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ANTENNA TEMPERATURE MEASUREMENT OF THE AERO GEO ASTRO MODIFIED HORN REFLECTOR

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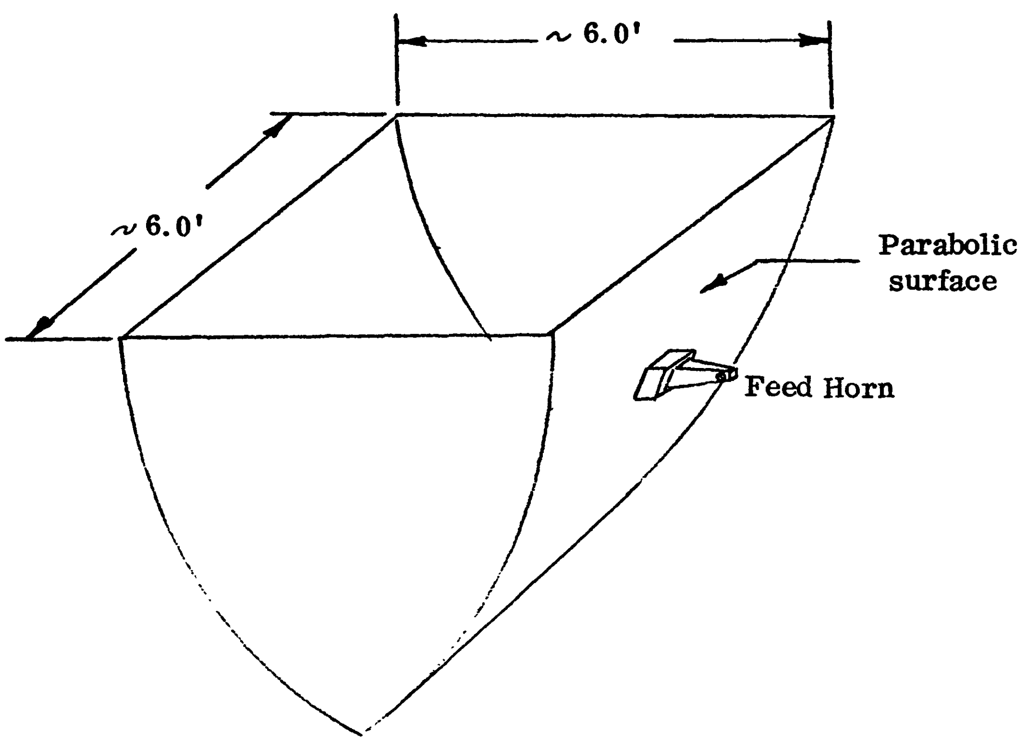
Abstract

The measured absolute antenna temperature for the modified horn at 4.995 GHz and zenith is 7 ± 3 °K. This figure could have been more accurate, but it is limited by the instability of the measuring system. Some possible causes of the instability were investigated but no conclusions have been reached as to its cause. The antenna does have a very low absolute temperature, and it could be used as a compact test unit that is often needed for low noise amplifier test systems.

Objective

The purpose of this experiment was to measure the absolute antenna temperature of a modified horn reflector antenna, as shown in Figure 1, and also in the photographs at the end of this report.



MODIFIED HORN REFLECTOR

Figure 1

This measurement was made at 4.995 GHz. Predicted temperature of the antenna was of the order of 5-6 °K. The measurement was started on December 17, 1964 and was completed on March 13, 1965.

Equipment Used

1. AIL parametric amplifier $T_e \cong 300$ °K, F = 4.995 GHz.
2. NRAO standard receiver.
3. Signal generator (FXR), Model C772A.
4. Hewlett-Packard slotted line, Model 809B.
5. FXR waveguide to coax transition.
6. AIL hot and cold source, Model 70.
7. S&M Electronics helium dewar and termination.
8. S&M Electronics nitrogen cooled termination.
9. Strip chart recorder, Weston Model 16701.
10. Hewlett-Packard counter, Model 5253A.
11. Hewlett-Packard transfer oscillator, Model 2590A.
12. Hewlett-Packard VSWR amplifier, Model 415C.
13. Miscellaneous connectors and attenuators.

Discussion

The method used to measure effective antenna temperature is relatively straightforward. First one must obtain a known temperature baseline. In this case the reference temperature was liquid helium at 4.2 °K, and the 50 ohm termination was placed in the helium bath. In any matched system, the power available is KTB, where K is the Boltzmann's constant, T is temperature °K, and B is the system bandwidth. With a given bandwidth, the noise power is directly proportional to the temperature. Figure 2 shows a simplified block diagram of the system.

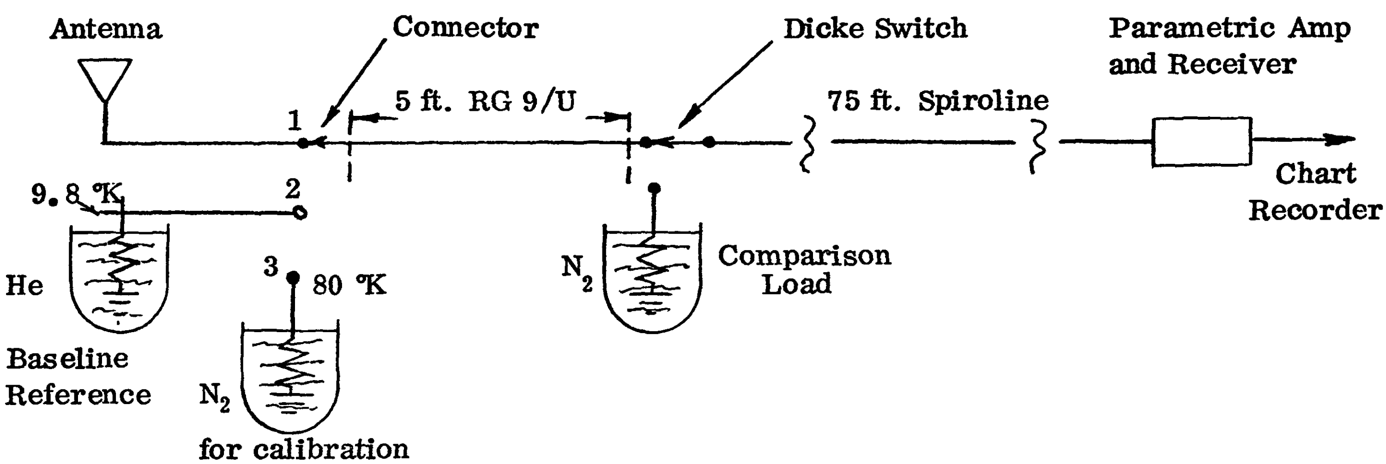


Figure 2

When the connector is in position 1, the power available is KT_AB, where T_A is antenna effective temperature. In position 2, power available is KT_hB, where T_h is the effective temperature of the reference termination. In this case, T_h is 9.8 °K rather than 4.2 °K because of cable loss between the termination and connector. Since R and B are the same, the output signal is proportional to input termination temperature.

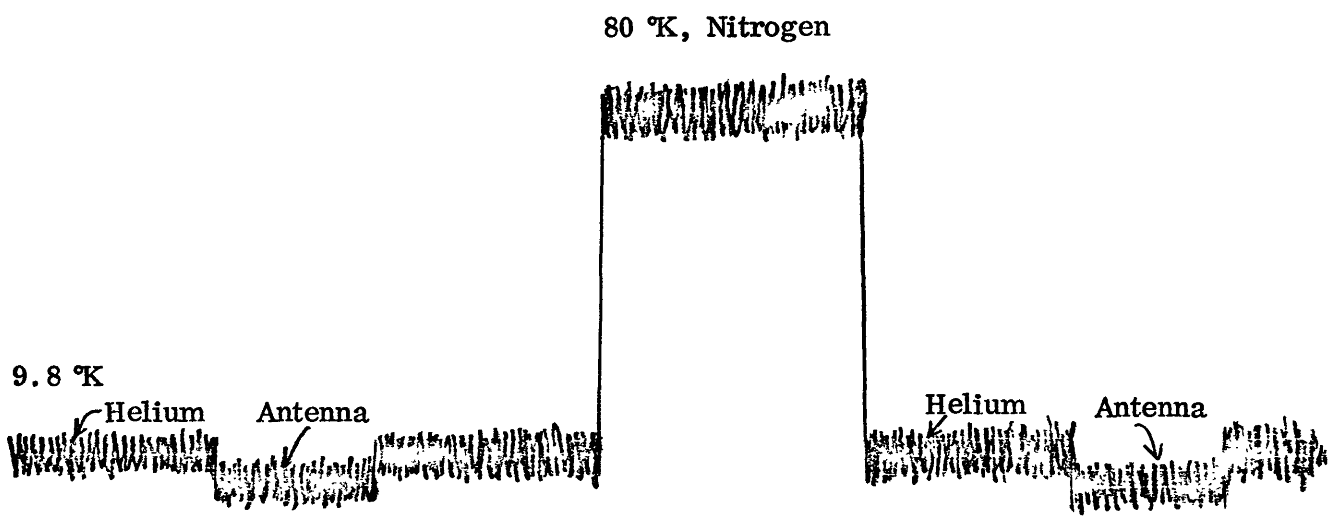


Figure 3

Typical Output Chart

Since the radiometer was used in the switched mode, a stable reference termination is required. This is shown as the comparison load in Figure 2. The temperature of this load is approximately 80 °K.

Figure 4 is an example of an actual measurement made on March 13, 1965. In this measurement and also many others, the system was not stable when either the helium termination or the antenna was being compared to a liquid nitrogen cooled load. The drift was of the order of 5 to 7 °K for a 10-minute period. This instability will increase the tolerance on the final antenna measured temperature. At first glance, it is apparent that the antenna zenith temperature is close to the 9.8 °K helium termination. If the scale factor is used (13 °K/inch for the example shown) and the midpoint of each period is used, the antenna temperature is $\cong$ 7 °K. However, the previously mentioned instability plus tolerance on the cooled terminations and error in reading the chart must be considered. The final figure is estimated to be 7 ± 3 °K.

Procedure

1. The gain, bandwidth, and frequency was checked on the parametric amplifier.
2. The VSWR was checked on all terminations.
3. The receiver was set up switching between two 80 °K (nitrogen cooled) terminations to check overall stability.
4. The signal side of the input switch was connected to the 9.8 °K helium termination, and the receiver was balanced (using the gain modulator) to obtain a 9.8 °K baseline reference.
5. The signal cable was then moved to the antenna feed horn input connector to get a comparison baseline for the antenna.
6. The cable was then moved back to the 9.8 °K reference.

7. Finally the cable was moved to a nitrogen reference load to obtain an 80 °K baseline for scaling purposes.
8. Steps 4 thru 7 were repeated.

Possible Causes of the Instability

The apparent drift in the temperature is approximately 5 °K. There are several possible causes for this instability.

1. Changes in temperature of the cable between the input connector and the comparison switch.

The temperature at the input of the switch is

$$T_{in} = \frac{T_A}{L} + \left(1 - \frac{1}{L}\right) T_L$$

where L is the loss in the cable, and T_L the cable temperature. The change in T_{in} caused by a change in T_L is then

$$\Delta T_{in} = \left(1 - \frac{1}{L}\right) \Delta T_L$$

For the cable used (5 feet of RG 9/U)

$$\Delta T_{in} = 0.25\, \Delta T_L$$

Therefore, the cable temperature would have to change about 20 °K to explain the instability. No such changes occurred, however, and changes in the cable temperature are not believed to be the cause of the drift.

2. Changes in system noise temperature, T_R

From reference (1),

$$\frac{\Delta T_A}{\Delta T_R} = L(1 - K)$$

where K is the gain modulation ratio

$$K = \frac{T_A + T_R}{T_C + T_R} = 0.8 \text{ in our case.}$$

We then have

$$\Delta T_A = 0.27\, \Delta T_R$$

and an apparent change of 5 °K in T_A requires a change of about 19 °K in T_R. Although no such changes in T_R were found when the system noise temperature was checked, changes in T_R of this magnitude might, however unlikely, occur.

Reference

Orhaug, T. and Waltman, W., "A Switched Load Radiometer", Pub. of the N.R.A.O., Vol. 1, No. 12, February 1962.

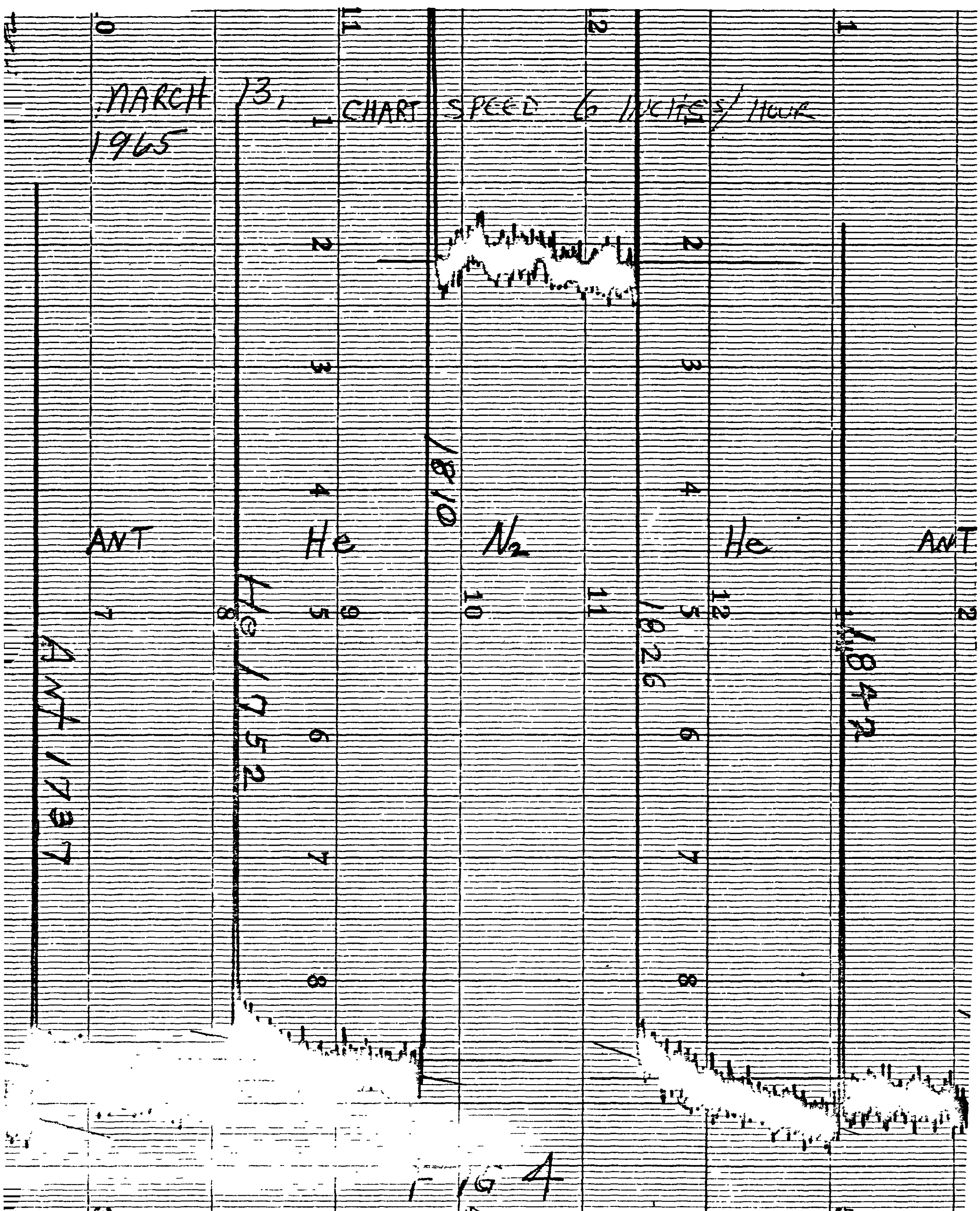
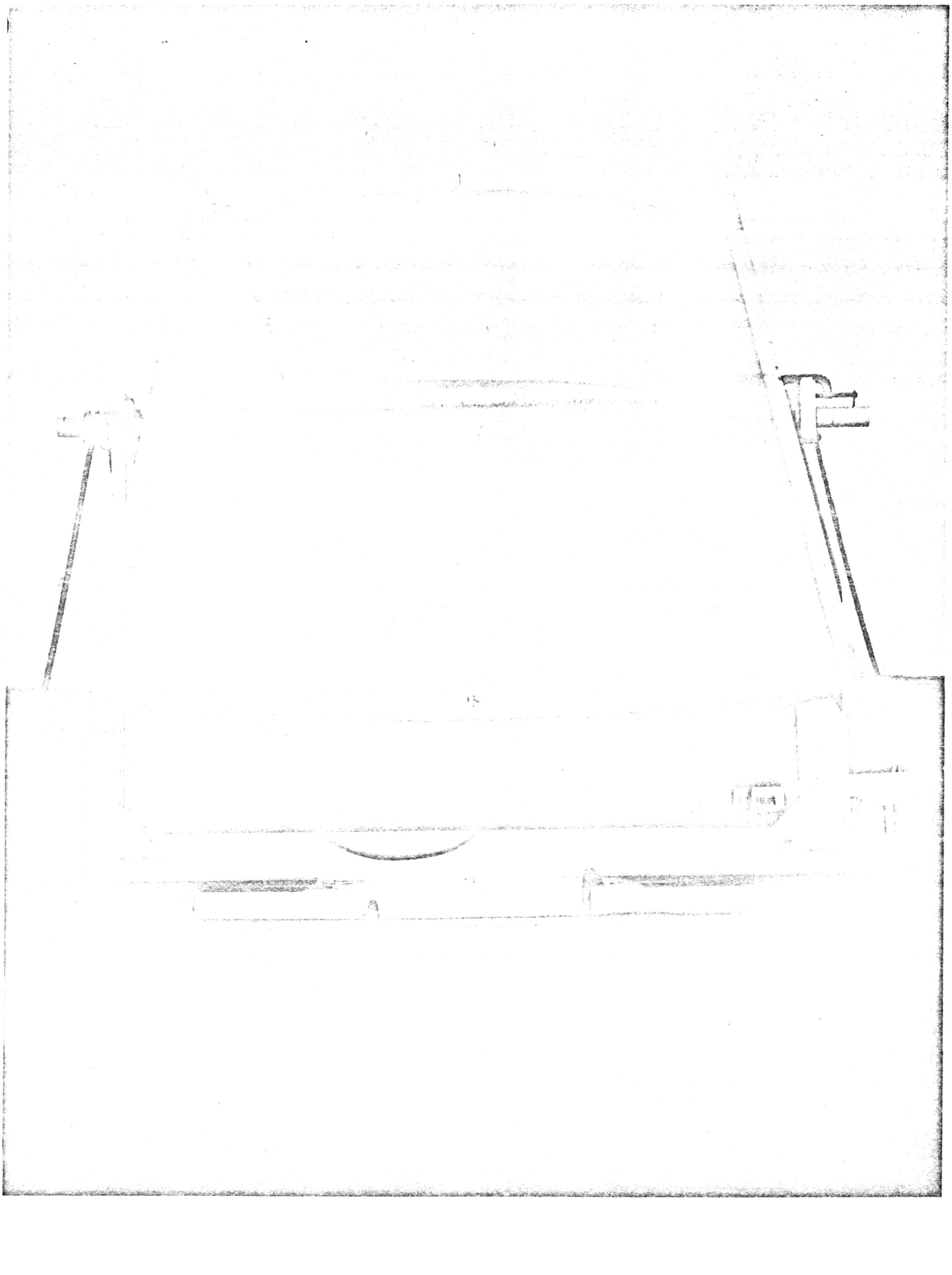
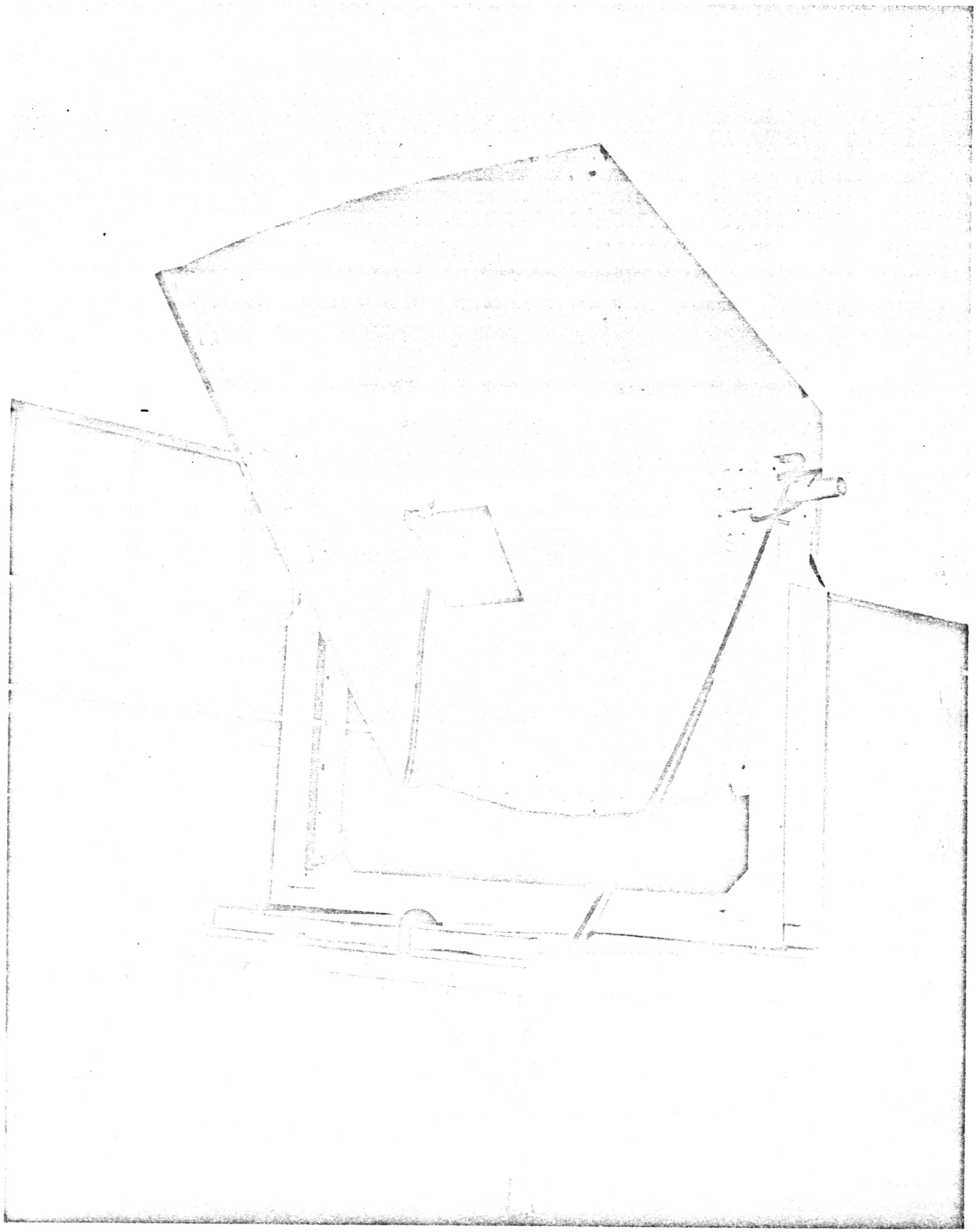
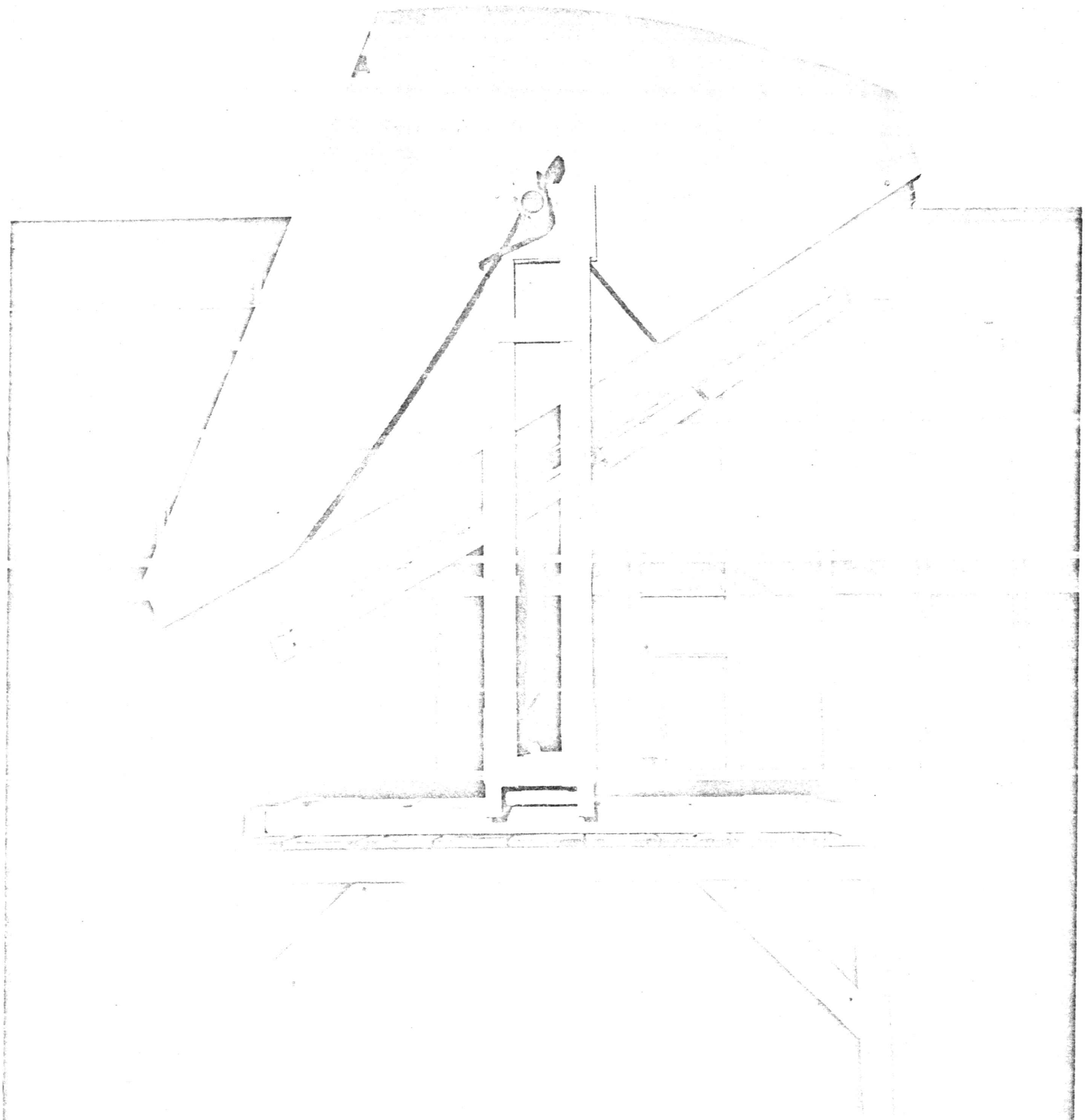


FIG 4

CHART NO. 240661



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