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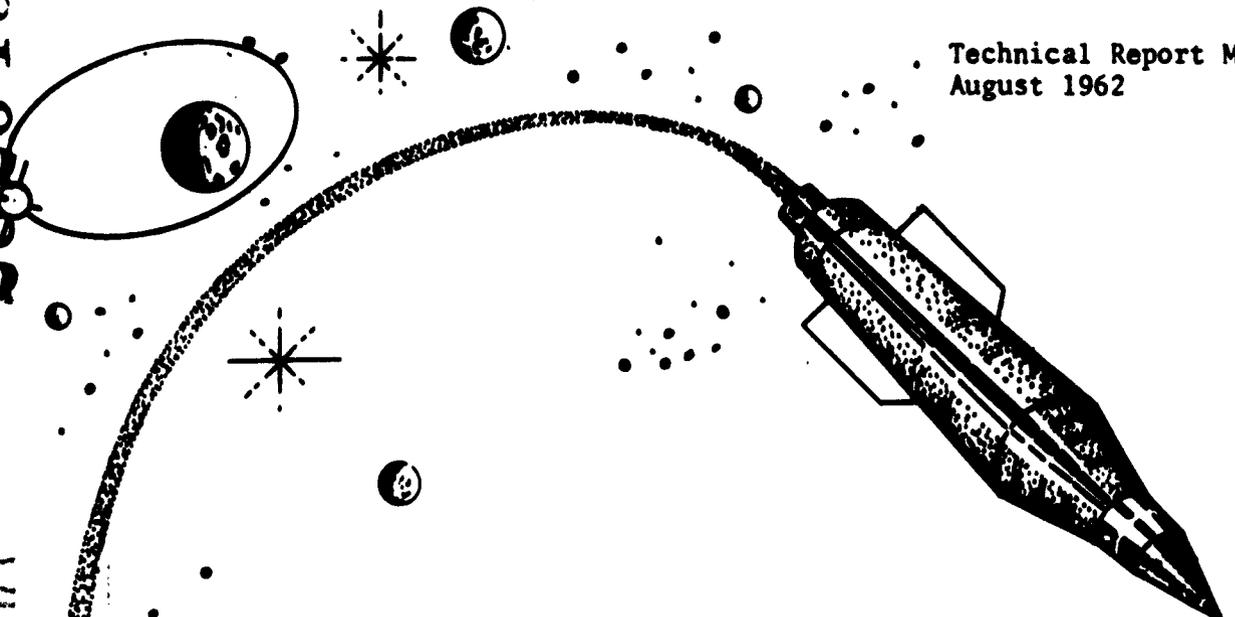
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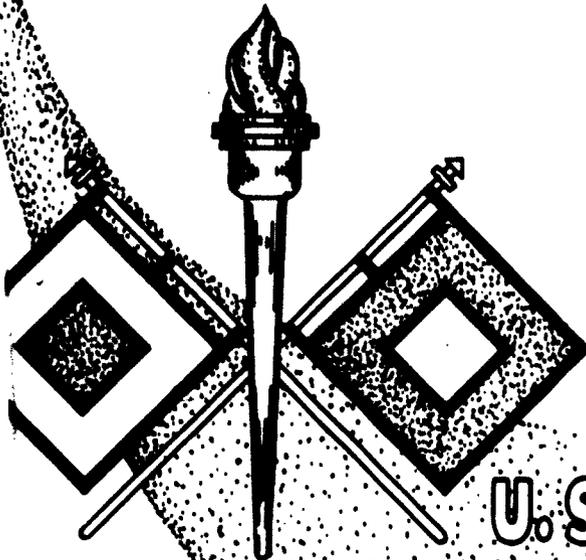
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METEOROLOGICAL ROCKET THERMOMETRY

PREPARED BY

MISSILE METEOROLOGY DIVISION



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METEOROLOGICAL ROCKET THERMOMETRY

By

George Q. Clark and John G. McCoy

MM 460

August 1962

MISSILE METEOROLOGY DIVISION

WHITE SANDS MISSILE RANGE
NEW MEXICO

ABSTRACT

The development of direct thermometry between 70,000 and 200,000 feet using sounding rockets has presented the researcher with a new and valuable tool for studying the upper atmosphere. This paper presents the development of nose cone Gamma, a temperature sensor-telemetry system designed to be carried aloft by the Arcas rocket and utilize a parachute descent. With the initiation of regular rocket soundings, periodic fluctuations were noted on the temperature recorder traces as the instrument approached and passed the 100,000- to 70,000-foot layer. Tests have been underway since January 1962 in an effort to explain these fluctuations, and current evidence indicates that they are a result of heat flow associated with oscillations of the instrument package on its parachute as it passes through this layer.

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INTRODUCTION

Man, in his desire to reach greater heights above the surface of the earth, has placed paramount demands upon the scientist who attempts to explain the parameters of the upper atmosphere. It is of little consequence whether the information is required in missile ballistic computations, in energy propagation studies, for more accurate weather prediction, or for any of its other myriad applications, there still remains a great void in our knowledge of the upper atmosphere.

We have had, since the 1930's, synoptic balloon soundings to altitudes up to 100,000 feet. Artificial satellites have provided a great amount of information from above 100 miles. Between the two remains a region where atmospheric interactions are practically unknown. The most feasible vehicle proposed to measure conditions through this region is the sounding rocket. To provide a more coordinated effort along these lines, the Department of the Army Chief Signal Officer conceived the Meteorological Rocket Network to unite efforts of the various government agencies and their missile ranges.

The first systematic rocket soundings utilized the Loki-Dart combination for observation of upper atmospheric wind. This system employs a Loki anti-aircraft booster and an inert dart to carry a radar chaff payload to an altitude in excess of 200,000 feet where it is expelled and tracked by radar until the chaff cloud becomes so dispersed as to be unsuitable as a finite radar target. A vast store of information as to the seasonal variations of winds in the upper atmosphere has been obtained from these soundings.

In the fall of 1959, the United States Army Signal Missile Support Agency at White Sands Missile Range, New Mexico, initiated a program to design and fabricate a sensing and telemetry package compatible with the Arcas rocket and existing meteorological ground equipment for the collection of wind and temperature data through the mesosphere. The product of this endeavor, known as the Alpha model, is illustrated in Figure 1. This package utilized many components which were at that time in production for the assembly of radiosonde transmitters as used on sounding balloons. A bracket was fabricated to facilitate mounting of the transmitter and battery pack to the nose cone base plate and an in-flight-reference circuit incorporated between the sensor and modulator. The bead thermistor was mounted on binding posts at the forward tip of the transmitter case so that it would be in the end null of the dipole antenna pattern and also would be the leading element as the instrument descended through the atmosphere. Power was supplied by water-activated batteries and one dry cell. The instrument was expelled from the rocket at apogee (in excess of 230,000 feet), approximately 125 seconds after launch, and was returned to earth on a 15-foot diameter radar reflective parachute. The radar track of the parachute descent yielded wind data and the instrument telemetry provided temperature data.



The first successful firing of this instrument which included the gathering of temperature data was performed at Ft. Churchill, Canada, 19 October 1959. The first data collected using this system to be published in Meteorological Rocket Network publications was acquired on 4 February 1960, at Point Mugu, California. The Alpha circuitry evolved through the Beta stage (early 1960) into the Gamma package which is at this time the most extensively used high altitude temperature telemetry system within the Meteorological Rocket Network, and was the basis for all of the tests discussed in this paper.

Figure 2 illustrates the Arcas sounding vehicle, the Gamma instrument package currently in use, and protective glass-phenolic nose cone. The schematic of the Gamma is reproduced in Figure 3. The 1680mc carrier is generated by the 5794A triode in a tuned cavity. Intelligence to be transmitted is impressed upon the grid of this tube in the form of pulses of sufficient negative magnitude to terminate the carrier. A blocking oscillator is utilized as a pulse generator whose repetition rate is varied as a function of resistance. By using a thermistor as the rate governing resistor, the pulse rate becomes a function of temperature. The use of a sensor whose resistance range varies the pulse rate over a suitable range (20-200cps) produces data compatible with existing ground gear. Another criterion for the sensor selection was the need for a fast response time, necessitated by the high fall rates and low densities at high altitudes. Victory Engineering Company's model 43A6 10-mil bead thermistor possesses enough desired characteristics to be acceptable. The bead is coated with glossy white Krylon to lessen the heating effect of solar radiation. Also incorporated in the instrument is a switching circuit to monitor periodically instrument performance exclusive of the sensor to provide a reference for data restoration in the event of shifts in the repetition rate from causes other than changes in thermistor resistance.

The power supply which mounts on the aft end of the instrument package consists of four Burgess V-20 30 volt carbon batteries and seven Mallory 1.34-volt mercury cells. The latter cells are potted in polyurethane near the center of the pack to provide insulation from temperature extremes. A black absorptive coating is utilized to lengthen the cell life through absorption of solar radiation.

A GMD-1 radio direction finder is used to track the instrument through its flight. The received signal enters a signal converter where the pulse is lifted from the carrier and converted to a varying DC voltage, the value of which is proportional to the audio frequency impressed on the carrier. This is recorded by a strip recorder as a function of time to be used in evaluating the atmospheric temperatures through which the sensor-transmitter passes.

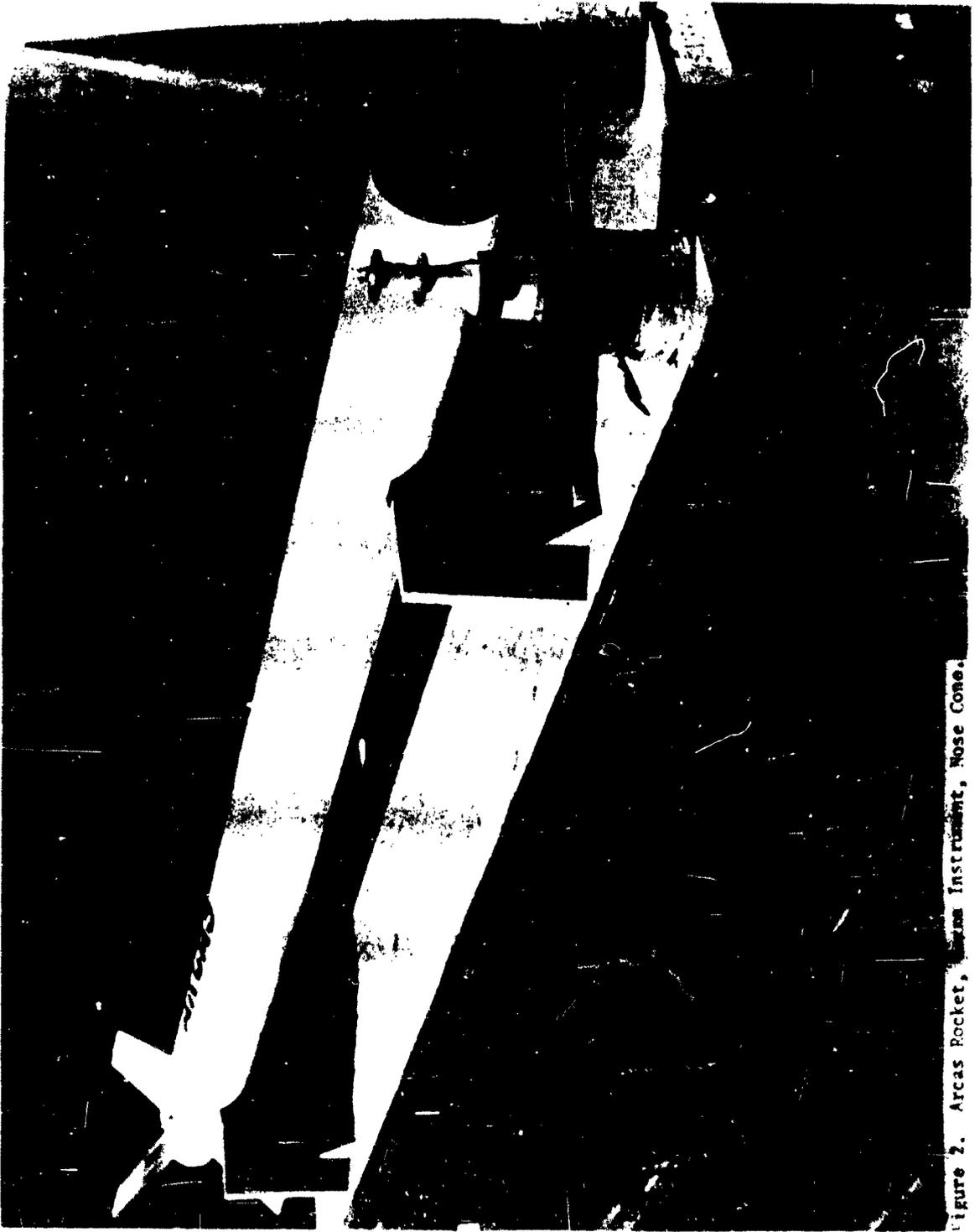


Figure 2. Arcas Pocket, Instrument, Nose Cone.

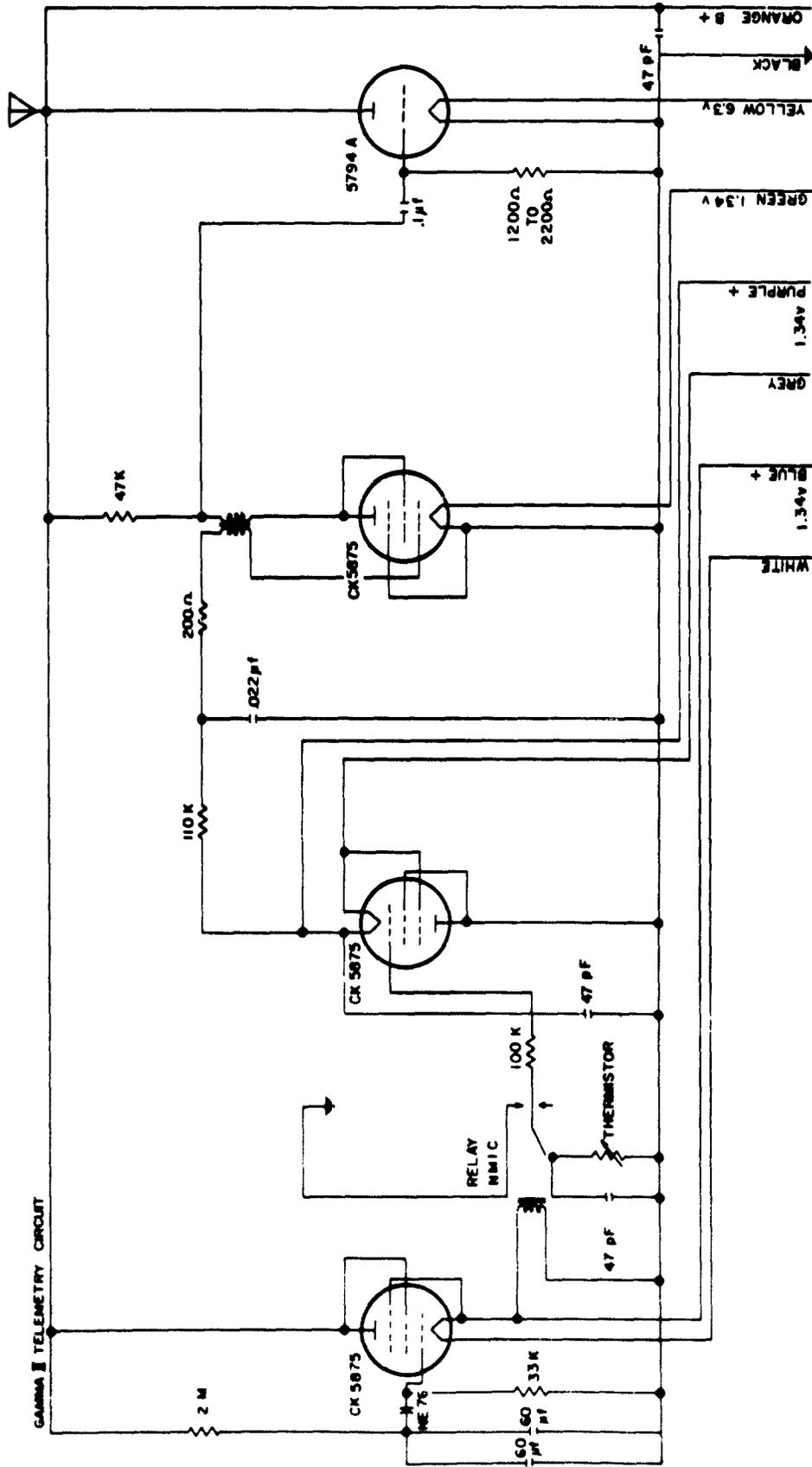


Figure 3. Schematic of Gamma II Temperature Telemetry Transmitter.

PROBLEMS IN HIGH ALTITUDE TEMPERATURE MEASUREMENT

In the examination of temperature records from the network stations at White Sands, Eniwetok, and Fort Greely it was found with few exceptions that there were pronounced regular fluctuations in the telemetry records indicating periodic heating of the bead at certain altitudes (Fig. 4). This regular spiking appeared around 100,000 feet and remained until the instrument descended to around 70,000 feet. These fluctuations on the Spring 1961 data (3) were studied and were found to average from 8.5°C amplitude at 100,000 feet to 4.5°C at 78,000 feet. When the temperatures collected by rocket-borne instrument packages were compared with the upper end of simultaneous balloon-borne radiosonde records, the base of the fluctuating Gamma record was found to agree with the ~~top~~. Although this enabled temperature profiles to be obtained from the telemetry records, investigation was continued toward the explanation of the fluctuations. There were several possible causes to which the fluctuations could be attributed.

(1) Variation of the intensity of solar radiation impinging on the sensor due to parachute oscillation would be responsible for periodic increases in the thermistor bead temperature above that of the free air surrounding it. This same effect could also be the result of radio frequency energy emitted by tracking radar, possibly focused on the sensor by the metalized parachute.

(2) The absorption of energy from collision of the bead and heavy cosmic particles would result in a sudden rise in sensor temperature.

(3) Passage of the sensor through an ionized environment could allow a current flow in parallel with the thermistor, giving a reduced resistance through the sensing circuit and hence resulting in higher temperature indication.

(4) Heat flow from the transmitter heat source via the binding posts to the thermistor bead could take the form of radiation, conduction through the leads, or conduction by air currents resulting from the oscillatory motion of the instrument package.

PROGRAM OF INVESTIGATION

The first experiments directed toward the solution of this problem were a series of night firings. Soundings at White Sands for 6 March and 27 April, and Eniwetok for 6 May, 2100 LST showed, in general, the period of the fluctuations to be the same as for day runs, but the amplitude was smaller (on the order of one-half) for nighttime firings.

On one flight at White Sands Missile Range a range radar silence was

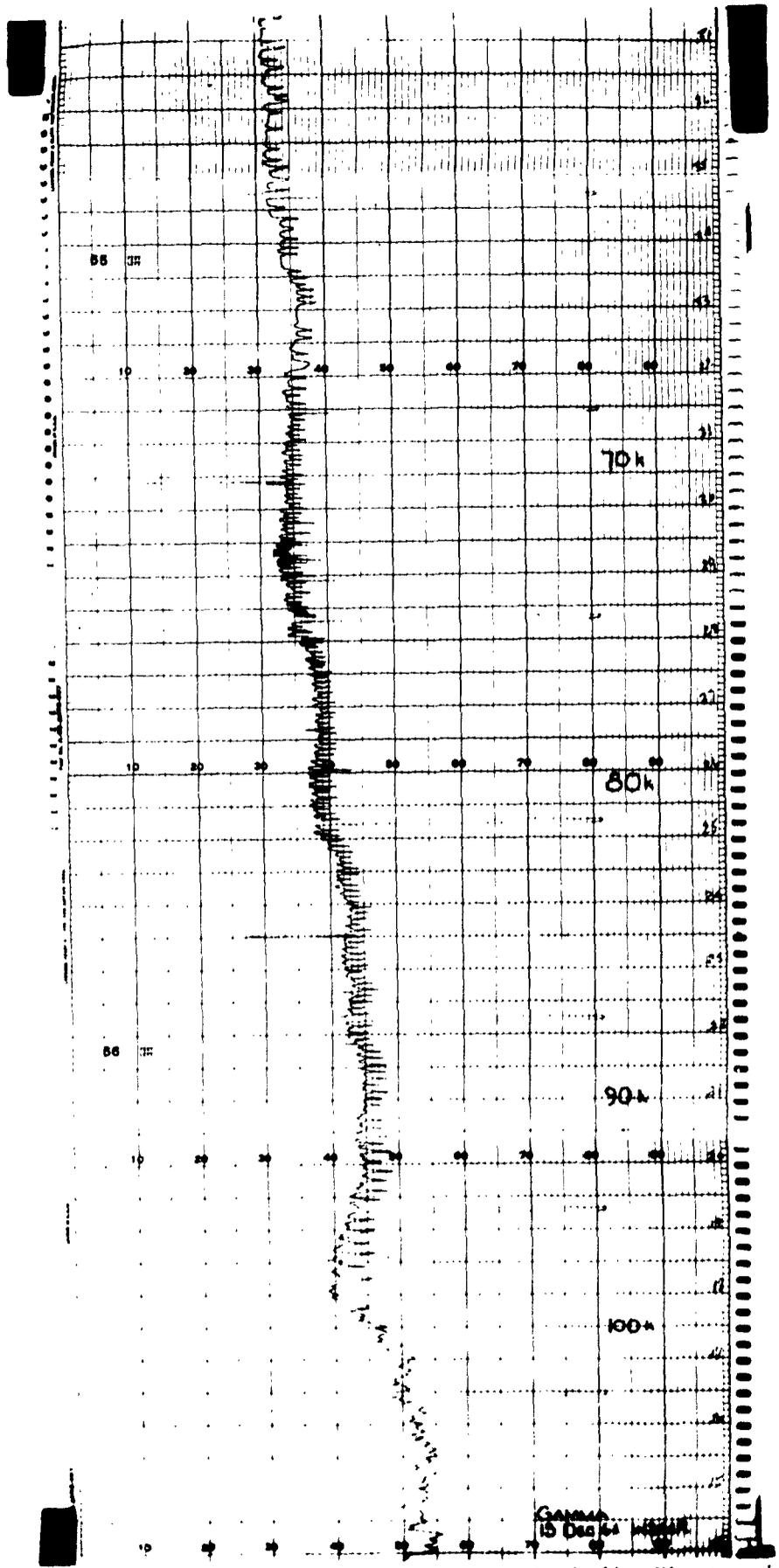


Figure 4. Typical Telemetry Strip Chart Indicating Periodic Fluctuations in Temperature.

requested during flight and the fluctuations persisted as before.

To determine the effect of discharge through an ionized environment, the binding posts, connections, and thermistor leads of an instrument were coated with clear Krylon plastic to provide a completely insulated circuit. This was flown 12 December 1961 and the fluctuating trace of previous records were still evident.

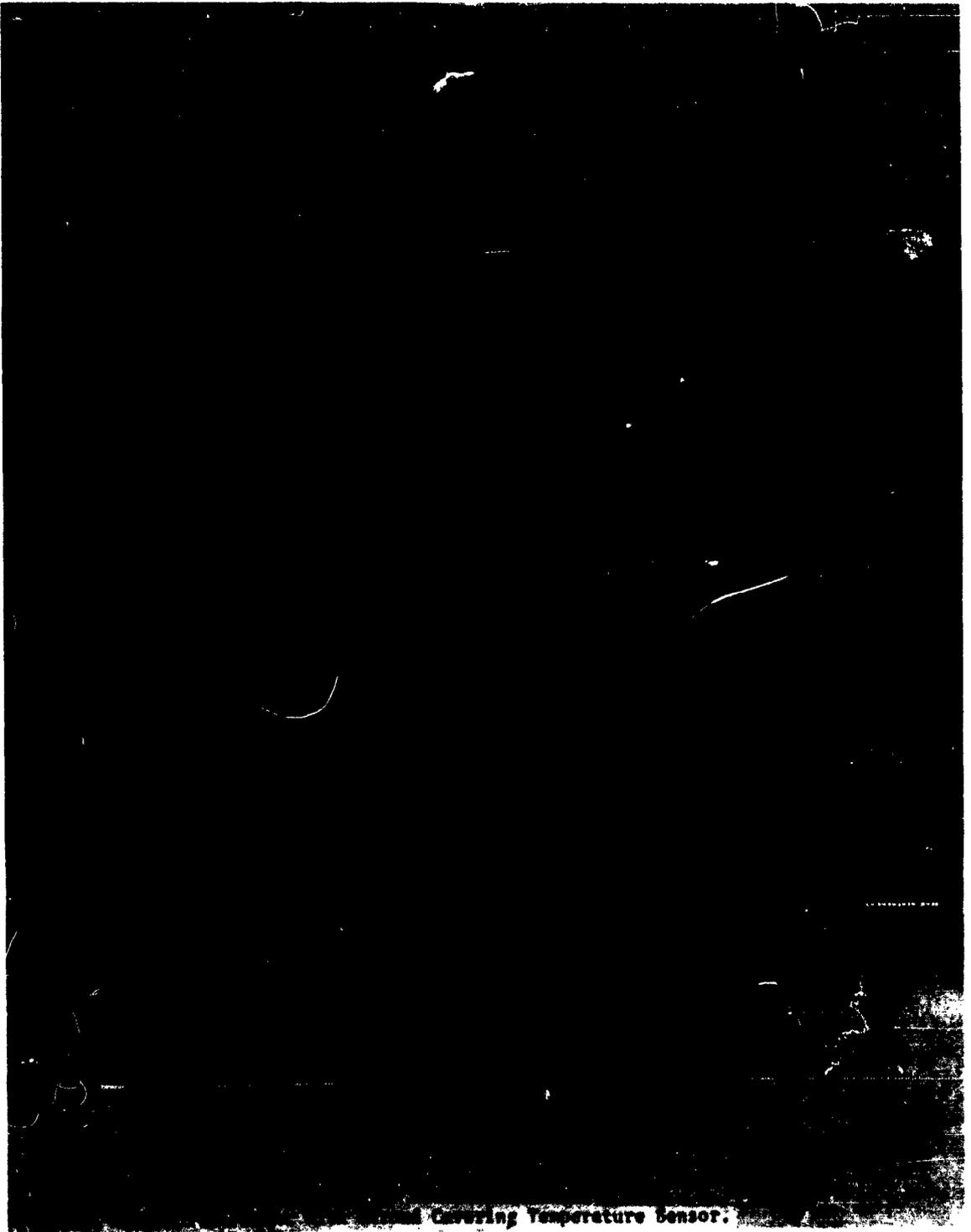
To determine the effect of radiation on the system, a transmitting instrument package was bombarded with gamma rays from a cobalt source to an intensity of 3000 roentgens per hour. There was no appreciable change in the instrument pulse period.

A series of three firings was conducted using Gamma type packages, modified with a plastic shroud (Fig. 5, Fig. 9c) to shield the sensor from the effects of solar radiation (optical frequencies and lower) and as partial protection from air currents passing between the binding post and the sensor. The records of these flights are reproduced in Figures 6, 7, 8. In the first firing on 3 January, (Fig. 6) the fluctuations were not reduced as expected, but reached greater amplitude than had been currently observed. It is felt that the shield was torn from the instrument upon expulsion from the motor. The records from the second (Fig. 7) and third (Fig. 8) firings had little or no fluctuations in the temperature trace.

The requirement for the final set of tests in this series was for a thermistor mount which would place the thermistor bead as the most forward element in the air stream as the package descends on its parachute. Prior to these experiments, the thermistor was suspended between the binding posts on a catenary formed by the 1-mil beads as shown in Figure 9a. Several prototypes were constructed and subjected to acceleration loading in a centrifuge and the one which proved most satisfactory (Fig. 9b, Fig. 10) (accepting up to 250 g 90° from its longitudinal axis) was built into several instrument packages. In this modification the normal solid binding posts were replaced with posts of silver-plated 1/16 inch brass tubing 2 cm long and the thermistor leads soldered into the free ends forming an arch to support the bead. The 14 daytime records (Fig. 11, 12) available at this time, using this type of mounting, indicate the major portion of the fluctuations to be eliminated. The minor component of the temperature fluctuations which remain seem to have a one-to-one correspondence to fluctuations in signal strength due to the pendulum effect of the instrument and its dipole antenna on the parachute. The night shot 1915 hours 21 February 1962 had no fluctuations throughout the entire record 147,000 feet to 67,000 feet (Fig. 13).

RESULTS

Relocation of sensors on the Gamma instrument package as described above eliminates major fluctuations which had been prevalent on the strip



Covering Temperature Sensor.

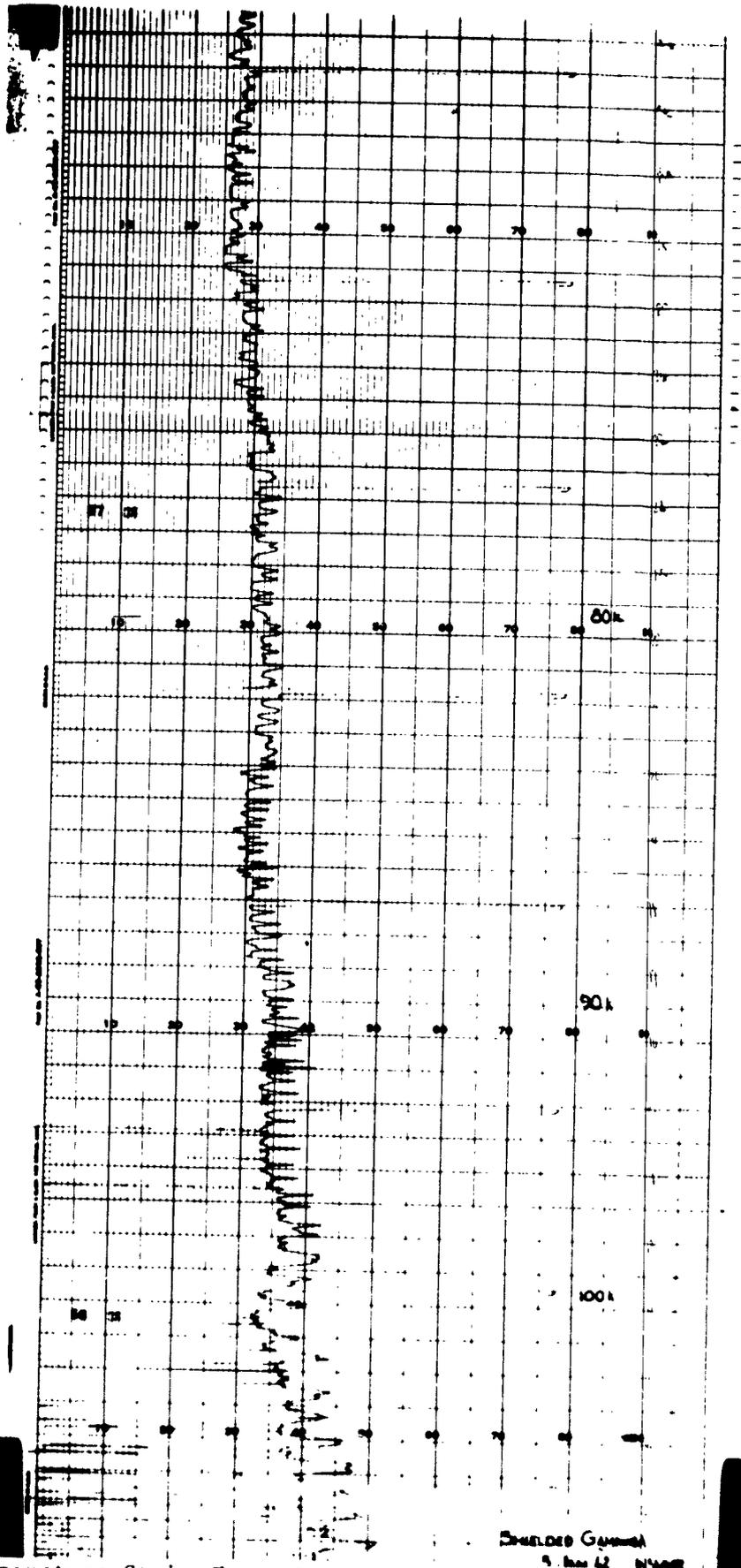


Figure 6. Temperature Strip Chart From Shielded Sensor - 5 January 1962.

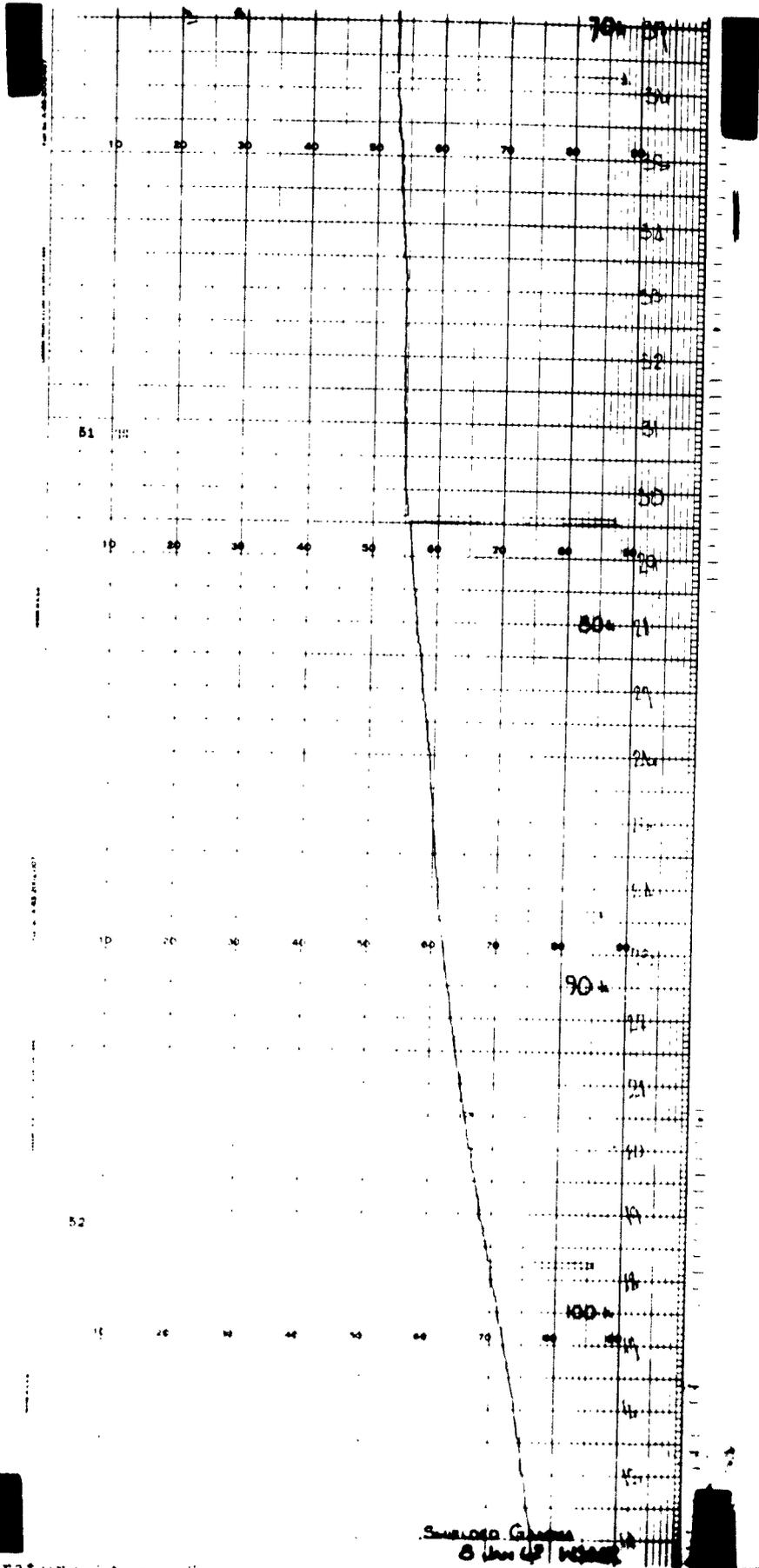


Figure 7. Temperature profile from depth sensor - 8 January 1962.

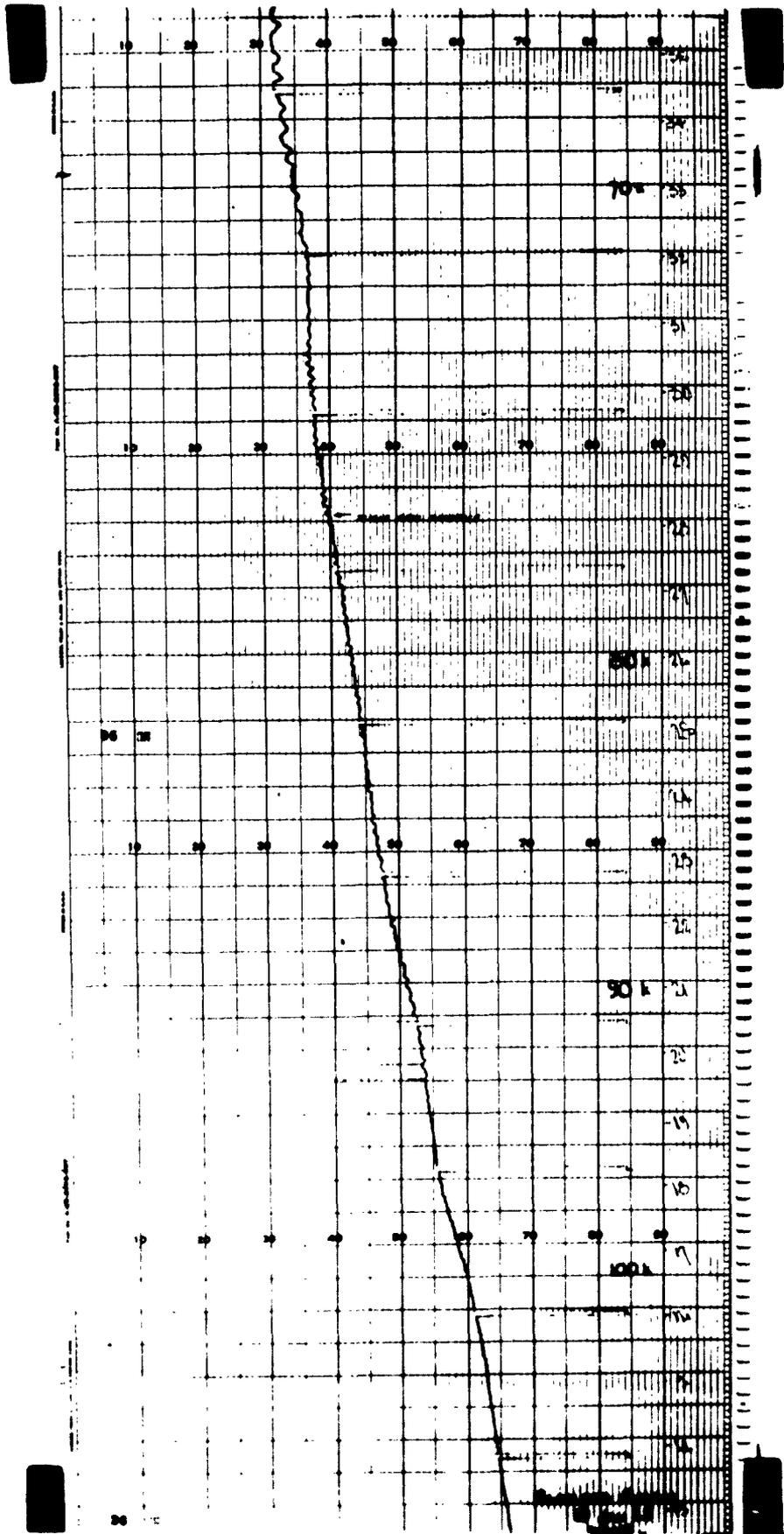
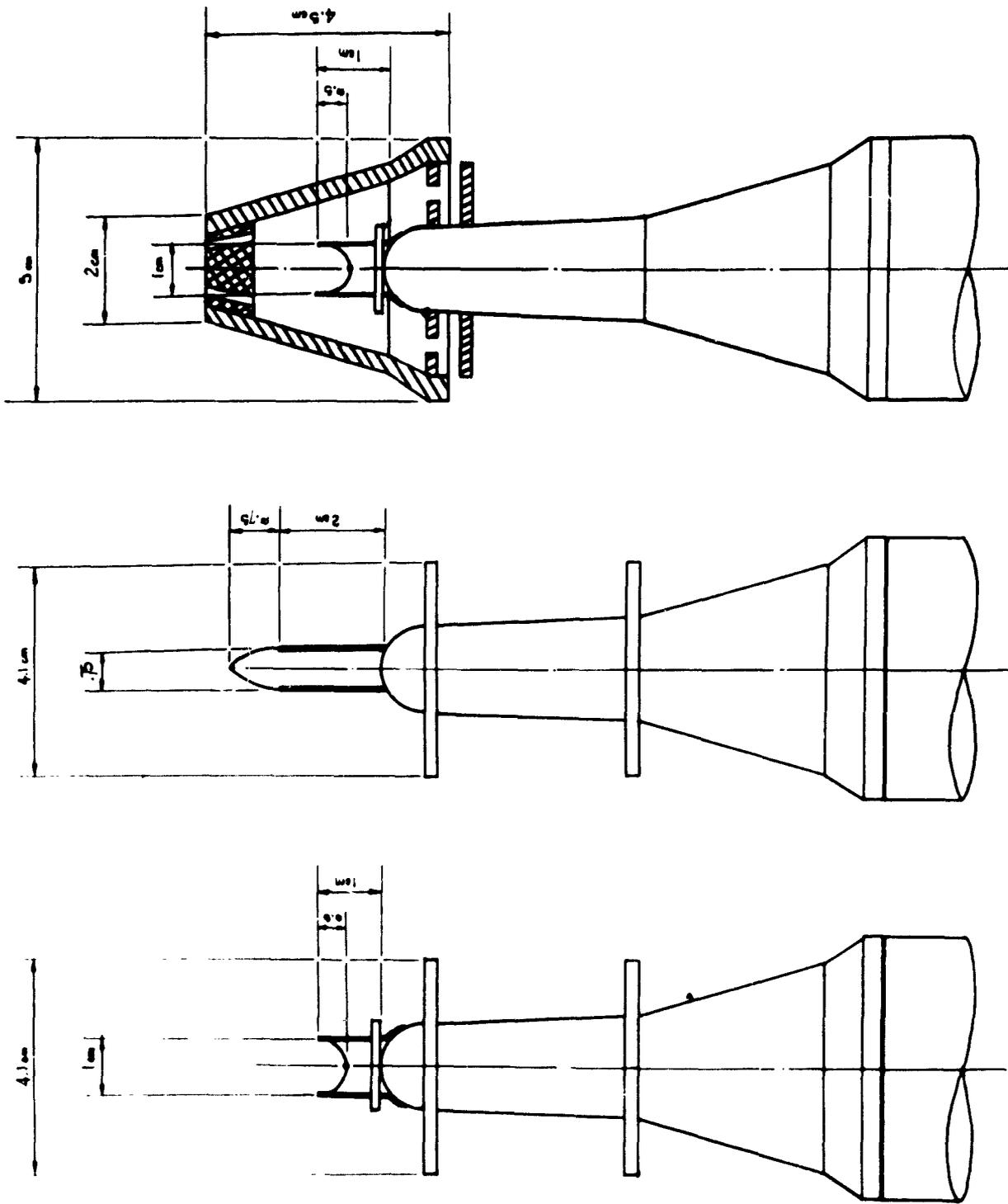
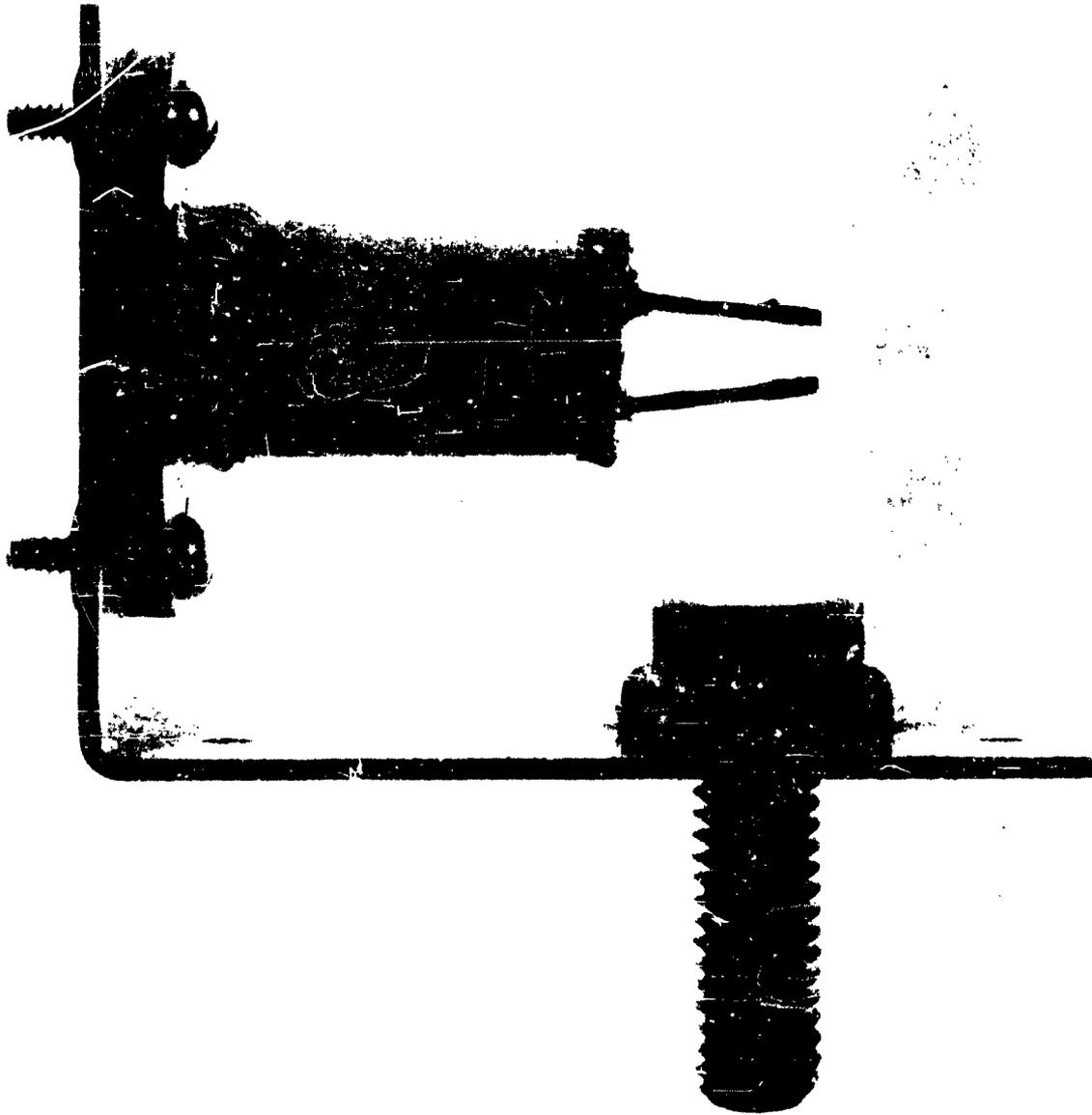


Figure 8. Temperature Strip Chart From Shielded Sensor - 19 January 1962.]



A B C

Figure 9. Methods of Bounting Temperature Sensors Used in Described Tests.



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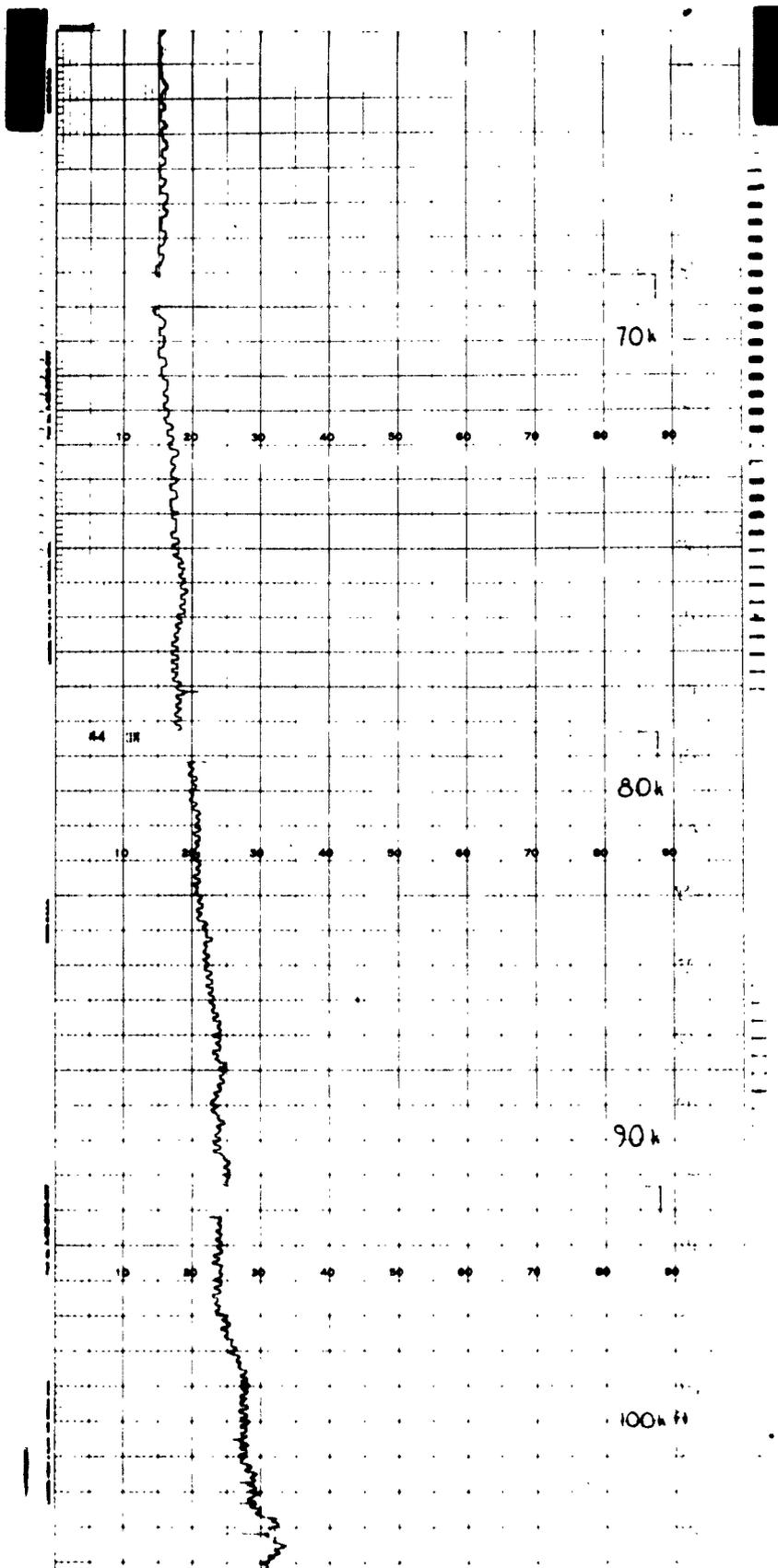


Figure 11. Daytime Temperature Records Obtained Using Sensor Mounts as in Figure 9 (3) - 17 January 1962.

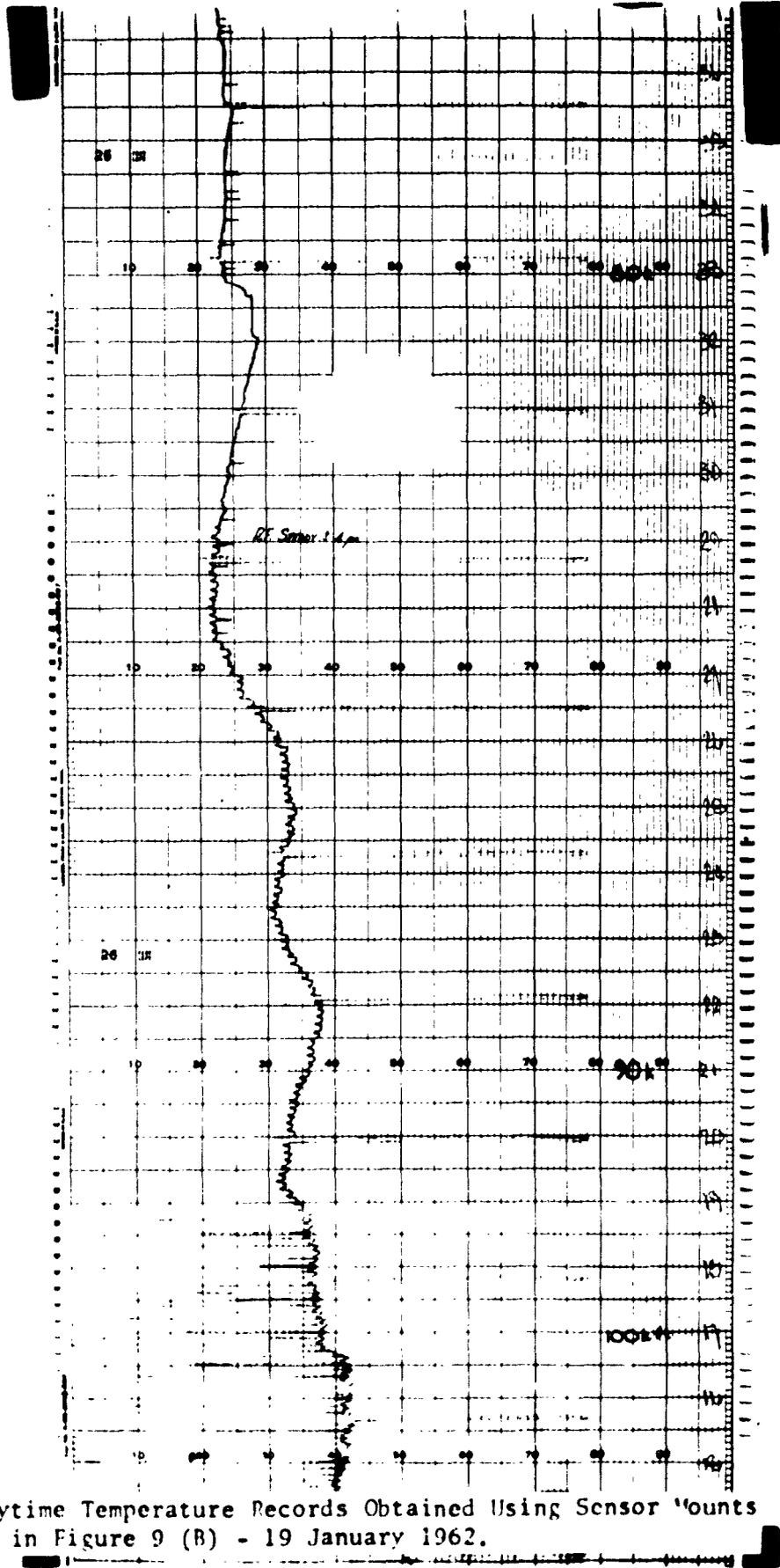


Figure 12. Daytime Temperature Records Obtained Using Sensor Mounts as in Figure 9 (B) - 19 January 1962.

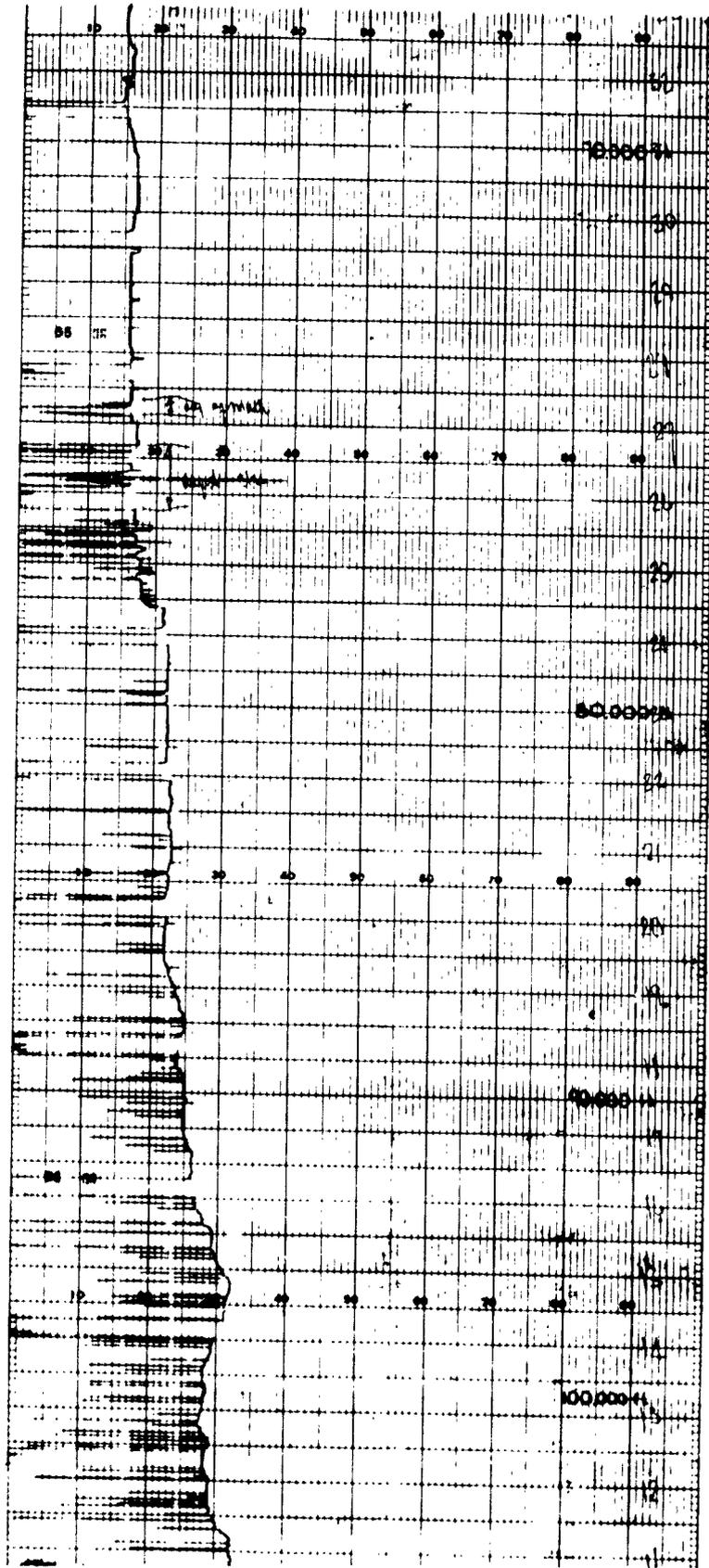


Figure 13. Nighttime Temperature Obtained Using Sensor Mounts as in Figure 9 (B) - 21 February 1962.



recordings of previous soundings. From this it would seem that the major component of these fluctuations is the result of air currents from the sensor binding posts to the thermistor bead warming the bead above ambient air temperature.

A one-to-one correspondence has been noted between the remaining minor fluctuations and the oscillations of the instrument on the parachute. The complete elimination of excursions in the night shot of 21 February 1962 (Fig. 13) indicated these were due to solar heating as the bead was oscillated into the sunlight.

The absence of searching in shielded sensor tests, which isolated the thermistor from optical frequency radiation and air currents but not the bombardment of heavy particles, eliminated from our consideration the absorption of energy from these particles. Subsequent tests also indicated that energy from range radar and gamma radiation has no observable effect on the instrument repetition rates.

CONCLUSION

The temperature excursions found on telemetry records of the Arcas-Gamma temperature sensing system are of a compound nature. The major portion of these fluctuations appears to be the result of air currents from the sensor binding posts to the thermistor bead warming the bead above the ambient air temperature. It has been calculated that for the air flow to take this path there must be an oscillation of the package to the magnitude of 50 degrees from the vertical. The minor excursions of the order of 2°C appear to be the result of solar radiation heating of the bead as it swings into the sunlight.

It is believed that the instrument descends on its parachute in a relatively stable manner until it approaches 100,000 feet. Near this level the pendulum oscillation increases greatly and the fluctuations on temperature recordings appear, remaining until the oscillation damps out. To substantiate this, plans are underway to fly a series of camera packages to photograph the behavior of the parachute throughout the descent.

As a result of these and other tests the Gamma instrument package has been redesigned to the configuration shown in Figure 14. It now incorporates the modified sensor mounting as described in this report, an improved battery pack for extended life, and provisions for an integral ranging transponder. This ranging system is of the interrogated pulse type as used successfully on radar beacons. The installation of this equipment will eliminate the need for tracking radar in an effort to permit soundings where radar is not available.

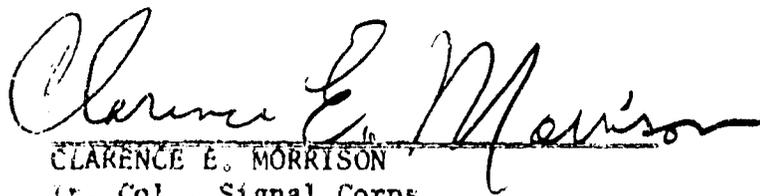


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NOTICES

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August 1962

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