NASA TECHNICAL MEMORANDUM

NASA TM X-53186

DECEMBER 22, 1964

N65 16927
(ACCESSION NUMBER)
27
(PAGES)
TMX-53186
(NASA CR OR TMX OR AD NUMBER)
1
(THRU)
08
(CODE)
(CATEGORY)

NASA TM X-53186

RADIOSONDE AUTOMATIC DATA PROCESSING SYSTEM

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NASA

George C. Marshall Space Flight Center, Huntsville, Alabama

GPO PRICE $ ______

OTS PRICE(S) $ ______

Hard copy (HC) $2.00

Microfiche (MF) $0.50

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Huntsville, Alabama

ABSTRACT

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This report describes an operational Automatic Radiosonde Data Processing System developed for use with the AN/GMD-2 Rawin Set. The method of reliably identifying the time-shared temperature, humidity and reference frequency information from a modified AN/AMQ-9 Radiosonde is described.

This report shows that automatic reduction of radiosonde data by the described method possesses operational capabilities as demonstrated by more than 300 balloon-borne meteorological soundings from September, 1963 to November 1964.

Author

*Richard A. Jendrek is associated with the Bendix Corporation, working under contract No. NAS8-5246.

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ATMOSPHERIC MEASURING GROUP
AERO-ASTROPHYSICS OFFICE
AERO-ASTRODYNAMICS LABORATORY

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RADIOSONDE AUTOMATIC DATA PROCESSING SYSTEM

SUMMARY

This report describes an operational Automatic Radiosonde Data Processing System developed for use with the AN/GMD-2 Rawin Set. The method of reliably identifying the time-shared temperature, humidity and reference frequency information from a modified AN/AMQ-9 Radiosonde is described.

The report shows that automatic reduction of radiosonde data by the described method possesses operational capabilities as demonstrated by more than 300 balloon-borne meteorological soundings from September, 1963 to November 1964.

I. INTRODUCTION

Rawin Set AN/GMD-1, developed by the U. S. Army Signal Corps, has been in operational field use by various meteorological activities since 1950. This equipment has proved very reliable in tracking the AN/AMT-4 and other 1680 mc radiosondes which use pressure transducers and provides an accurate means for direct altitude computation.

The Control Recorder units of both the AN/GMD-1 and the AN/GMD-2 Rawin Sets provide manual remote control of the tracking antenna and tuning of the 1680 mc receiver as well as power distribution. Both Control Recorders will periodically print the numerical values of the azimuth and elevation angles and elapsed time from release. The AN/GMD-2 Control Recorder will print the slant range and computed altitude values simultaneously with the time and tracking angles. Both Rawin Sets normally employ the AN/TMQ-5 Radiosonde Recorder to trace the temperature, humidity, and reference signals with a pen on a continuous strip chart.

The separate tracking and meteorological data thus recorded must be manually transferred from the charts point-by-point and correlated with elapsed time for computing and developing the desired upper air profiles. In an effort to eliminate the requirement for an operator to perform this task, a number of schemes for automatic and semi-automatic processing of radiosonde data have been devised with varying degrees of success.

The system described herein was supplied by the Bendix Friez Instrument Division for the National Aeronautics and Space Administration's Atmospheric Research Facility at Marshall Space Flight Center, Huntsville, Alabama. The complete system was designed and constructed within six months and was delivered to MSFC for installation in September 1963.

II. DESCRIPTION OF SYSTEM

A. Data Processor

The Bendix Friez Model 1146450 Radiosonde Automatic Data Processor is shown in Figure 1. All ADP component chassis are constructed for installation in standard 19-inch relay racks. The total mounting height required is 95 inches. To minimize engineering design effort a number of functional units used in the system were procured as "off-the-shelf" items with only minor modifications required in some cases to provide system interface. The remaining units which include the tracking data Digitizer, the Converter-Detector, and the Control-Decommutator were wholly designed and fabricated at Bendix Friez. The latter two units contain the logic and control circuits essential for automation of the meteorological data transmitted by the radiosonde. The Data Processor automatically commands an IBM 526 printing summary punch to punch cards at 5- or 10-second intervals as desired. A typical card is shown in Figure 4 .

B. Radiosonde Changes

A special commutator was designed for installation in the transponder sondes (AN/AMQ-9) used with this system. The new commutator, shown in Figure 3, differs from the one it replaces principally by the nominal 1/2 second reference segments preceding each temperature and humidity segment. These short reference segments are used to identify a change from one sensor to the next in the radiosonde measuring circuit. As a consequence of adding the 1/2 second identifiers, it was necessary to reduce the nominal duration of the remaining temperature, humidity, and reference segments from 4.5 seconds to 3.9 seconds.

The slant range is measured and punched out in meters, requiring a change in the ranging modulation frequency from 81,940 cycles per second to 74,950 cycles per second. The tuned amplifier in the AN/AMQ-9 radiosonde was returned to the lower frequency after the special commutator was installed.

C. Rawin Set Modifications

The data processor was designed to operate with either of two AN/GMD-1B Rawin sets upgraded to contain the ranging measurement capability of the AN/GMD-2. The ranging modification consisted of reworking two pairs of transmitter and comparator to measure in meters and installing them on the two pedestals. A high pass filter and the transmitting antenna were installed on the spinner pylon, and the pedestal swing links were turned to the GMD-2 position. The GMD-1 Control Recorders were modified to be compatible with the converted pedestals. This required a plus and minus 27 volts direct current supply for receiving tuning, a new Receiver Tune switch, and some rewiring. The printout, the visual indication, and the monitoring of slant range data are handled by the data processor.

III. THEORY OF OPERATION

A. Decommutation Method

1. Commutator Tracking

The approach to automatically recognizing and keeping in step with the alternations between temperature, humidity and reference frequency from an AN/AMQ-9 radiosonde was chosen as a result of assuming that signal fading conditions would exist during at least part of the radiosonde flight. The standard AN/AMQ-9 Radiosonde Set transmits a repeating pattern of:

reference	4.5 seconds
space	.5 seconds
temperature	4.5 seconds
space	.5 seconds
humidity	4.5 seconds
space	.5 seconds
temperature	4.5 seconds
space	.5 seconds.

The reference frequency is 190 $\pm$ 20 pulses per second and the temperature and humidity frequencies are always below the actual reference frequency by at least 15 pulses per second. Notice that "frequency" and "pulse per second" are interchangeable. Recognition of the reference frequency is simply finding the highest frequency of the three. Upon detecting the reference frequency, a delay of 5, 10, and 15 seconds will locate the temperature, humidity, and the temperature frequency transmission periods, respectively. However, if a signal dropout occurs during the reference frequency transmission, a 20-second block of data is lost. A method of determining when a change is being made from one frequency to the next was therefore adopted.

First, this identification could not be the normal 0.5 second space (of zero frequency) between data frequencies since a signal dropout would produce zero frequency. Second, a circuit to detect a change in frequency could not be used since the temperature and humidity frequencies are often equal at some time during the flight. This method is further plagued by atmospheric noise and signal dropouts which would look like a change in frequency. The commutator in the radiosonde was therefore replaced with a new commutator having 0.65-second reference identifiers between the various data frequencies. In case a signal dropout occurs during a reference identifier, an "auxiliary advance" circuit in the data processor will advance the decommutator one step. It will not command a measurement of data since the previous data are probably closer to the proper value than a data transmission disturbed by a partial signal dropout.

The new commutator pattern is listed in Table 1 below.

TABLE 1. COMMUTATOR PATTERN

Transmitted Data	Transmission Duration
Reference (190 pps)	3.9 sec
Temperature	3.9 sec
Reference Identifier	0.65 sec
Humidity	3.9 sec
Reference Identifier	0.65 sec
Temperature	3.9 sec
Reference Identifier	0.65 sec
Humidity	3.9 sec
Reference Identifier	0.65 sec
Temperature	3.9 sec

NOTE: Each data transmission listed in Table 1 is separated by approximately a 0.4-second space.

2. Recognition of Reference Frequency

The primary difficulty in recognizing the reference frequency is the spread of 40 pulses per second allowed by the specification and the fact that zero humidity can produce a pulse rate just 15 pulses per second below the actual reference frequency. To attempt to recognize reference as any frequency above 170 pulses per second would erroneously detect a zero percent humidity frequency (175 pps) of a radiosonde having a reference frequency of 190 pulses per second. To eliminate this difficulty, the automatic data processor stores and updates the reference frequency continuously during the flight. The reference frequency can then be automatically detected as that frequency within 10 cycles per second of the stored reference. This scheme will be workable for all normal shifts in the radiosonde blocking oscillator.

B. Meteorological Data Handling

1. Method of Measurement

The measurement of the temperature and humidity data is made in the voltage realm with 0.905 volts corresponding to 190 cycles per second. A typical meteorological signal plotted with time as the horizontal axis is shown in Figure 4. The linear conversion to voltage is accomplished in the Converter-Detector unit. Referring to the block diagram in Figure 5, the output of the frequency to DC voltage converter is connected to the "signal loss detector," the "reference detector," and the A to D Converter. The A to D Converter is a digital voltmeter-ratiometer with front panel decimal display. This unit measures the reference frequency (voltage), the temperature ratio, and the humidity ratio. The "signal loss detector" will actuate if the frequency falls below 10 cps (0.047 VDC) for more than one half second. The "reference detector" will actuate if the incoming frequency is within 10 cps of the stored reference frequency. The measurement and storage of meteorological data are linked with the decommutation method as described below.

2. Decommutation Logic

The tracking of the radiosonde commutator is accomplished by a stepping switch. Each time the "reference detector" is actuated, the stepping switch is advanced. The stepping switch "home" position corresponds to the reference segment of the commutator with the remaining five positions corresponding to the temperature and humidity segments. The stepping switch therefore keeps in synchronism with the radiosonde commutator. When the "reference detector" is actuated longer than 1.5 second (as it is during the 3.9 second reference frequency transmission) the stepping switch will "home" unless it is already in the "home" position. A word description of the sequence of events, starting with the reference frequency, will show the signal flow through the simplified block diagram of Figure 5. The reference detector actuates for 3.9 seconds and immediately advances the stepping switch to "home" from the last temperature position. After 1.5 seconds, the "home detector" generates a home command which will reestablish synchronism if the stepping switch had fallen out of step. After 2.2 seconds total delay, a measure command is sent to the A to D Converter. The mode command of the A to D Converter is connected through the stepping switch to the VOLTS mode. The DC input (reference frequency) is measured; the decimal output is converted to binary coded decimal (BCD), and appears at the BCD-to-Analog Converter input. Within 0.33 second after the A to D Converter receives its measure command, it generates an end-of-measure command which goes through the "signal loss detector," the stepping switch, the "reference quality" circuit, and the "reference detector." The command then causes the BCD-to-Analog Converter to store the data appearing at its input. The "reference quality" circuit will inhibit storage of the reference frequency if it is more than 5 cps below the previously stored reference. This guards against storing the reference frequency during even a slight signal dropout.

Figure 5 shows that there is no reference identifier preceding or following the reference data transmission. The stepping switch advances to the first temperature position after 3.2 seconds total delay (by means of a circuit not shown on the simplified block diagram). At 2.2 seconds later than the advance of the stepping switch, a measure command is sent to the A to D Converter to measure the incoming temperature frequency (voltage). Now the A to D Converter mode command is switched to "ratio" to measure the DC input as a ratio of the reference voltage from the BCD to analog converter. Within 0.33 second after the A to D Converter receives its measure command it generates an end of measure command which goes through the "signal loss detector," and the stepping switch to the Temperature and Humidity Translator Storage. The command causes the output of the A to D Converter to be stored in the temperature section of the Temperature and Humidity Translator Storage.

The stepping switch is advanced to the next, or humidity, position when the first reference identifier shown in Figure 5 actuates the "reference detector." At 2.2 seconds after the stepping switch is advanced a measure command is sent to the A to D Converter. This time the store command appears on the "store H" line of the Temperature and Humidity Translator Storage unit. The stepping switch is advanced each time a reference identifier is received until the long reference frequency is received when the entire sequence described above is repeated.

In case one reference identifier is not received due to a signal dropout the Control-Decommutator contains an "auxiliary advance" circuit which will advance the stepping switch. No measure command will be generated since the "reference detector" will not have actuated. Synchronization of the stepping switch with the radiosonde commutator is maintained, and the temperature or humidity information punched out on the IBM card is the previously stored data.

C. Tracking Data Handling

The azimuth, elevation, and slant range data from the pedestal are in the form of synchro-signals. By means of a selector switch on the Control Decommutator front panel, the operator switches to the desired pedestal and control recorder. Reed relays within the GMD Junction box connect the Data Processor to the synchro-signals. In the Digitizer, the synchro signals position digital encoders and front panel indicators by means of servo-motor drives. The digital outputs are stored in their respective Translator Storage units on command from the Timer. Azimuth, elevation, and slant range data are stored simultaneously to be punched out on the card identified with the proper elapsed time.

IV. RAWIN SET OPERATION

A. Controls and Indicators

The C-577 Control Recorder contains all the control and monitoring functions required for the Rawin Set except for the indication of ranging signal strength and a slant range printout. The range monitoring meters were therefore mounted on the Control-Decommutator front panel and the slant range printout is provided by a digital printer (unit 14 in Figure 6).

B. Important Aspects of Rawin Set Performance

The primary difference between operating a Rawin Set as a GMD-1 and a GMD-2 is that, for good results in the GMD-2 mode, all parts of the Rawin Set must be operating at or very near peak performance. The GMD-1 made with an AN/AMT-4 radiosonde requires only the tracking and reception of a 1680 megacycle signal with an amplitude modulated meteorological pulse. The GMD-2 mode with an AN/AMQ-9 radiosonde is more complex. The received signal is frequency-modulated with the meteorological pulse and a 75 kc sine wave ranging signal. In addition, in the GMD-2 mode, a 403 mc signal with 75 kc ranging modulation is transmitted to the radiosonde.

1. Receiver Adjustments

The frequency modulated signal from the radiosonde has a frequency deviation which is nearly equal to the 600 kc minimum discriminator bandwidth. It is therefore important to maintain accurate automatic frequency control - more so than with the AM signal from an AN/AMT-4. The IF strips were aligned at Bendix Friez with a sweep generator and an oscilloscope to ensure proper discriminator alignment. After the receiver is aligned with a properly tuned IF strip, a partial loss of the incoming 1680 mc signal will not cause the receiver tuning to drift. The ranging and meteorological signals are then smooth and undisturbed during partial signal loss.

2. Antenna Control Performance

Tracking accuracy and freedom from antenna hunting also improve the ability to obtain clean meteorological and ranging data. When the received signal strength varies because of the swinging of the radiosonde, the antenna should not change position or the meteorological and ranging data will be disturbed. Careful phasing and Antenna Control trimming ensure positive and smooth tracking of the AN/AMQ-9 radiosonde.

The thyratrons in the Antenna Control units were replaced with solid state SCR Switching Units, Friez Part No. 1142256. These units eliminate the need to be replacing thyratrons and then readjusting the Antenna Control after installing new thyratrons. The greatly lengthened MTBF (mean time between failures) of the Antenna Control Unit increases the reliability of the sounding operation.

C. Raw Data Fallback Capabilities

Complete backup data are available for:

1. Checking the accuracy of the Automatic Data Processor punched card output either during a sounding or at any desired time.

2. Manual data handling in case of a malfunction at a critical time.

The ADP system is designed to give the operator the ability to observe the output in printed form on the IBM cards, to observe the meteorological data on the A to D Converter, and to observe the azimuth, elevation and slant range data. The printed card can be compared with AN/TMQ-5 record to ensure that the meteorological data are being processed properly. In the event that the IBM 526 printing summary punch would hang up due to a damaged card or some other reason, the raw data will be available from three paper records. The azimuth and elevation angles are printed (with time) by the C-577 Control Recorder. The slant range and elapsed time are printed by the Auxiliary Slant Range Printer, and the meteorological data are recorded by the AN/TMQ-5 Meteorological Recorder.

V. TEST PROGRAM

The ADP system was shipped from Bendix Friez to MSFC early in September 1963, for installation at the MSFC Atmospheric Research Facility. A criterion for acceptance of the system by NASA was the completion of ten perfect radiosonde flights. A further requirement was the launching of both the AN/AMQ-9 radiosonde and the AN/AMT-4 radiosonde on the same balloon to correlate the atmosphere data received simultaneously from both systems. The AN/AMT-4 was tracked with the GMD-1B Rawin Set in the normal manual mode and the AN/AMQ-9 was tracked with the modified AN/GMD-1B Rawin Set in the automatic mode.

The installation and preliminary flight tests were completed by September 24, and the first official acceptance flight tests were started. During October the ten acceptance flights were completed, and the system was placed in full operation.

During these tests, the raw atmospheric parameters were plotted from the AN/AMT-4 and AN/AMQ-9 Radiosondes. No manual or computer reduction was accepted for qualification.

The AN/AMT-4 raw data consisting of temperature and humidity ordinates and elevation and azimuth angles were plotted every 30 seconds.

The AN/AMQ-9 raw data consisting of temperature and humidity ratio elevation, azimuth angles, and slant range were plotted every five seconds. These data were compared with those plotted from data punched on summary punch cards.

After comparing the AN/AMT-4 and AN/AMQ-9 Radiosonde raw data with that of the ADP System, all data errors were found within the accuracy of these radiosonde's sensors.

Since two modified AN/GMD-1B Sets were used on each flight, the ADP System was switched from one set to the other during each flight. The only change in the data was in slant range, with an error of less than 10 meters per switching.

One important aspect of GMD-2 performance was discovered from computing a final difference of the data on an IBM computer. During the preliminary tests, the slant range data would be changing at the rate of, say, 30 meters per five seconds except for occasions where the first difference would read 170, then -110. This slant range runout was found to be due partially to signal fading. The comparator is designed to function with a 75 kc ranging signal input of 0.015 to 0.150 volts RMS. Below 0.015 volts RMS input, the comparator gear train can continue running. A transistorized circuit was therefore added which will stop the servo-motor when the input to the comparator falls below a certain level. The adjustment was made once and has not required readjustment during the succeeding year's operation.

During the preliminary tests, the preparation of the modified AN/AMQ-9 radiosonde was determined to be an important part of a good ADP sounding. The commutator must be cleaned with a "pink pearl" or soft pink eraser immediately before use. The slight tarnishing of the gold commutator which occurs over a period of a few days causes erratic meteorological data to be transmitted from the radiosonde.

VI. CONCLUSIONS

This report has shown that the Friez Model 1146450 Radiosonde Automatic Data Processor, when used with the modified AN/AMQ-9 radiosonde, will reliably process the tracking and meteorological data for transfer to a computer. The approach using reference identifier segments on the radiosonde commutator provides a means of decommutation in the presence of signal fading conditions.

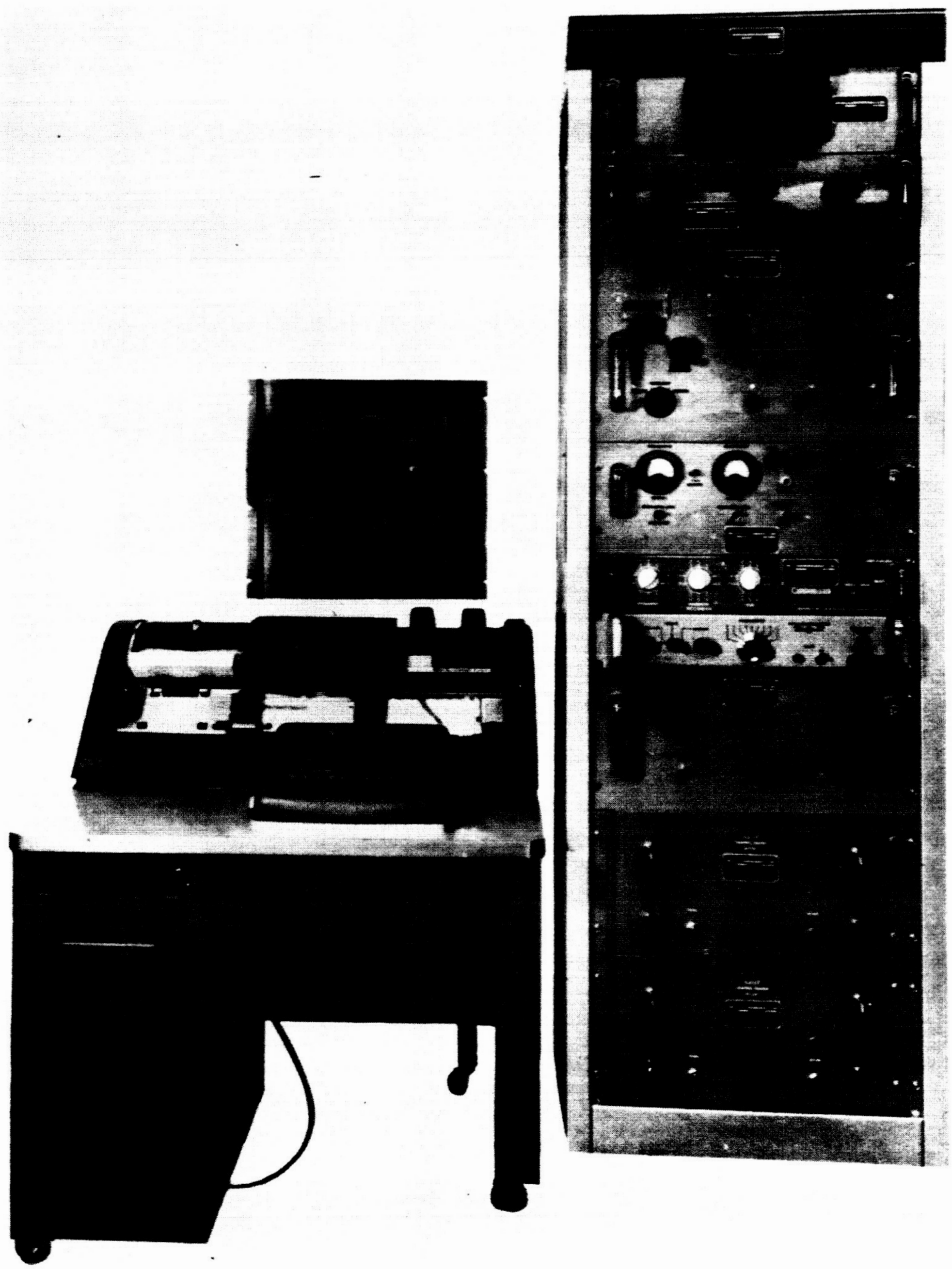


FIGURE 1. RADIOSONDE AUTOMATIC DATA PROCESSOR WITHIN SLANT RANGE PRINTER

FIGURE 2. ADP SYSTEM INSTALLATION

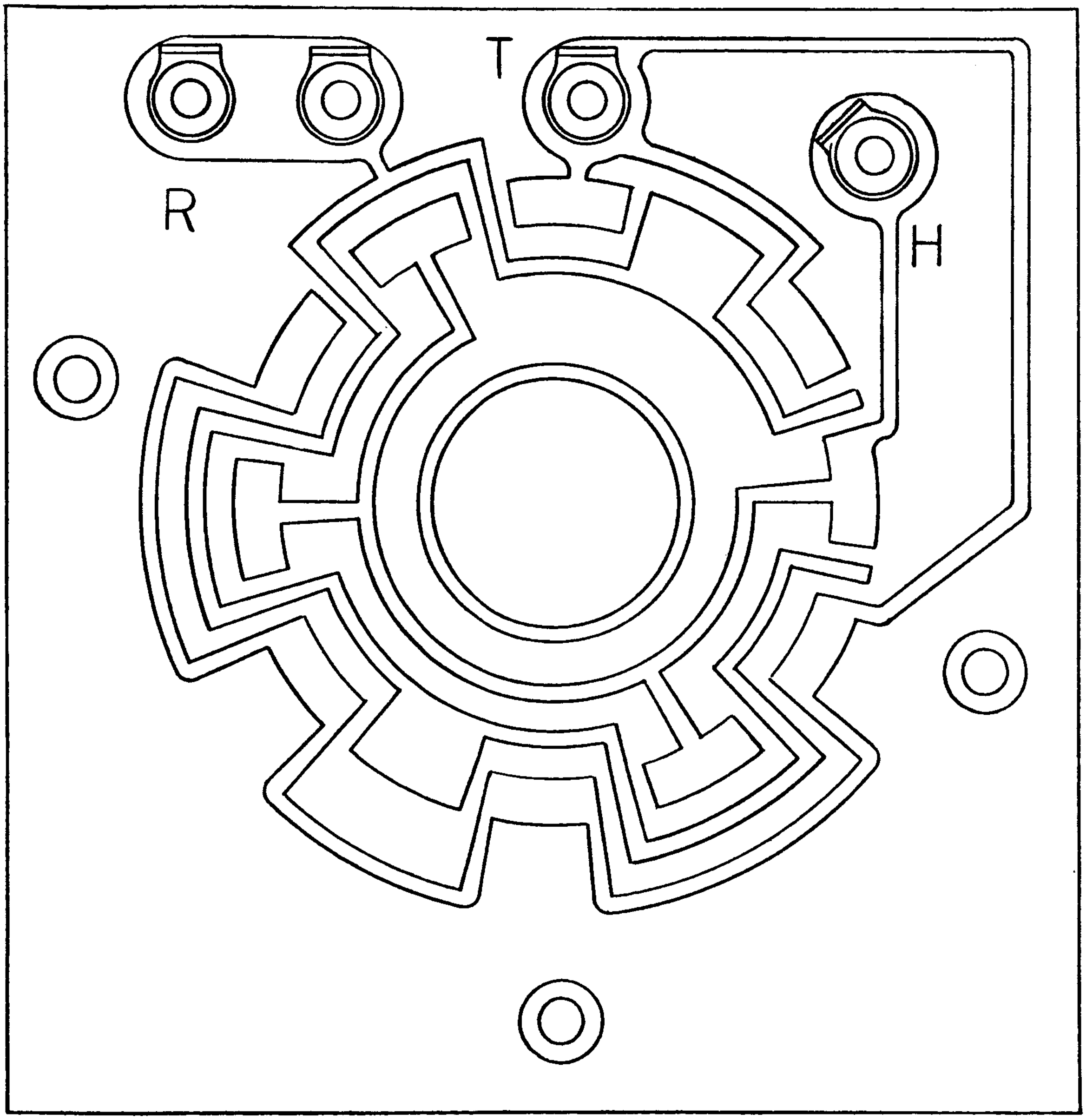
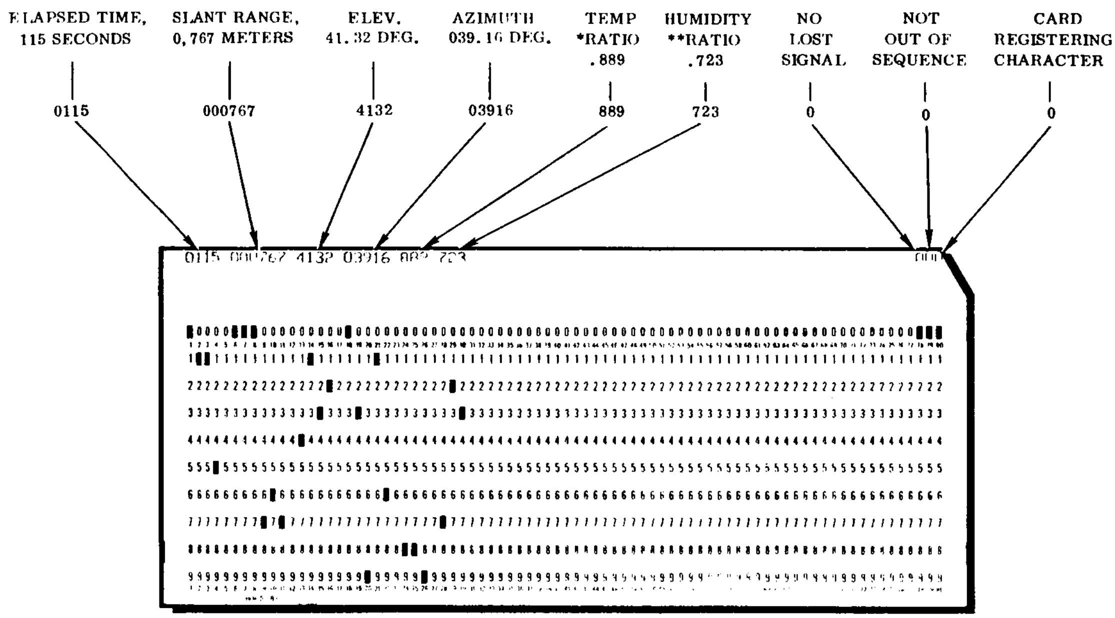


FIGURE 3. RADIOSONDE COMMUTATOR FOR ADP SYSTEM



Note:
Black areas on card represent punched holes.

* Ratio of temperature frequency to reference frequency
** Ratio of humidity frequency to reference frequency

166-L3

FIGURE 4. TYPICAL CARD SHOWING OUTPUT FORMAT

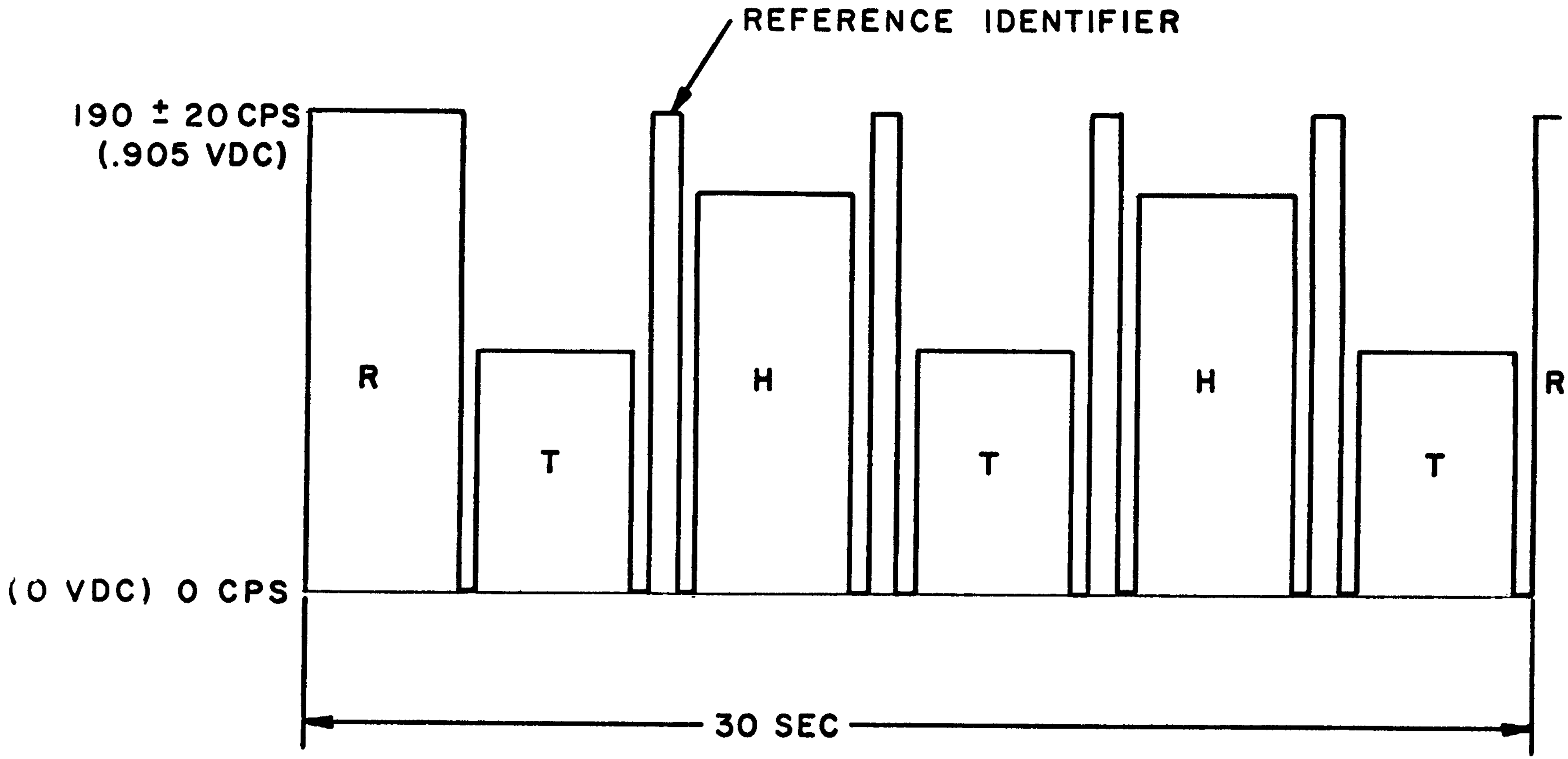


FIGURE 5. METEOROLOGICAL SIGNAL PATTERN

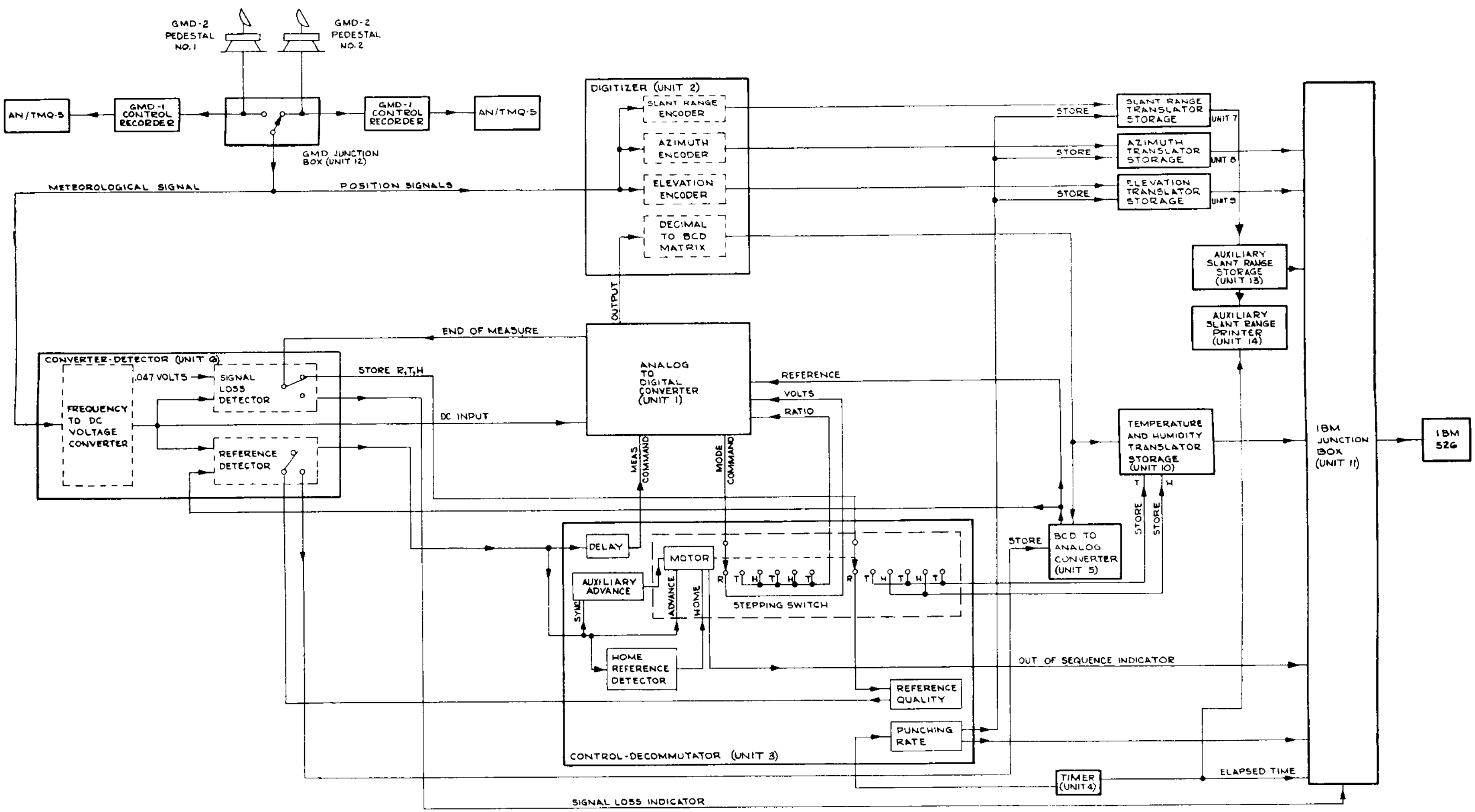


FIGURE 6. ADP SYSTEM BLOCK DIAGRAM

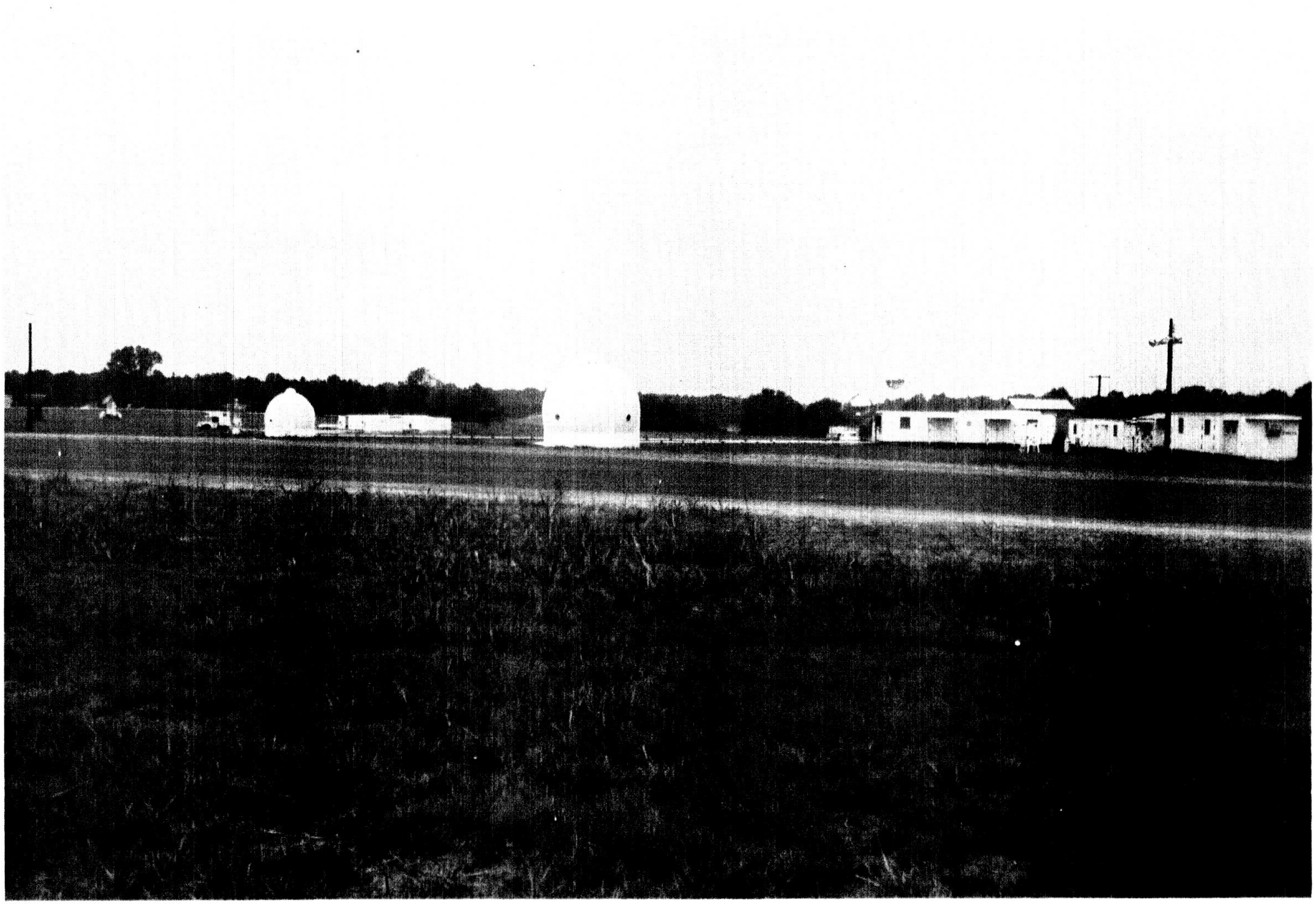


FIGURE 7. MSFC ATMOSPHERIC RESEARCH FACILITY

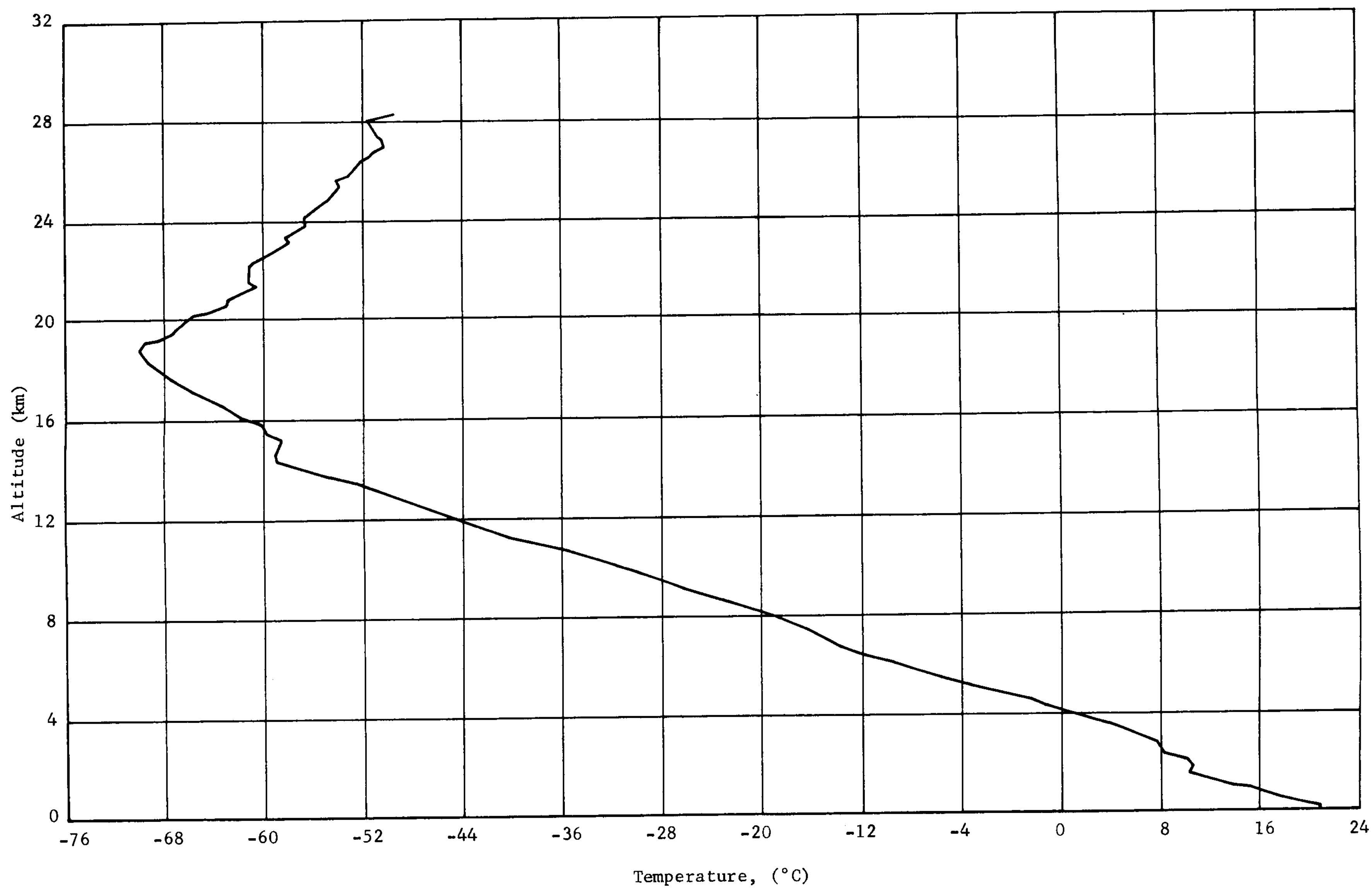


FIGURE 8. SAMPLE OF ATMOSPHERIC DATA (TEMPERATURE VERSUS ALTITUDE)

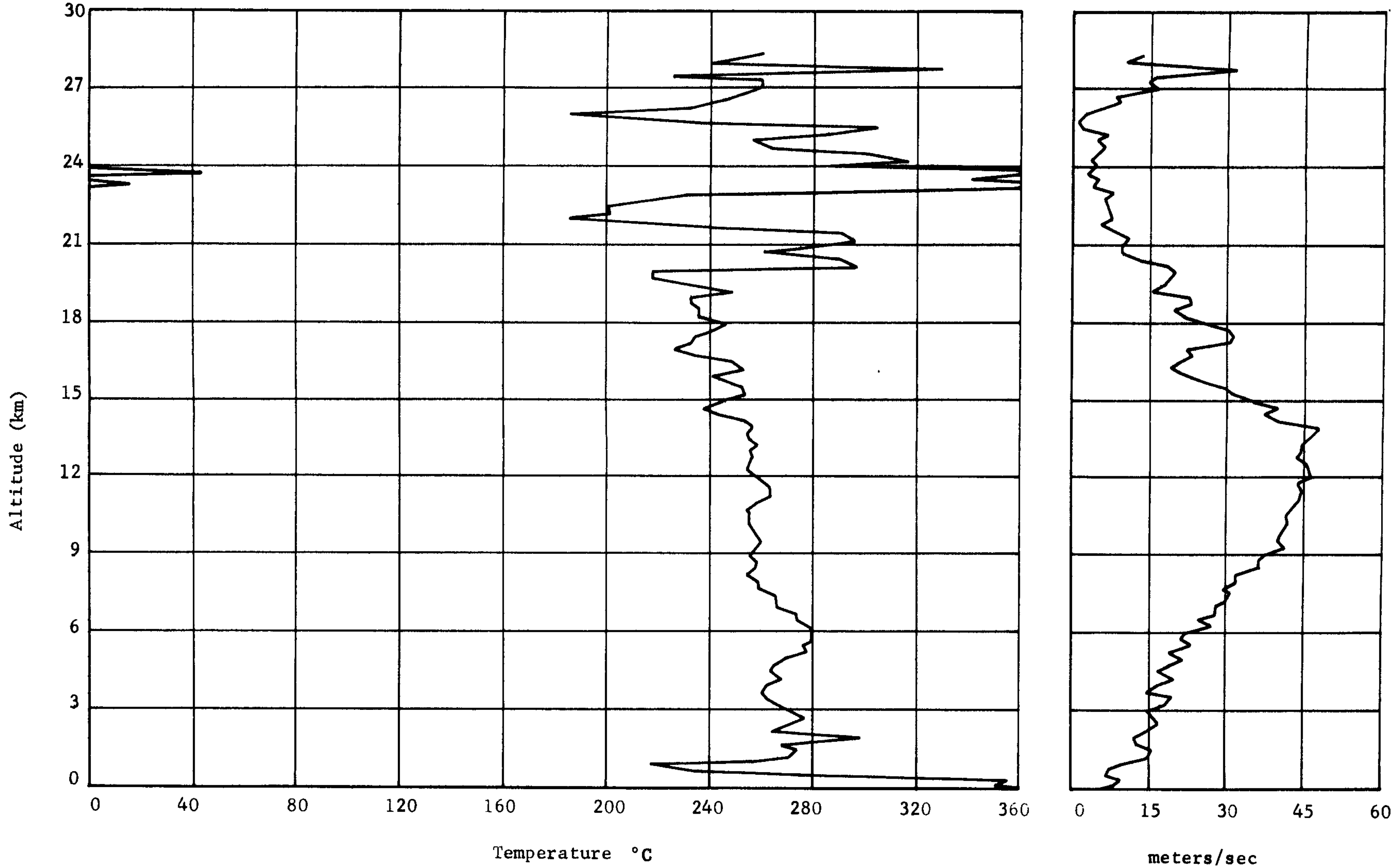


FIGURE 9. SAMPLE OF WIND DATA (WIND SPEED AND DIRECTION VERSUS ALTITUDE)

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December 22, 1964 APPROVAL NASA TM X-53186

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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