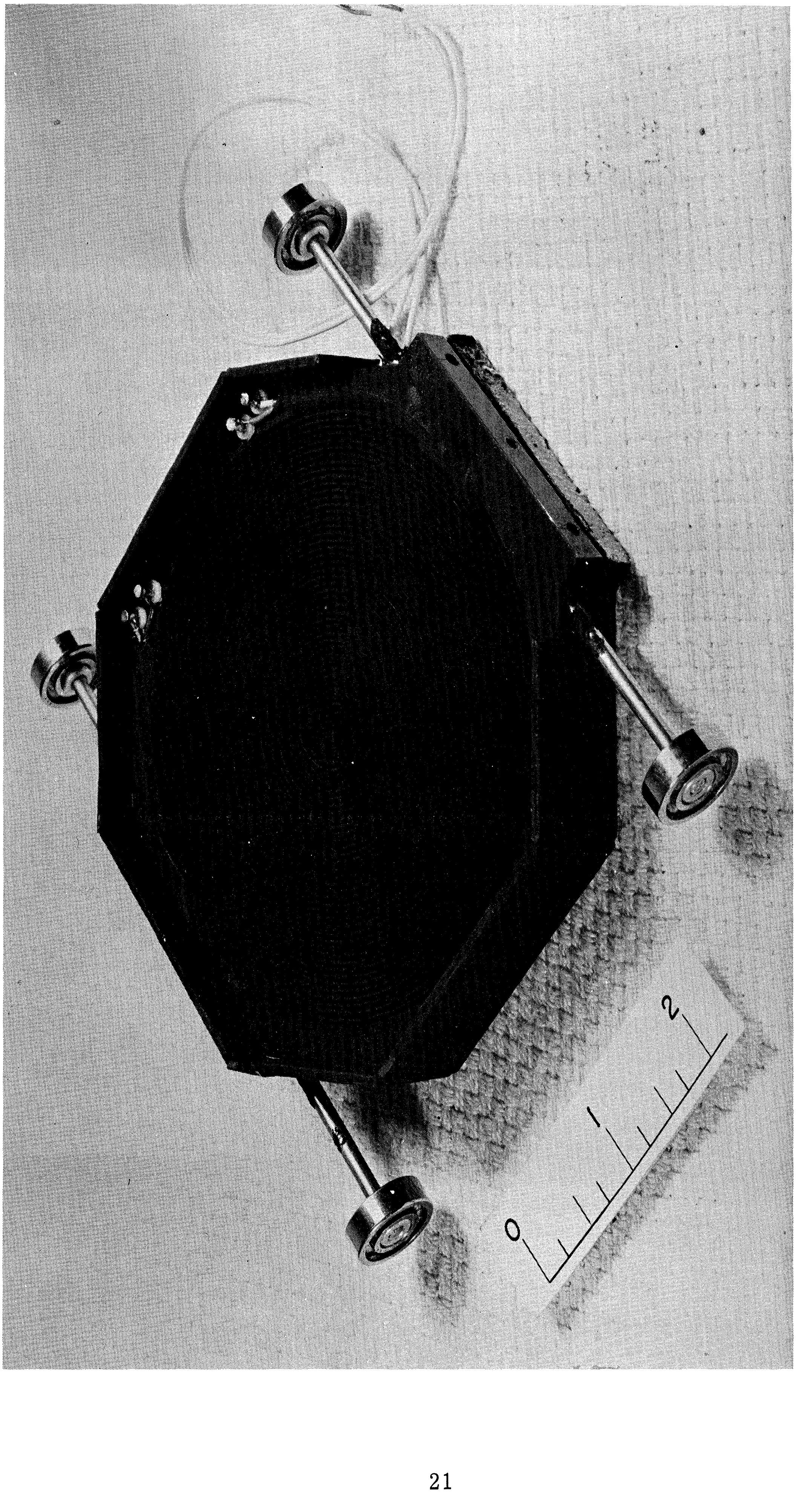

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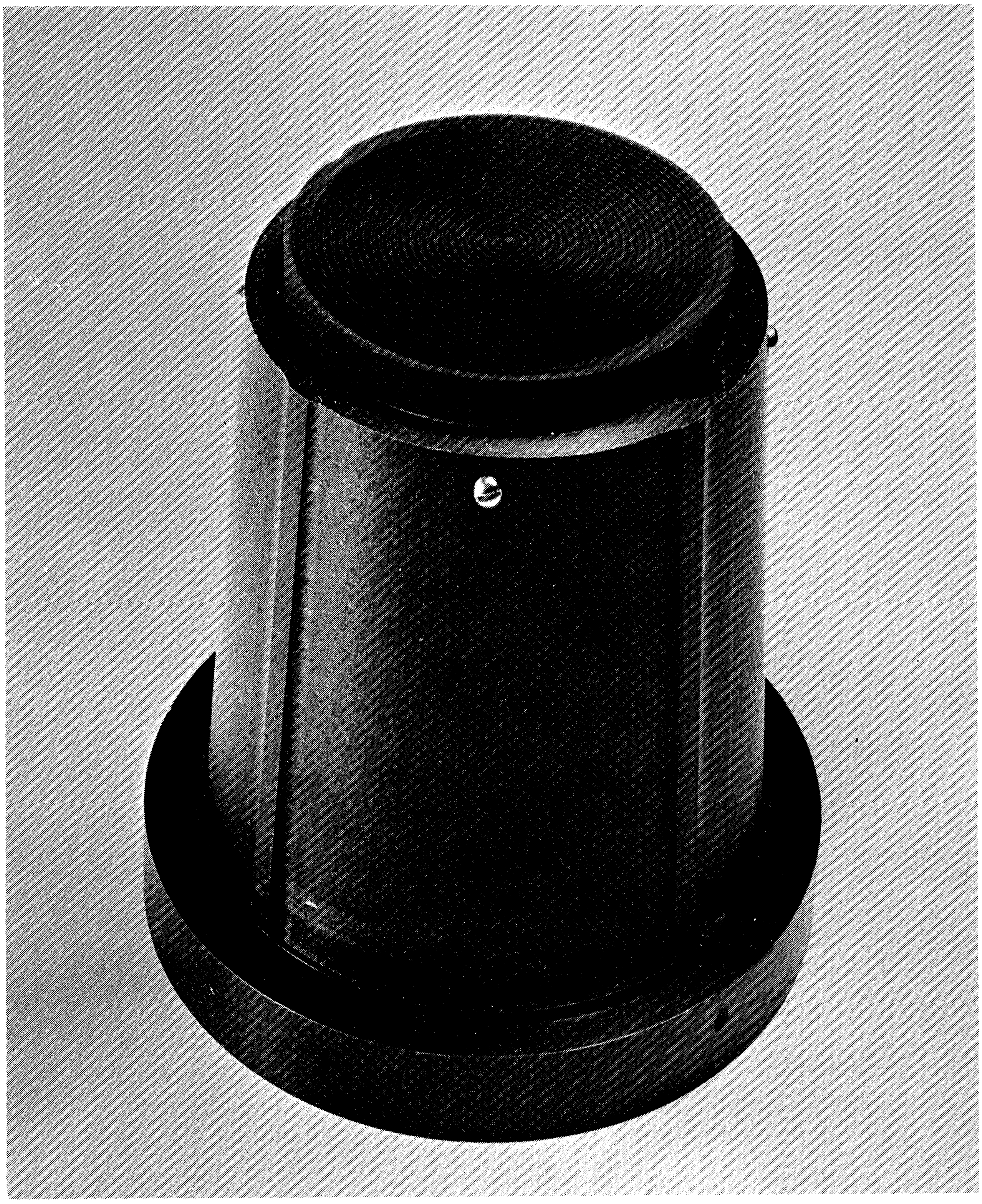

Figure 12