UNIVERSITY OF MINNESOTA

FINAL REPORT - NSR24-005-238

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(NASA-CR-145610) [PHOTOMETER DEWAR SYSTEM FOR NASA C141 AIRBORNE TELESCOPE (KUIPER FLYING OBSERVATORY)] Final Report (Minnesota Univ.) 37 p HC $4.00 CSCL 03A

N76-12896

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O'BRIEN OBSERVATORY

FINAL REPORT

Introduction.

In 1972, the University of Minnesota proposed to build a photometer dewar system for the NASA C141 airborne telescope, now known as the Kiuper Flying Observatory. One motivation for the unsolicited proposal which led to this contract was the belief of the principal investigator (E.P. Ney) that the C141 might become operational as a flying telescope without adequate instrumentation for making infrared observations of the stars and the planets. In order to minimize the requirements in the aircraft the photometer was to be designed with a focal plane beam switching system so that the airplane telescope could be used in a normal optical mode at the bent Cassegrain focus and with the photometer operated in the pressurized cabin of the airplane. The photometer was to be equipped with a flip mirror so that the astronomer could inspect the object being studied and verify that the system was tracking properly. The concept was to produce a system which could be used in almost the same manner as the ground based infrared photometers and dewars in use at the O'Brien Observatory of the Space Science Center of the University of Minnesota. The initial instrument was to have multiple interference filters matched to the atmospheric windows between 1.6 microns and 20 microns allowing direct comparison of the airplane telescope with ground based telescopes utilizing these same windows in the atmosphere but with the ground based telescopes suffering from atmospheric extinction. The original goals were threefold:

1). To make an operating infrared system without requiring a wobbling secondary on the telescope.

2) To use this system in flight and to compare observations of standard stars with those made at O'Brien Observatory in order to evaluate the operation of the aircraft observatory and to measure the transmission of the atmospheric windows widely used in ground based infrared observations.

3) To evaluate the airplane environment as an observatory and in particular to find out how serious airplane vibration and the flow of air past the open telescope might be in introducing noise in the observations.

Instrumentation.

Figures 1 and 2 are drawings of the photometer dewar system, and Figures 3, 4 and 5 are photographs of the finished equipment.

The dewar is a liquid nitrogen jacketed, liquid helium containing dewar holding one quarter liter of nitrogen and one quarter liter of liquid helium. It is smaller than the optimum ground based instrument which holds one half liter each of the two cryogens. However, the ground based system holds pumped liquid helium for three days and requires the addition of liquid nitrogen every twelve to eighteen hours. Since an airplane flight only lasts for eight hours the smaller dewar was chosen for economy of size and weight. The airplane dewar will hold pumped helium in excess of twelve hours and requires nitrogen addition every six hours. The nitrogen addition is a simple procedure involving pouring the cryogen into the dewar through a funnel. Ten filters are mounted inside the dewar and are cooled to 80°K. Nine of these filters operate at wavelengths of 1.2, 1.6, 2.2, 3.5, 4.8, 8.5, 10.6, 12.5 and 18 microns. Each of these has a bandpass $\Delta\lambda$ such that $\frac{\lambda}{\Delta\lambda} = 10$. The tenth filter (nicknamed Alice) is a wide band filter extending from 0.3 microns to about 3 microns. It passes all the short wavelength radiation but eliminates the long wave thermal radiation. It is possible to detect hot sources with Alice at about 15 times greater sensitivity than the other short wavelength filters. Actually, Alice is a piece of microscope slide glass cooled to nitrogen temperature - hence, the nickname "through the looking glass".

The detector substrate contains a gallium doped germanium bolometer constructed by J. Stoddart. It has a thermal conductance (G) of about .3 microwatts/$_{\circ K}$ at the operating temperature of 1.1°K. Its responsivity is about a million volts per watt and its D.C. electrical noise equivalent power (NEP) about 2×10^{-14} watts.

The photometer contains a translating mirror beam switcher of the sort first developed by Fred Gillett at U.C.S.D. The chopper is mechanically moved by a cam at 10 Hz. Alternate gearing allows chopping at lower frequencies.

The dewar is of the general design developed at Minnesota. The nitrogen dewar is supported and filled through two fiberglass necks and the helium dewar is supported by a single inner fiberglass neck and by stainless steel "rigidizers" at the opposite end. No super insulation is utilized. The helium dewar is packed with "chore girl" copper to minimize "sloshing noise" when the dewar contains superfluid helium below the lambda point. Attention is paid to attempting to minimize microphonics as much as possible. The dewar weighs 5 pounds and the photometer weighs 10.5 pounds.

Observational Experience.

The system characteristics were determined in the laboratory with the "Maasometer" - a device for measuring the responsivity at all wavelengths with a small source operating at 550°K. This source is viewed through 10 Meters of room air by an eight-inch telescope to which the airplane system is attached.

After the characteristics had been determined the airplane dewar and photometer were used at the O'Brien Observatory on the 30-inch telescope to observe standard stars and establish the ground based sensitivity. When the resistance of a bolometer is monitored it becomes an absolute instrument and actual fluxes may be measured to several percent.

Two observing sessions were scheduled on the C141 telescope. These will be referred to as the A and B series. The A series took place near the fall equinox, August 12-23, 1974. This series has been described in detail. The system was used on the ground at Ames and in three flights. Table 1 shows the comparison of the signals obtained with those at O'Brien. The airplane telescope has the expected aperture advantage (36" versus 30") and in addition produces appreciably larger signals in the poorer atmospheric windows. Note especially 5 microns, 18 microns and to a lesser extent 3.5 microns.

Table 1. Zero magnitude microvolts airplane dewar.

site \ wavelength	1.6	2.2	3.5	4.8	8.5	10.6	12.5	18
Marine O'Brien Observatory winter	81	51	16.6	1.8	0.35	0.28	0.13	0.03
Ames - telescope on ground	125	72	24	2.4	0.46	0.42	0.19	
Average Flight	143	105	45	9.4	0.7	0.48	0.29	0.11
Ames ground 36" / O'Brien 30"	1.54	1.41	1.45	1.33	1.31	1.50	1.46	
41,000 feet / ground	1.14	1.46	1.88	3.92	1.52	1.14	1.53	(3.7)

Since water vapor is the primary obscuring agent, the 5 microns of precipitable water vapor above the aircraft is a great advantage compared to a minimum of 500 microns at the highest driest mountain sites. (Mt. Lemmon and Mauna Kea).

In the A series we did have some problems with microphonics which kept us from reaching the ultimate sensitivity of the system.

However, in spite of the microphonic noise there were strong indications of the presence of sky noise worse at longer wavelengths and probably introduced by the turbulent boundary layer flow over the telescope cavity.

Although the A series was primarily an engineering sequence, a rather important scientific result was obtained. A very exciting object dubbed the "Egg nebula" had just been discovered and was being studied by a number of scientists at many observatories. This object (which is the most optically polarized object in the sky) is believed to be an excellent candidate for a pre-planetary system (like the sun and its planets). It was crucial to determine the nature of the infrared radiation at wavelengths longer than 18 microns, and an additional filter operating at 29 microns was used in the airplane to compare the egg with the Galilean satellites Jupiter III and Jupiter IV. The capability of the airplane system in making this measurement was a non negligible input in determining the physical characteristics of this very interesting astronomical object.

Attachments I and II describe the "Egg nebula" alias IV Zwicky 67 and indicate the role the airplane observations played.

The B series took place about the spring equinox, March 20, 1974.

During the interval between fall and spring a series of laboratory tests had been made to reduce the microphonics in the system. A modified doorbell banger was used to pound the dewar and produce levels of vibration comparable to those encountered in flight. These experiments led to a considerable improvement. In addition, improvements had been made in the aircraft servo system and the net result was that in the one flight that was made the microphonics were essentially negligible.

The B flight confirmed the presence of sky noise at the long wavelengths and showed that this sky noise is the limiting effect in determining sensitivity longward of 5 microns, in the mode of operation which we chose (chopping at 10 Hz). It is alleged by other observers that the sky noise is less at higher chopping frequencies but a synchronous demodulator noise run which we made did not indicate a large improvement at higher frequencies. There must be some improvement, however, because ground based sky noise seems to have a 1/f characteristic.

It was hoped in the B series to extend the observations to some interesting infrared stars, and to observe at wavelengths outside the atmospheric windows. These observations required the use of a wobbling secondary with adjustable throw and accurate offset guiding by the airplane telescope system. Neither of these capabilities existed in a workable form in the airplane as of the date of the March series. The success of the first flight in proving the limitations and verifying the transmission of the windows first measured in August was such that another engineering flight was not required. Alternate scientific programs utilizing the airplane systems "as is" were not judged by the principal investigator to be of sufficient scientific value to justify further flights.

It is hoped that further development of chopping secondaries and offset guiding will make such observations possible in the future.

Summary.

A). The Minnesota dewar photometer system allowed realization of the three goals listed in the introduction. To reiterate:

1) The system produced did allow the evaluation of an operating infrared system without a wobbling secondary on the telescope.

2) The system was used to study the transmission in the atmospheric windows and showed the very great advantage of observing with only 5 microns of precipitable water as opposed to ≈ 500 microns at the best ground based sites.

3) The airplane environment was evaluated and it was shown that in the chosen mode (chopping at 10 Hz) the sky noise in the aircraft produced the limit on sensitivity at wavelengths longer than 5 microns.

An unexpected scientific bonus was obtained in measurements of the "Egg nebula" at wavelengths longer than 20 microns.

Recommendations.

Future scientific usefulness of the airplane will depend on the following:

1) Installation of a completely reliable fully adjustable wobbling secondary for which the throw and frequency are adjustable from the control panels.

2) Offset guiding capability which will make it possible to nod the telescope utilizing stars as dim as 12th for offset guiding.

3) Attention to the problem of the boundary layer and the apparent limitation it imposes on signal to noise in the wavelength range from 5 to 50 microns.

4) Attempts to make the system more like a ground based telescope where one has accurate pointing and knowledge of right ascension and declination to the order of 10 arc seconds. The inertial navigation system accurately gives the position of the aircraft but no system presently measures the position of the telescope with respect to the aircraft allowing the calculation of right ascension and declination and image rotation which the astronomer needs and is used to.

It is believed by the principal investigator that further development along these lines can make the Kuiper airborn observatory an important national facility with unique capabilities to complement the largest and the most sophisticated ground based telescopes.

It is important as a goal, however, to try to improve the reliability and ease of operation so that astronomers may come with difficult observing programs and some hope of succeeding with them rather than having to compromise with less interesting "back-up programs" invented to try to "work around" the shortcomings of the airplane system in its present form.

DRAWINGS: 871 D1: PHOTOMETER SECTIONAL VIEWS (NOT FILMED)

871 E1: PHOTOMETER EXTERIOR VIEWS (NOT FILMED)

REPRINTS:

STUDIES OF THE INFRARED SOURCE CRL 2688
E P NEY K. M. MERRILL, E E BECKLIN G NEUGEBAUER AND C G WYNN-WILLIAM
REPRINT FROM THE ASTROPHYSICAL JOURNAL 198:L129-L134. June 15

SKY AND TELESCOPE VOL 49 NO 1 JANUARY 1975
SKYLAB PUBLISHING CORP 1974

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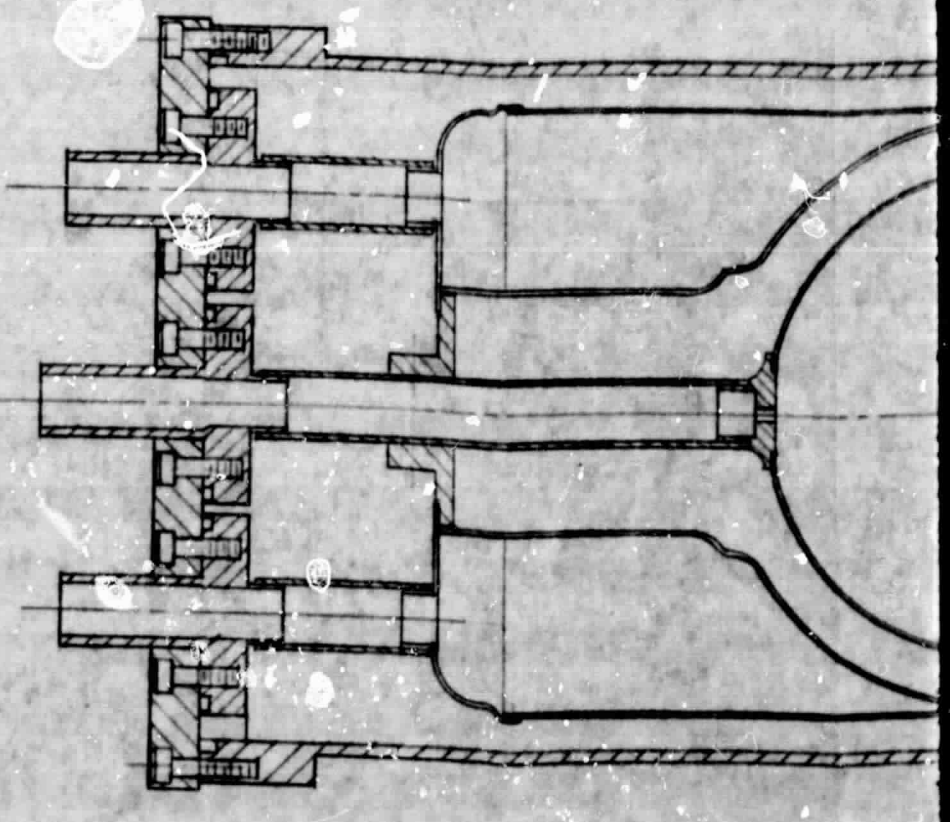

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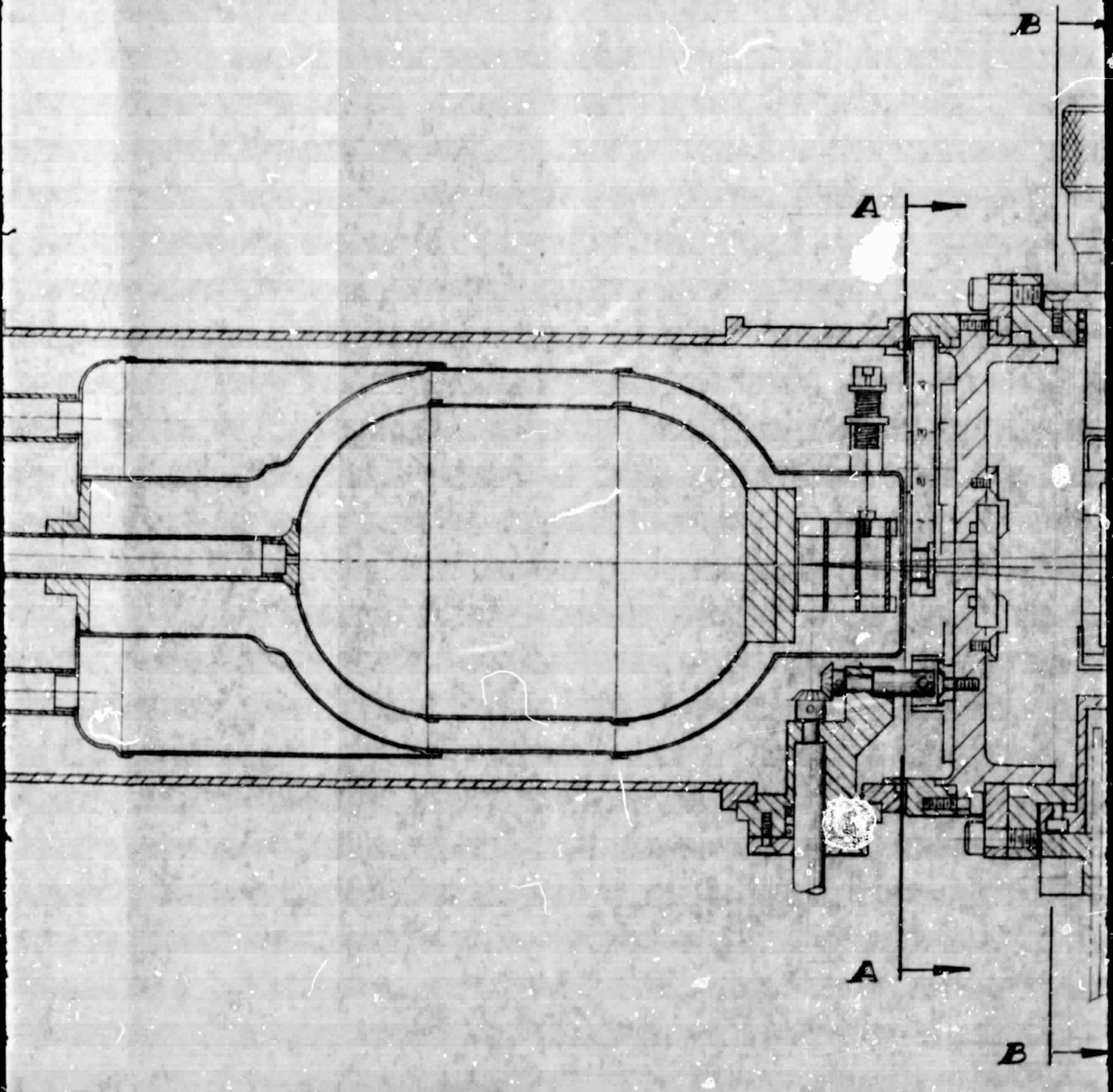

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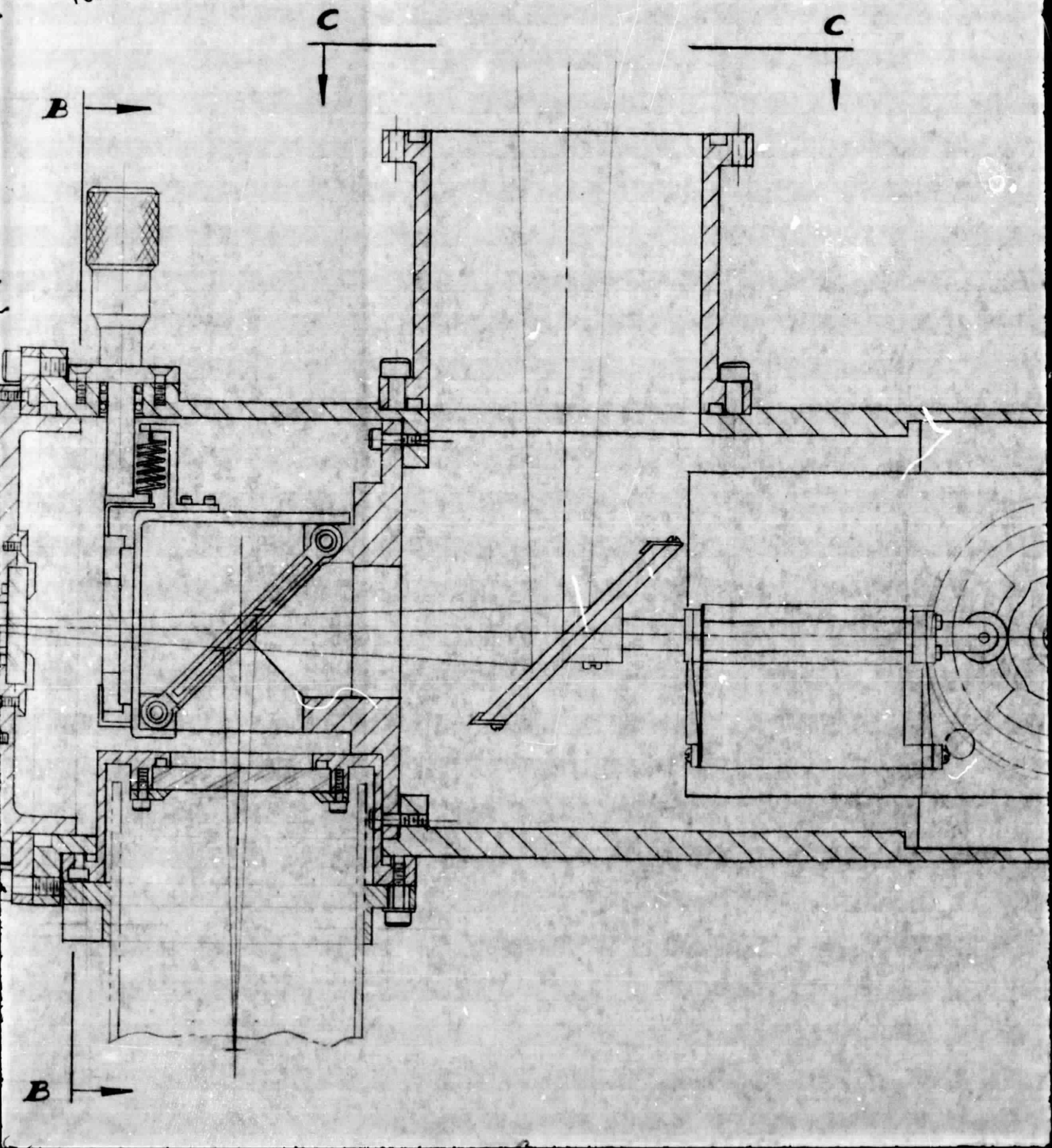

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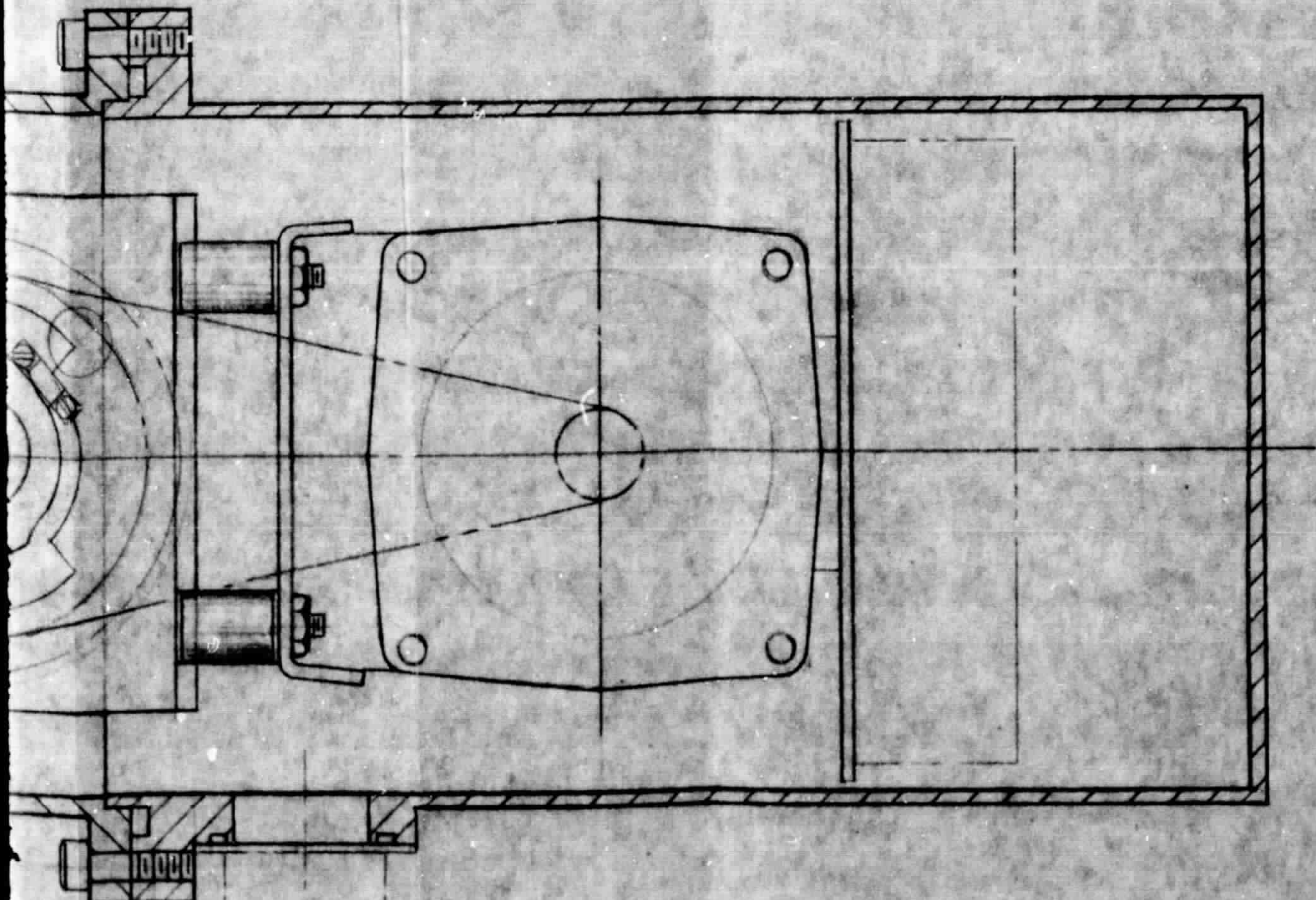

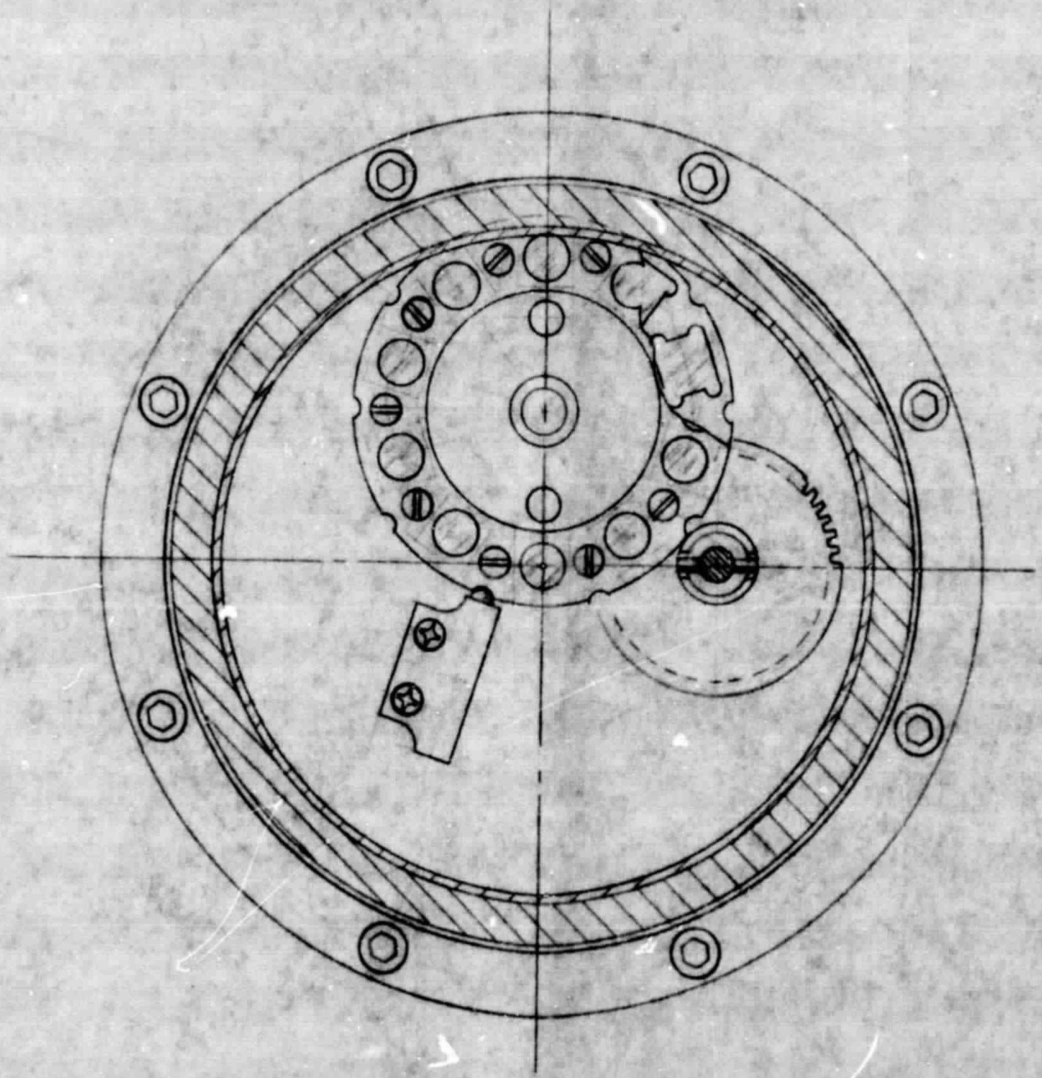

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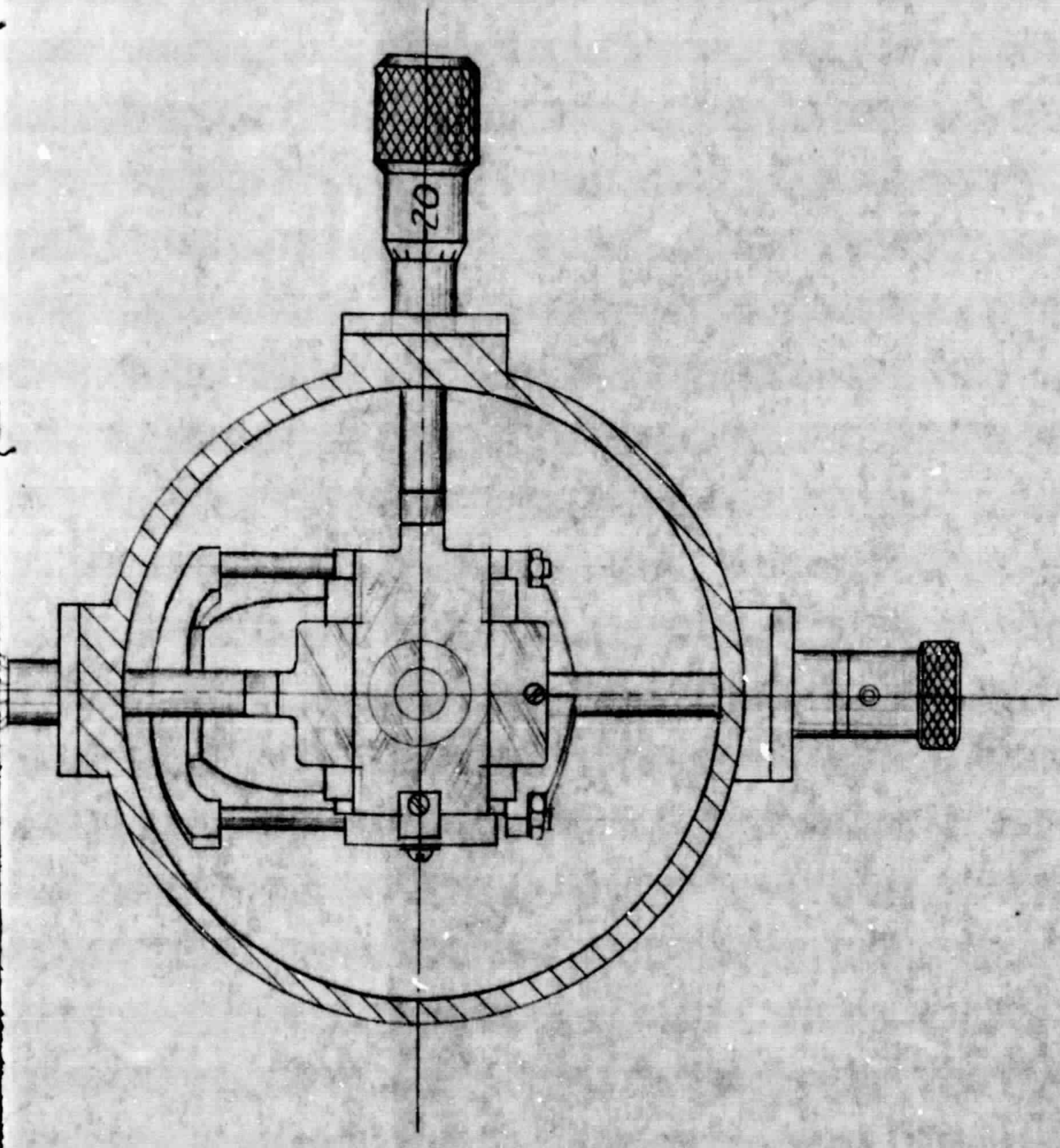

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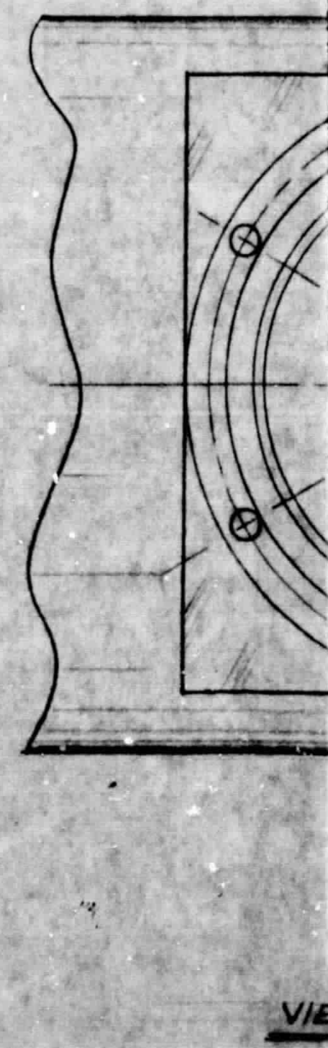

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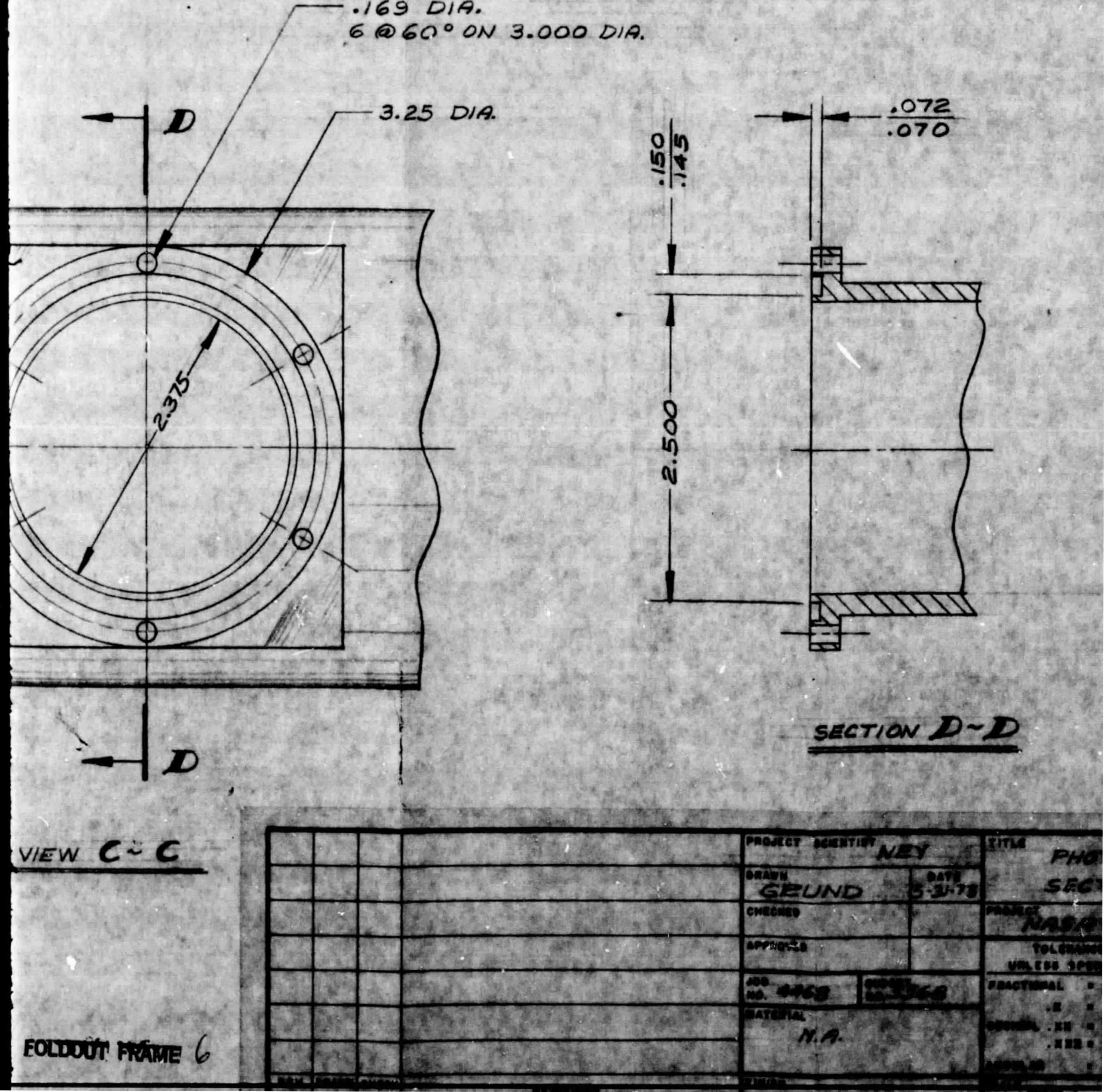

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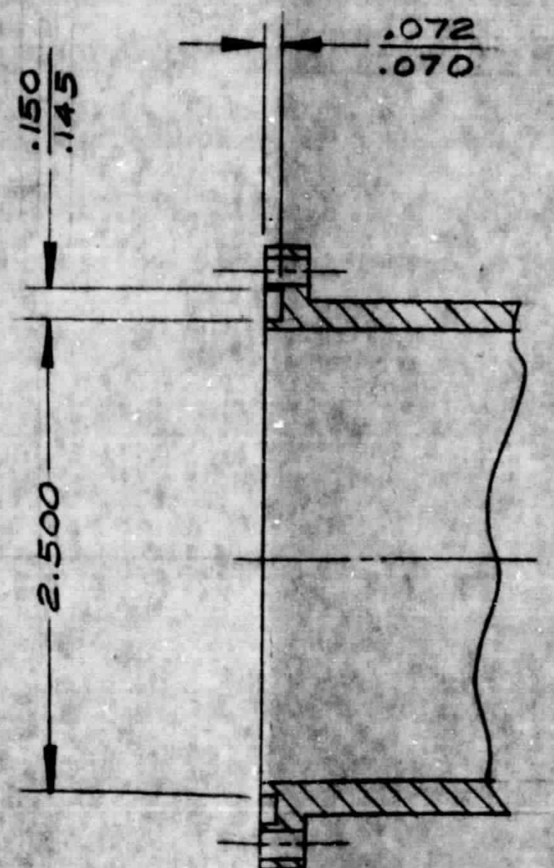

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PROJECT SCIENTIST NEY

TITLE PHOTOMETER SECTIONAL VIEWS

DRAWN GRUND DATE 5-31-73

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PROJECT NASA/ARC 36" AIRBORNE TELESCOPE

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