NASA CR-132266

N73 31411

LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS

UNIVERSITY OF COLORADO

BOULDER, COLORADO

80302

FINAL REPORT

ADVANCED APPLICATIONS FLIGHT EQUIPMENT (AAFE)

125 mm ULTRAVIOLET SPECTROMETER

CONTRACT NAS1-10388

LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS

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FINAL REPORT

FOR

AAFE 125MM ULTRAVIOLET SPECTROMETER

CONTRACT: NAS1-10388

DATE: December, 1972

Revised May, 1973

Approved:

James D. Cunningham

James D. Cunningham
AAFE Program Manager

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ACKNOWLEDGMENTS

This final report has been prepared under the direction of James D. Cunningham by Robert J. Schroeder.

The author wishes to thank Gail P. Anderson and Ken Kelly of the scientific staff; K. A. Gause and G. G. McNutt of the Space Instruments Division, for their valued technical guidance, advice and support.

1.0 INTRODUCTION

This final report of the Advanced Applications Flight Equipment 125MM Ultraviolet Spectrometer instrument describes the activities beginning at the stage wherein the conceptual work and/or scientific feasibility has been established and leading up to, but not including, the production of flight prototype hardware. These activities were carried out under contract number NAS1-10388 from the National Aeronautical and Space Administration, Langley Research Center to the University of Colorado, Laboratory for Atmospheric and Space Physics (CU/LASP) and were concluded in September 1972. The text below gives a history of the activities through the life cycle of the contract.

2.0 PURPOSE

The contract negotiations were completed in November 1970 directing CU/LASP to design and fabricate an instrument to measure atmospheric ozone as a function of height, latitude, and time, resulting in a December 1970 start date for the conceptual design. Additional design constraints provided for measurements of ozone concentration in the earth's atmosphere in the 25 Km to 50 Km region, provided for the sensor field of view to be approximately one-half of one degree, to furnish a fine global grid to study the effects of the ozone in the atmosphere, and provided for the resolution of the instrument to be approximately 10 Angstroms.

3.0 INSTRUMENT DESCRIPTION

The 125MM Ultraviolet Spectrometer consists of a telescope (125MM), an Ebert monochromator section (125MM) and a detector system consisting of two photomultiplier tubes with signal processing electronics to measure UV radiation in the 1050 - 4000 Angstrom range. See Figure 1a. The instrument case was machined from a solid 5" x 8¼" x 16" block of 6061-T651 wrought aluminum alloy and its finished weight was 4 3/4 pounds. The total weight of the instrument weighs 16 pounds. The design was based on the modular concept. The electronics and telescope baffling system, for example, are self-contained modules which when integrated to the instrument case, which in itself is a module, will form a complete instrument. The electronics consist of:

- Two Photomultiplier Tubes
- A High Voltage Power Supply for Each Tube
- A Preamplifier Discriminator for Each Tube

- Optical Fiducial Reader
- A Low Voltage Power Supply
- Engineering Data
- A Logic Module
- A Motor Driver

All of the above modules are side mounted entirely within the instrument case.

3.1 Instrument Case

The instrument case is the structural backbone for everything else. It is the optics mount for the mirrors. It is the thermal path that conducts heat away from the electronics, it is the stable platform or optical bench for the mirrors, and it forms a dark light-tight box for the optics.

Early in the effort it became apparent that the instrument case configuration presented a problem for optimum machining from a solid block of wrought aluminum alloy. The problem was to obtain an instrument case with the least amount of machining set-ups. Configuration studies were carried out in an attempt to obtain this goal. The final configuration provided for machining of the optical cavity and electronics cavity in one set up. The instrument case was subjected to a low temperature stress relaxation before final machining of critical surfaces. The stress relaxation was done at 375° F ± 10° F for four hours with an oven cool.

3.2 Optical - Mechanical Elements

The optical mechanical elements of the instrument consist of an off-axis telescope mirror, an Ebert monochromator, entrance and exit slits, and a periscope. The telescope focuses light on the entrance slit of the monochromator. Light from the entrance slit strikes one-half of the Ebert mirror which has a 125MM focal length. The light from the Ebert mirror is collimated onto the grating. The scanning grating disperses the light and returns it to the other half of the Ebert mirror. The light is then focused on the two exit slits. Behind the two exit slits are two photomultiplier tubes (see paragraph 3.6.1). Light from each slit is focused on its respective photomultiplier tube; however, the light is directed to one photomultiplier tube by means of a periscope positioned in back of one of the exit slits. The light focused on the photomultiplier tubes is converted to electrical signals that are proportional to intensity.

3.2.1 Primary Mirror

The primary mirror configuration is 2.000 x 1.594 with chamfers on the four corners. Two of the chamfers are .15 x 45 degrees, and the other two are .62 x 45 degrees. The mirror is symmetrical about a center line in the 2.000 direction. The optical surface is spherical with the focal point at 4.921 (125MM). The optical axis is .40 below the edge of the mirror in the 1.594 direction. The material from which the mirror is made is optical fuzed quartz per MIL-G-174. The optical surface is luminized and coated with magnesium fluoride for greater than 70% reflecting at 2150 Å. The mirror surfaces which contact the mirror mounting pads are fine grind surfaces.

3.2.2 Entrance Slit

A straight entrance slit whose aperture size is .014 x .394 is positioned at the focus of the telescope mirror. It is made from .012 thick Berylluim Copper, No. 172A per specification QQ-C-533 and heat treated to MIL-H-7199 for one-half hard quality.

3.2.3 Ebert Mirror

The Ebert mirror configuration is 2.000 x 3.38 with chamfers on the four corners. Two of the chamfers are .12 high x 35 degrees, and the other two are .43 high x 30 degrees. The mirror is symmetrical about a center line in the 2.000 direction. The optical surface has a 9.843 (250MM) radius and its axis is the intersection of two lines located 1.00 from the edge and 1.75 from the bottom of the mirror. The material from which the mirror is made is borosilicate No. 2 glass, Class 1, Grade A, precision annealed per MIL-G-174. The optical surface is ½ fringe quality, aluminized and coated with magnesium flouride for greater than 70% reflectivity at 2150 Å.

3.2.4 Grating

The Ebert mirror collimates light onto a 3600 lines/MM grating whose physical size is 28MM x 32MM x 10MM thick. The ruled area of this grating is 26MM x 26MM. Its blaze wavelength is 2400 Å, and blaze angle is 25° 36'. The ruled surface is coated with magnesium fluoride for reflectivity at 1216 Å, and the material from which the grating is made is borosilicate crown No. 2 glass. The geometrical relationship between the normal to the grating and the column of light striking the grating from the Ebert mirror determines which wavelengths will appear at the exit slits. As the grating is turned, the different spectral features (lines, bands and continua) are swept across the exit slits.

The relationship that governs which lines will appear is:

$$N\lambda = d\ (\text{Sin } i + \text{Sin } r)$$

Where N = Spectral order

λ = Wavelength of light

d = Grating constant

i = Angle of incidence between the incoming light and the grating normal

r = Angle of reflection

See Figure 6. As stated in paragraph 3.0 of this report, the wavelength range of interest is from 1050 Å to 4000 Å.

The data format is determined by the method in which the grating is moved. The scan is a repeated linear sweep for ease of analysis and optimum data gathering. That is, the scan starts at the short wavelength, then rapidly returns to the short end to start over. See paragraph 5.5 for further facts pertinent to the scan time.

3.2.5 Exit Slit

The exit slit has two apertures, the size of each being .0216 x .4724 with a center distance between them of .085. Two apertures are necessary in order to direct light to each of the photomultiplier tubes. The exit slit is made from the same material as the entrance slit.

3.2.6 Mirror Mounting

A deceptively simple looking problem, mirror mounting has a number of subtleties to be accounted for when designing for heavy vibration environments. Two items of prime concern are maintaining precise alignments and not straining the mirror. These considerations are somewhat at odds with the need to survive vibration and shock qualification tests. The philosophy was to reduce the number of piece parts in a mirror mount to a bare minimum--even at a sacrifice in the ease of adjustment.

The approach was to register the front and back surfaces of the mirror against plastic-tipped adjustment pins. These pins are slipped into holes machined into the case. To adjust the mirror the tip of the pins have to be machined. The plastic material mentioned, Fluorosint TFE Resin, is actually a pellet insert cemented into a counter bore in the adjustment pin. The plastic surface in contact with the mirror is spherical to allow tipping the mirror during alignment. This material is good in compression and will maintain its dimensional accuracy over long periods of time. To be aware of the dimensional stability of the plastic material, a half-thousandth change in any one pin can be detected in the optical alignment. Experience has shown that the mirrors could be removed and replaced in the instrument any number of times without causing a shift in alignment.

The mirrors are held against master reference pins by spring loaded cylinders. See Figure 2. The cylinder ends are also plastic-tipped and are coaxial with the reference pins so that the glass is loaded in compression without imparting a torque to it.

In terms of the ability of the glass to survive vibration and shock, it is simply noted that no glass has ever been damaged in instruments utilizing this concept of mirror mounting.

3.3 Light Shade

The light shade configuration, essentially a system of baffles, was designed to limit the incoming light to the primary mirror to $3^{\circ} \times 8^{\circ}\ 25'$. The concept of this module was based on the Mariner 9 design. The configuration is built up with three separate subassemblies; one mounting longitudinally to the instrument case, one mounting to the end of the instrument case, and the third, designed as a non-critical interface, mounting to the end of the light shade, to be configured according to the spacecraft requirements. It should be noted that the field of view of the instrument is further constrained by the entrance slit to less than one-half degree.

3.4 Monochromator

The monochromator design posed no design problems in that its design was based on the successful Mariner 9 concept. The monochromator consists of a spherical mirror in the Ebert Configuration and a movable grating. A discussion of these two items was carried out in paragraphs 3.2.3 and 3.2.4. The rotation angle of the grating ranges from 0 degrees to 45 degrees relative to the Ebert center line.

3.5 Grating Drive Mechanism

The grating drive mechanism is a self-contained module mounted to the case. The grating is articulated by a cam and pin follower which is driven by a hermetically sealed Hysteresis synchronous motor and gear train.

Inasmuch as the motor is in the optics cavity and is in close proximity to the diffraction grating a sealed motor drive was mandatory to preclude the possibility of depositing oil on optical surfaces. This was accomplished by using an output gear set in the planocentric configuration and then sealing the motor and speed reducer to the planocentric pinion by a bellows. The planocentric configuration uses an internally toothed ring gear on the output driven by a pinion. The pinion does not rotate in engagement with the gear in the usual manner but carries the ring gear along as it moves in translation along a circular path inside the ring gear. As a tooth of the pinion engages a tooth of the ring gear, the ring gear moves along with that tooth until the motion of the pinion moves it away from that point of contact and into engagement with the next tooth on the pinion. In this way, the ring gear is "walked" around by the motion of the pinion.

For a more detailed explanation of planocentric operation, consider Figure 3. As the eccentric causes the pinion gear to move in translation while the six pins riding in counterbores in the gear guide the path of translation to a pure circular motion. It should be noted from Figure 3 that the concentric internal toothed output gear is able to impart the required force as a result of the equal and opposite moment existing between the eccentric and the appropriate pins.

The planocentric gear can provide an unusually large speed reduction in a single step. In this case a reduction of 25 to 1 is achieved by using a 100 tooth gear on the output and a 96 tooth gear on the pinion. The gear ratio is determined by the ratio of the number of teeth on the output gear to the difference in numbers of teeth between the output and pinion gears.

$$\frac{100}{100-96} = 25$$

To see why this is true consider the expressions for the tangential velocities on the eccentric and the output gear.

$$V_t = e\,\omega_e$$

where

V_t = tangential velocity of the eccentric

e = eccentric arm

ω_e = angular velocity of the eccentric

also

$$V_t = r_o \; {}_o$$

where

V_t = tangential velocity of the output gear

r_o = output gear pitch radius

ω_o = angular velocity of the output gear

Since the angular velocity of the planocentric pinion is zero because it is moving with pure circular translation, all points on the pinion move with the same velocity. It follows that whatever velocity is imparted to the pinion by the eccentric will be transmitted unchanged to the output gear by the pinion.

$$e\,\omega_e = V_t = r_o \omega_o$$

$$\omega_e = \frac{r_o \omega_o}{e}$$

See Figure 4.

The pitch radius is clearly proportional to the number of teeth on the output gear and the eccentric is proportional to the difference in numbers of teeth between the output gear and the planocentric pinion.

There are some practical considerations to be taken into account when using an internal gear and a spur gear whose pitch circles are almost the same diameter. A secondary interference occurs about 10 teeth behind the point of engagement just as the teeth are separating. This is eliminated by making the addendum of each gear smaller and results in a modified stub tooth form.

Since these gears run in hard vacuum and are unlubricated, the material choice is important because of cold welding considerations. Nitralloy 135M single gas nitrided to R_c60 hardened to a depth of approximately one thousandth of an inch was used for both the pinion and the output gear. The bearings that support the output gear and cam are unlubricated ball bearings with teflon coated cages. The bearings internal to the sealed portion of the drive such as the eccentric bearings or the gear box bearings have a phenolic retainer impregnated with a silicone based oil.

3.5.1 The Motor and Gearbox

No discussion of the planocentric drive would be complete without mentioning the motor and gearbox. The motor is built on a size 11 servo motor frame.

The rotor bearings are preloaded for smooth operation as a protection against Brinelling during vibration, qualification testing, and flight launch conditions. This sensitive adjustment is made by measuring the coast-down time of an unpreloaded rotor and then slowly increasing the preload until the coastdown time is decreased by 20%. This insures that all radial play of the bearings has been removed but that these small and somewhat delicate bearings are not damaged or overloaded in a way which would shorten their life.

The center to center distance between the motor pinion and the first gear in the gearbox is critical for high efficiency and long life. In this area a few ten thousandths of an inch can be the difference between success and failure. And since the rotor has had all the radial play removed it is doubly important to locate the gearbox accurately.

In the interest of high efficiency and reliability the gearbox design approach is to dowel the stainless steel parts together and then line bore all bearing positions. In this way the gear shafts are guaranteed to be parallel and not shift out of adjustment during vibration. All gears and shafts are integral parts also made from Nitralloy 135M. The shaft bearings are preloaded by machining spacers to fit at the final assembly process.

To give a feel for the performance of the finished heremetically sealed high vacuum drive it was determined that the efficiency of the planocentric gear set approached that of spur gears and that the overall drive efficiency is approximately 90 to 95%. The accuracy of the drive depends on precision machining, and hand fitting of parts to produce the desired results.

The assembly is a many-step, rather complex and time consuming process. The planocentric drive has many virtues.

It is efficient and has a long life. It has been run in vacuum for test periods up to 10,000 hours. It is rugged and reliable. It acts as a bulkhead feedthrough and a speed reducer.

3.6 Circuit Design and Testing

Printed circuit boards were used extensively in the circuit design. An effort was made to select components and design low power radiation resistant circuitry of high reliability which could survive the anticipated environment.

Complimentary metal oxide semi-conductor (C/MOS) integrated circuits were used in the electronics because they require a very small amount of drive and bias current, they have built-in gate protection against static charges, and they operate over a wide voltage range. Six readings were taken during thermal testing of the electronic subsystem: at +50°C, + 25°C, +15°C, 0°C, - 15°C and -30°C. See Figure 5 for the functional block diagram of the electronics subsystem.

3.6.1 Photomultiplier Tubes (PMT)

The tubes selected were an EMR ASCOP 541F-09-18 with a cesium telluride photocathode and a magnesium fluoride window and a 541F-10-18 with a cesium telluride photocathode and a barium fluoride window. The tubes are operated with the photocathodes at ground potential.

3.6.2 Preamplifier Discriminator

The output from each photomultiplier tube (PMT) is connected to a preamplifer-discriminator. The preamplifier amplifies the pulse output from the PMT to an amplitude acceptable to the discriminator. The discriminator rejects pulses below fixed threshold levels, thus eliminating a major portion of the noise inherent in photomultiplier tube systems. The pulses not rejected by the discriminator will appear at the preamplifier-discriminator output as pulses with fixed amplitude and duration.

The outputs of the preamplifier-discriminators are connected to the data processor and control section. This section converts the data from the PMTs to the spacecraft data format and provides the necessary internal controls for proper instrument operation.

3.6.3 Data Processor

The data processor and logic consists basically of one 15 bit counter for each photomultiplier and preamplifier channel, a data compression counter to reduce the data to 8 bit words and a multiplexing system to present both detector channels on one data line.

The data compression counter receives the 15 bits of information from the channel counter. This data is then shifted towards the most significant bit end of the counter. The number of shift pulses required to shift the most significant (one) bit to the end of the counter is recorded in a (four) bit register. The data from this (four) bit register then becomes the first (four) bits of the 8 bit data word. The successive (four) bits in the 15 bit counter then become the last (four) bits of the 8 bit data word.

Automatic high voltage control is provided by a 16th bit in the channel counter. When the channel pulse count is high enough to cause a one in the 16th bit a logic signal is commanded to the high voltage to turn down the gain of the phototube; this is for protection of the tube in high light level conditions. When the light intensity is reduced sufficiently to reduce the count in the channel counter to one the command is removed and the high voltage returns to normal automatically.

The optional command section provides flexibility for spacecraft equipped with ground command capability to exercise the experiment through added functions in flight.

3.6.4 Motor Drive

The electronic motor drive module is a 300 Hertz two-phase square wave inverter that provides power to the grating drive motor.

3.6.5 Optical Fiducial

The optical fiducial reader contains a light source and a phototransistor. It identifies an index mark on the grating scan code wheel and initiates a pulse to the electronics logic and data module. The logic module generates two consecutive all one's eight bit words. This results in two consecutive decoded data count numbers that are larger in value and are easily recognized on the data stream. This pulse occurs during flyback of the scanning grating and indicates start of scan in the main data stream.

3.6.6 Engineering Data

Engineering data lines provide the means to check the status of critical and non-critical parameters, i.e., temperature LVPS voltages, etc.

3.6.7 High Voltage Power Supply

There are two identical high voltage power supplies; one for each PMT. These units are designed to operate indefinitely under short circuit or corona conditions. They are also equipped with external shutdown capability which will permit them to be shut down by the data processor and control device. This feature is included for protection of the photomultiplier tubes.

3.6.8 Low Voltage Power Supply

The low voltage power supply converts the spacecraft +28 V power to the levels required to operate the instrument. In addition, the power supply generates a clock which is used to drive the high voltage power supply. The low voltage power supply consists of a drive inverter, a power inverter, rectifier and filter assemblies, and output regulator.

The power inverter contains a transformer which provides the necessary secondary voltages to provide low voltage power to the instrument. These secondary voltages are rectified, filtered and regulated. Each regulator is provided with current limiting to protect the low voltage power supply from isolated failures.

4.0 ASSEMBLY, TEST AND CALIBRATION

The assembly, test and calibration of the instrument will be discussed in subsequent paragraphs under this general heading.

4.1 Assembly

The assembly of the instrument followed established rules for handling space qualified hardware only to the extent that all assembly work was accomplished by NASA qualified assemblers wearing appropriate clean room garments (hat, smock, gloves). Traceability or Configuration Control was not established because the contract stated that flight hardware would not be built. Individual parts were, however, packaged in plastic, sealed and stored in Controlled Inventory whenever they were awaiting assembly. Dowel pins were extensively used for aligning the various sub-assemblies to the instrument case. This provision makes it possible to disassemble and reassemble without losing registration.

Threaded fasteners are torqued using CU/LASP established torque values. The threaded fastener is the self-locking type and the threaded insert is the non-locking type. It should be noted that the locking element of self-locking screws is gradually degraded with use; therefore, the torque of each screw is measured during installation to verify the integrity of the locking element. When a screw fails to develop its minimum prevailing torque during installation, it is replaced with a new screw of like configuration.

4.2 Test

Tests were conducted at the subassembly level and at final assembly. In-house acceptance test procedures were prepared for items such as transformers, logic module, low voltage power supply module, high voltage power supply module, and the preamplifier/discriminator. Final assembly tests included optical alignment tests, operations of the instrument with the Bench Checkout Equipment to determine operational verification, various tests conducted in a vacuum chamber to verify the integrity of the instrument in this environment.

4.3 Calibration

The ozone experiment requires a calibration from 2000 Å to 3000 Å. This is accomplished by three overlapping methods.

The first method uses a NBS calibrated tungsten strip lamp which illuminates a Magnesium Oxide screen providing a known uniform diffuse source. This method is used for the region 2250 Å to 3000 Å.

The second method uses a NBS calibrated photodiode to measure the total flux from a monochromator and light source combination. This light will illuminate a Magnesium oxide screen. This method is used for the region 2000 Å to 2537 Å.

The third method uses a theoretical molecular branching ratio to give a relative calibration for the region 2000 Å to 3000 Å. The light source is made with low energy electrons colliding with low pressure gases. Nitric Oxide and Nitrogen is used at about 10^{-4} MM of Mercury pressure. Previously measured electron cross sections will be used to check the absolute calibration.

A collimated xenon light source is used to measure the off axis scattering. This source approximates the solar flux in the 2000 Å to 6000 Å region. The instrument is rotated in this beam and the relative scatter versus angle is measured.

The xenon light source is used with an electronic shutter and a Magnesium Oxide screen to simulate the earth as viewed from a rotating spacecraft. The recovery time of the instrument is then measured. To specify quantitatively the state of polarization of a beam of light, just four numbers called the Stokes parameters, are required.

These parameters will be measured. A Polacoat ultraviolet polarizer is used to measure the linear components. A Fresnel rhomb plus the Polacoat is used to measure the elliptical component. A deuterium lamp with a Magnesium Oxide screen is used for the source. A monochromatic collimated source is used to map the angular sensitivity of the instrument. This measurement can be accomplished by rotating either the instrument or a source mirror. This same arrangement is used to measure the internal scattering of the instrument.

The sensitivity versus wavelength is measured with the movable grating stopped. This measurement is for the 2000 - 3300 Å region, and is done for three grating settings; 2000 Å, 2500 Å and 3000 Å.

5.0 PERFORMANCE PARAMETERS

The performance parameters for the instrument are listed in the following paragraphs.

5.1 Spectral Range

The spectral range of 1050 Å to 4000 Å will be scanned by the instrument.

a. The cesium telluride tube with magnesium fluoride window will measure the spectrum between 1150 Å and 1900 Å. This is channel No. 1.

b. The cesium telluride tube with barium fluoride window will measure the spectrum between 1700 Å and 3400 Å. This is channel No. 2.

5.2 Dynamic Range

The dynamic range of the instrument is from 10 Rayleighs per 20 Å interval to 200 kilorayleighs per 20 Å interval for channel No. 1 and 10 Rayleighs per 20 Å interval to 5 megarayleighs per 20 Å interval for channel No. 2.

5.3 Resolution

The resolution of the instrument for first order spectra is 10 Å.

5.4 Accuracy

The accuracy of measurement is 10%.

5.5 Scan Time

One scan is made every 3 sec. 180 millisec of the scan time is required for grating flyback, i.e. return of the grating to the beginning of the scan range.

5.6 Sampling Rate

Each channel is sampled every 20 msec. Channel 2 is sampled 10 msec. after channel 1. There are 50 samples/sec/channel or 100 samples/sec total.

6.0 ADAPTIVE MODE REAL TIME ANALYSIS

Photochemical theory predicts very little change in ozone concentration as a function of latitude at and above the 40 KM (2mb) level because of fast (1 hour) time constants. Satellite results show a direct contradiction to this photochemical theory.[1] There are apparent changes in O_3 as a function of season, latitude, and longitude. (See figures No. 7 through 12.)

In the past[2] global analysis of ozone has involved large, expensive, complicated computer procedures. A real time analysis of ozone must avoid these characteristics, providing fast, inexpensive, and correct solutions. To satisfy these requirements implies using the minimum number of input parameters while maintaining an overdetermined system. Also, adaptability to a small computer system requires using the smallest possible matrix size.

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[1] London, J., Anderson, G.P., Frederick, J., "The Global Distribution of Atmospheric Ozone Derived from OGO-4 Satellite Observations," EOS, Transactions of the American Geophysical Union, Vol. 53, II, November, 1972.

[2] Anderson, G.P., "The Vertical Distribution of Ozone Between 35 and 55 KM as Determined from Satellite Ultraviolet Measurements," Masters Thesis, University of Colorado, 1969.

The actual system of equations used to solve for the vertical distribution can vary. The simplest technique for pressures less than 10 mb (above 30 KM) involves the single scattering solution to the transfer equation.[3] This equation, when converted to a matrix formulation, yields only 4 independent parameters or 4 independent pieces of information available about the O_3 distribution. If another algorithm for finding the vertical distribution were used, there would still remain only 4 independent parameters governing that distribution above 30 KM. From ground based measurements, Mateer[4] found only 4 indpendent parameters governing the distribution from 0 to 40 KM. To find the total vertical ozone profile from 0 to approximately 60 KM would then involve between 4 and 6 independent variables. The most succinct choice of these variables has not been considered here but must involve

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[3] Anderson, G.P., "The Vertical Distribution of Ozone Between 35 and 55 KM as Determined from Satellite Ultraviolet Measurements," Masters Thesis, University of Colorado, 1969.

[4] Mateer, C.L., "A Study of the Information Content of Umkehr Observation," University of Michigan Technical Report No. 2, 1964.

careful consideration of the limited information content of the problem as a whole.

Using these criteria, the minimum input hypothesis has been constructed.

6.1 Vertical Ozone Measurement Minimum Input Hypothesis

The choice of wavelengths for determining the vertical distribution is based on:

1. the number of mathematically free (independent) parameters is limited, i.e., no more than 6, more likely 4. (The present inversion technique has only 4 significant eigen values governing the distribution above 30 KM).

2. the wavelengths chosen should fall in an even distribution within the stratosphere.

3. by choosing two sets of wavelengths to independently derive the vertical distribution, one can establish reliability.

4. the instrument resolution should be sufficient to wash out the fine structure of the absorption coefficient, i.e., 10 Å.

The wavelengths chosen according to the above are two sets of 6 wavelengths each*

*If it is possible to find more independent parameters through a new mathematical formulation, the 12 wavelengths should still be enough to overdetermine the system.

	Set #1	(Å)	Set #2	~ α_λ (cm^{-1})	~ alt(km) 0° Zenith
Set #1	2555			296	48
		2700		200	46
	2775			125	44
		2835		71	42
	2875			46	40
		2920		28	38
	2960			17	36
		2995		10	34
	3020			7	32
		3045		5	30
	3075			3.5	30
		3125		1.7	20

The total ozone measurement can be done using two pair of wavelengths between 3100 and 3400 Å, plus one wavelength outside the Huggins absorption band. This scheme supplies redundancy plus an estimate of ground and sky albedo.

	Set #1	(Å)	Set #2	
Set #1	3125			
		3175	Set #2	Necessary for changing zenith angle also
	3300			
		3400		
	3600	ground albedo		

7.0 INTERFACE DEFINITION

The interface requirements are defined in the following paragraphs.

7.1 Mechanical Interface

The Ultraviolet Spectrometer must be mounted to a spacecraft structure through mechanical mounts. Two configurations can be adopted; one with an interface plate, and one without an interface plate.

7.2 Electrical Interface

Electrical interface requirements with a typical spacecraft are described below.

7.2.1 Power

A. +28V DC at 600 ma nominal-actual +24V DC to 36V DC

B. Optional Power

1. 400 HZ 28V RMS nominal, Min. 24V RMS, Max. 60V RMS
2. 2400 HZ 28V RMS nominal, Min. 24V RMS, Max. 60V RMS

7.2.2 Spacecraft Timing

A. Read sync command maximum repetition rate 5 milliseconds; typical 10 milliseconds

B. Data shift clock Min. 2 KHZ

7.2.3 Word Length

A. Min. 8 bits

7.2.4 Ground Commands

A. Optional (generally 8 bit serial command to change high voltage, change counter integration time or override experiment auto functions).

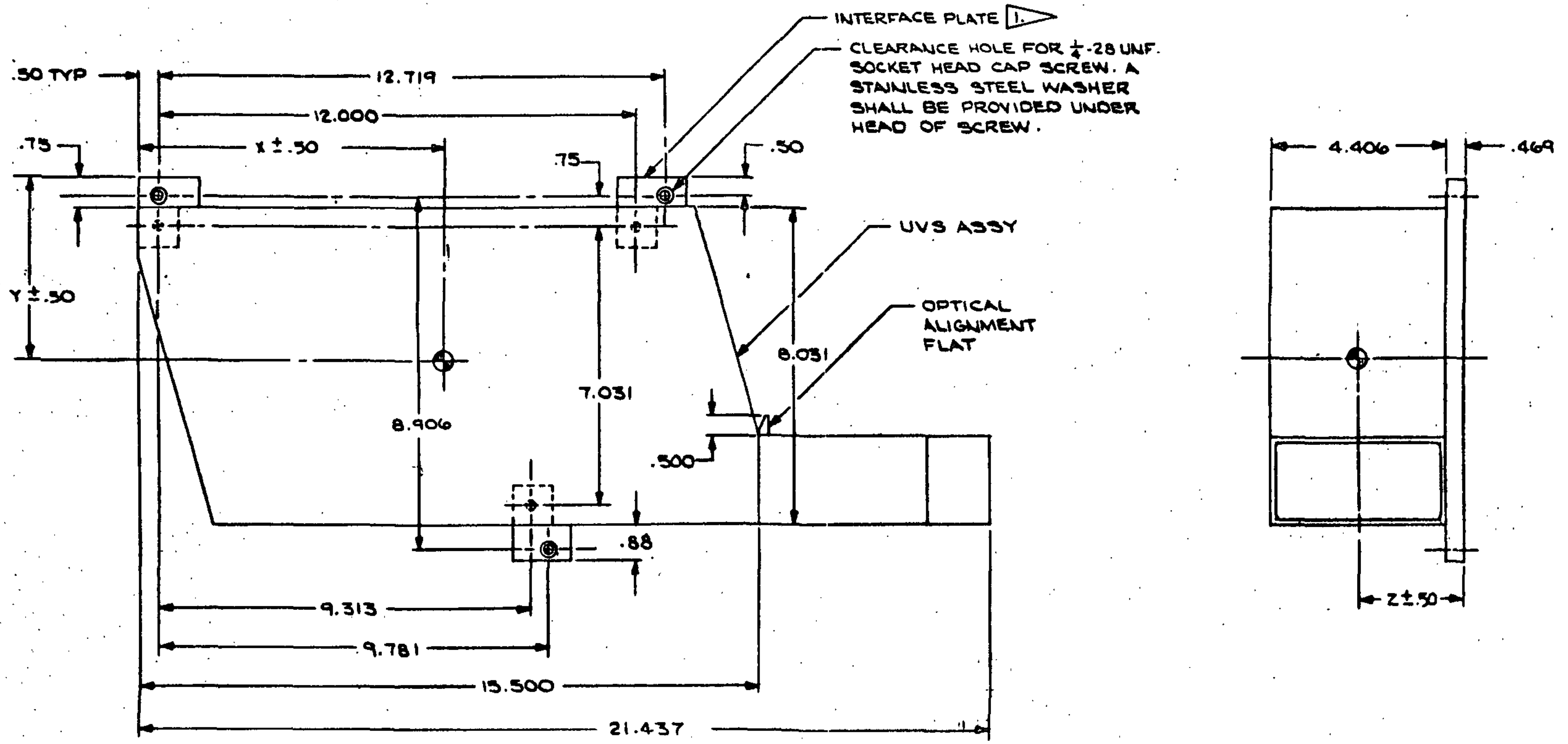
8.0 PHOTOGRAPHS

Several representative photographs of the instrument are included in this report for informational purposes.

REVISIONS				
LTR.	DESCRIPTION OF CHANGE	DRAWN	APPROVED	DATE
A	RELEASE FOR EXPERIMENTAL	[illegible]	[illegible]	[illegible]

GENERAL NOTES UNLESS OTHERWISE SPECIFIED

1. INSTRUMENT CAN BE MOUNTED TO STRUCTURE IN EITHER OF TWO CONFIGURATIONS: WITH OR WITHOUT INTERFACE PLATE.



PHYSICAL PROPERTIES		
WEIGHT		16 LBS
CENTER OF GRAVITY	X	7.67
	Y	4.66
	Z	2.64

ITEM NO.	NO. REQD	PART OR IDENTIFYING NO.	PART NAME	STOCK SIZE OR MANUFACTURER	MATERIAL

BILL OF MATERIAL

UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES
MILLIMETERS ARE IN PARENTHESIS
TOLERANCES: .XXXX BASIC
.XXX ±.005 (.13)
.XX ±.02 (.51)
ANGLES ± 0° 30'

Metric Equivalents, to the nearest .01 mm, Are Given For General Information Only And Are Based Upon 1 Inch Equals 25.4 mm.

DO NOT SCALE DRAWING
REMOVE BURRS & SHARP EDGES
MACHINE FINISH

CONTRACT NO.	NAS1-10388	
DRAWN	[illegible]	1-7-72
CHECKED	[illegible]	1-7-72
APPROVED		
APPROVED		

ENGINEERING DIV-LASP
UNIVERSITY OF COLORADO
BOULDER

UVS OUTLINE

125 MM

SIZE	CODE IDENT NO.	
C	28981	2-20506-00-0001
SCALE 1/2		SHEET 1 OF 1

NEXT ASSY	USED ON
	AAFE
APPLICATIONS	

APPLICABLE SPECIFICATIONS

FIG. NO. 1

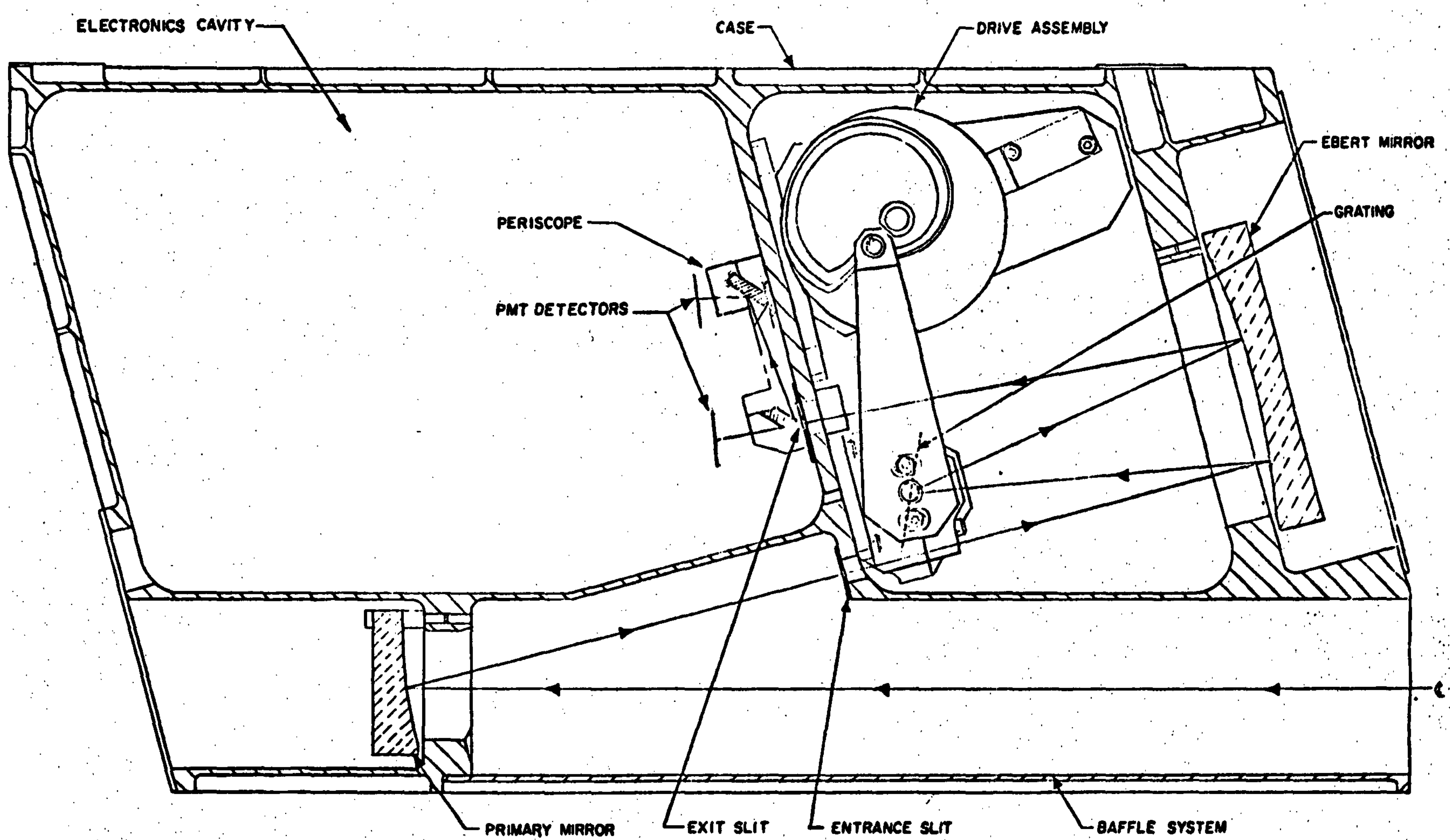

ELECTRONICS CAVITY
CASE
DRIVE ASSEMBLY
EBERT MIRROR
GRATING
PERISCOPE
PMT DETECTORS
PRIMARY MIRROR
EXIT SLIT
ENTRANCE SLIT
BAFFLE SYSTEM

FIG. NO. 1a

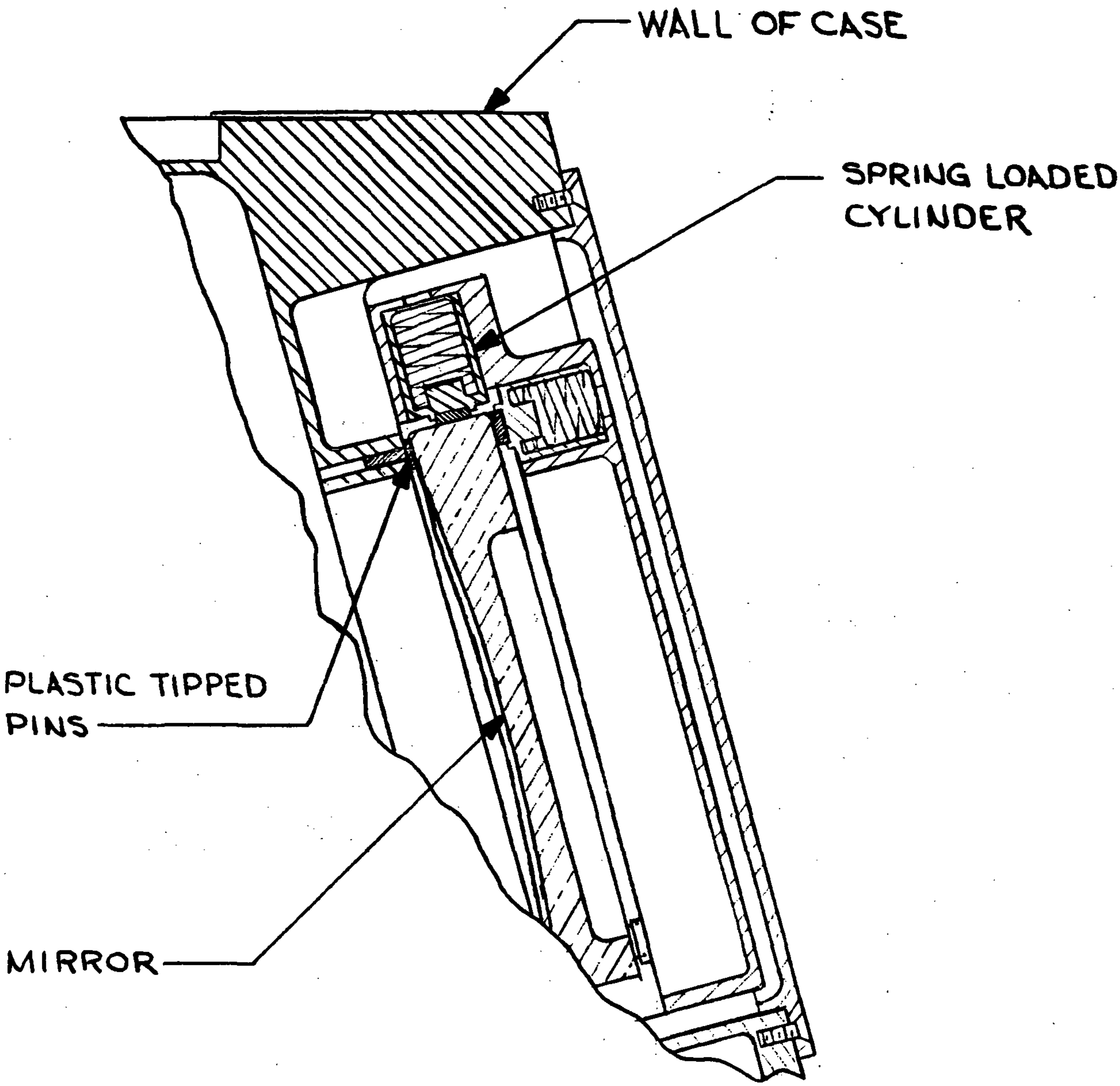
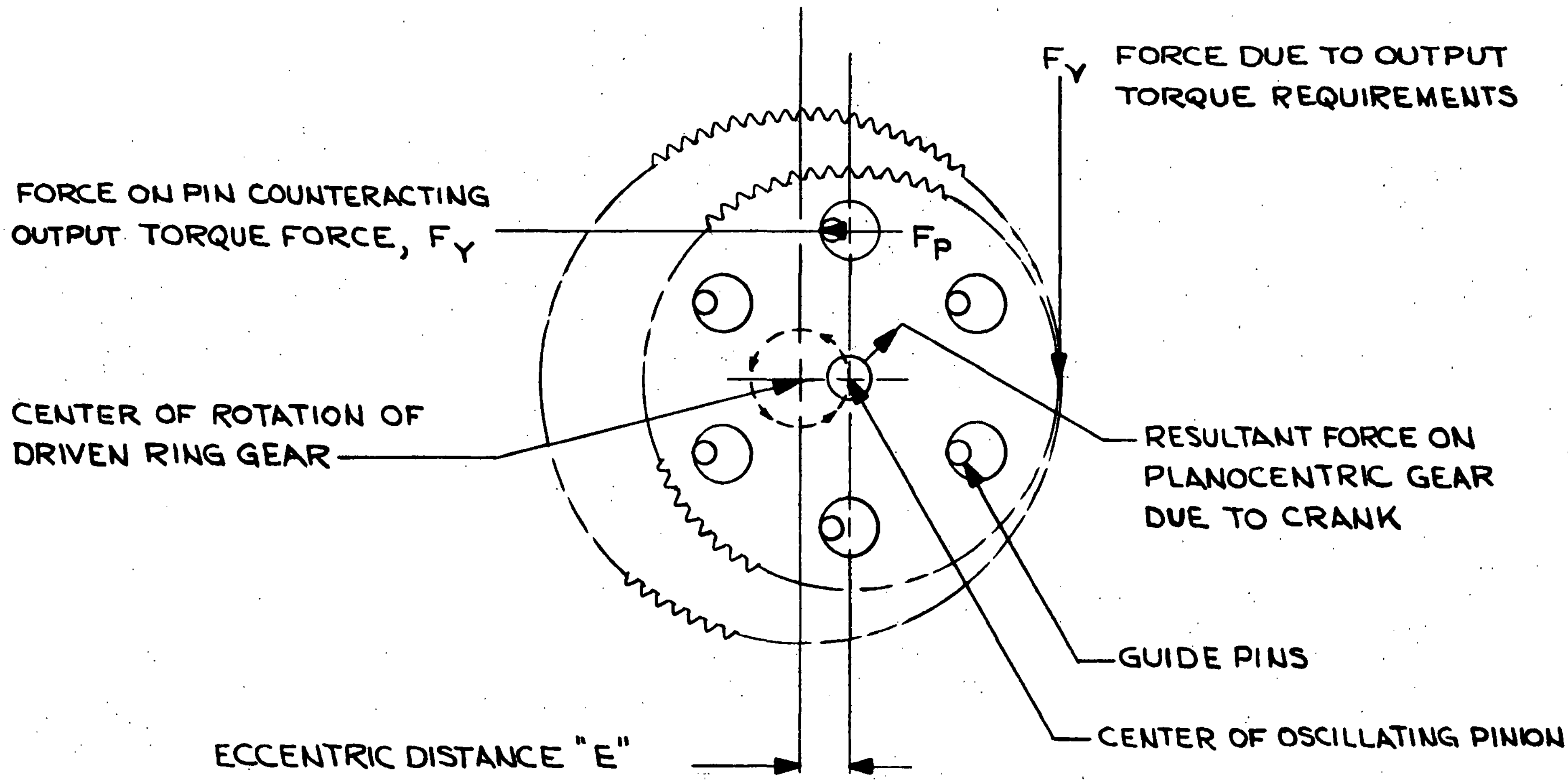

WALL OF CASE
SPRING LOADED
CYLINDER
PLASTIC TIPPED
PINS
MIRROR

FIG. NO. 2



FORCE ON PIN COUNTERACTING OUTPUT TORQUE FORCE, F_Y
F_Y FORCE DUE TO OUTPUT TORQUE REQUIREMENTS
F_P
CENTER OF ROTATION OF DRIVEN RING GEAR
RESULTANT FORCE ON PLANOCENTRIC GEAR DUE TO CRANK
GUIDE PINS
CENTER OF OSCILLATING PINION
ECCENTRIC DISTANCE "E"

FIG. NO. 3

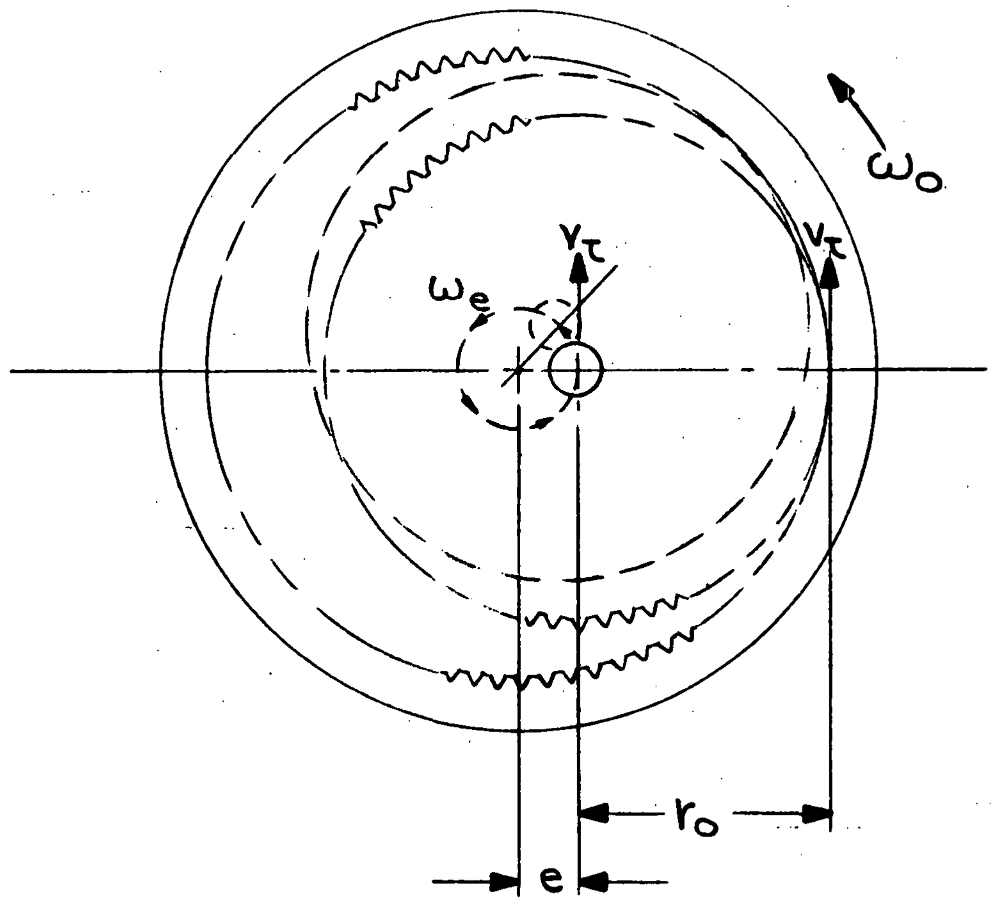
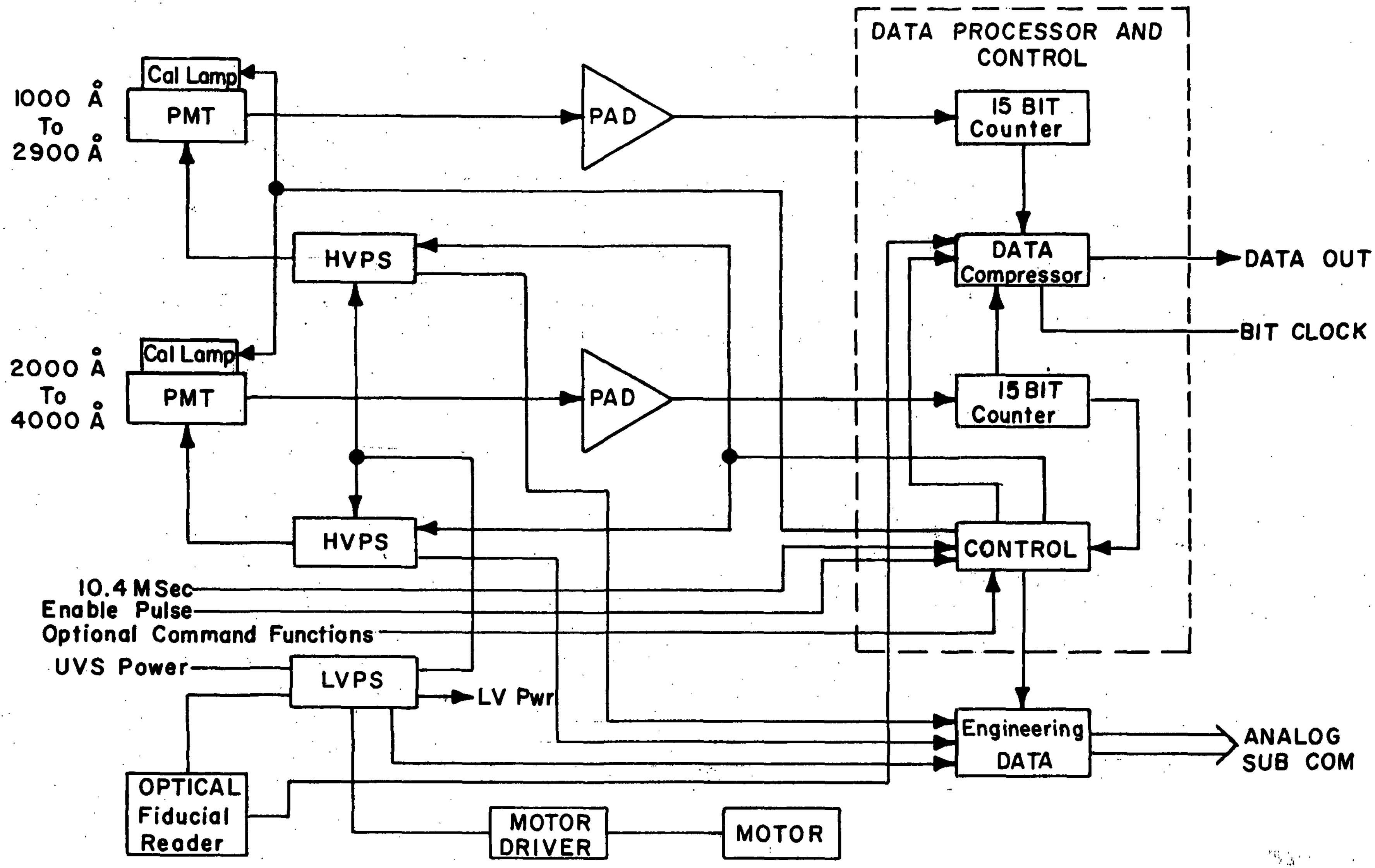


FIG. NO. 4

PAD = Preamplifier Discriminator



FUNCTIONAL BLOCK DIAGRAM

FIG. NO. 5

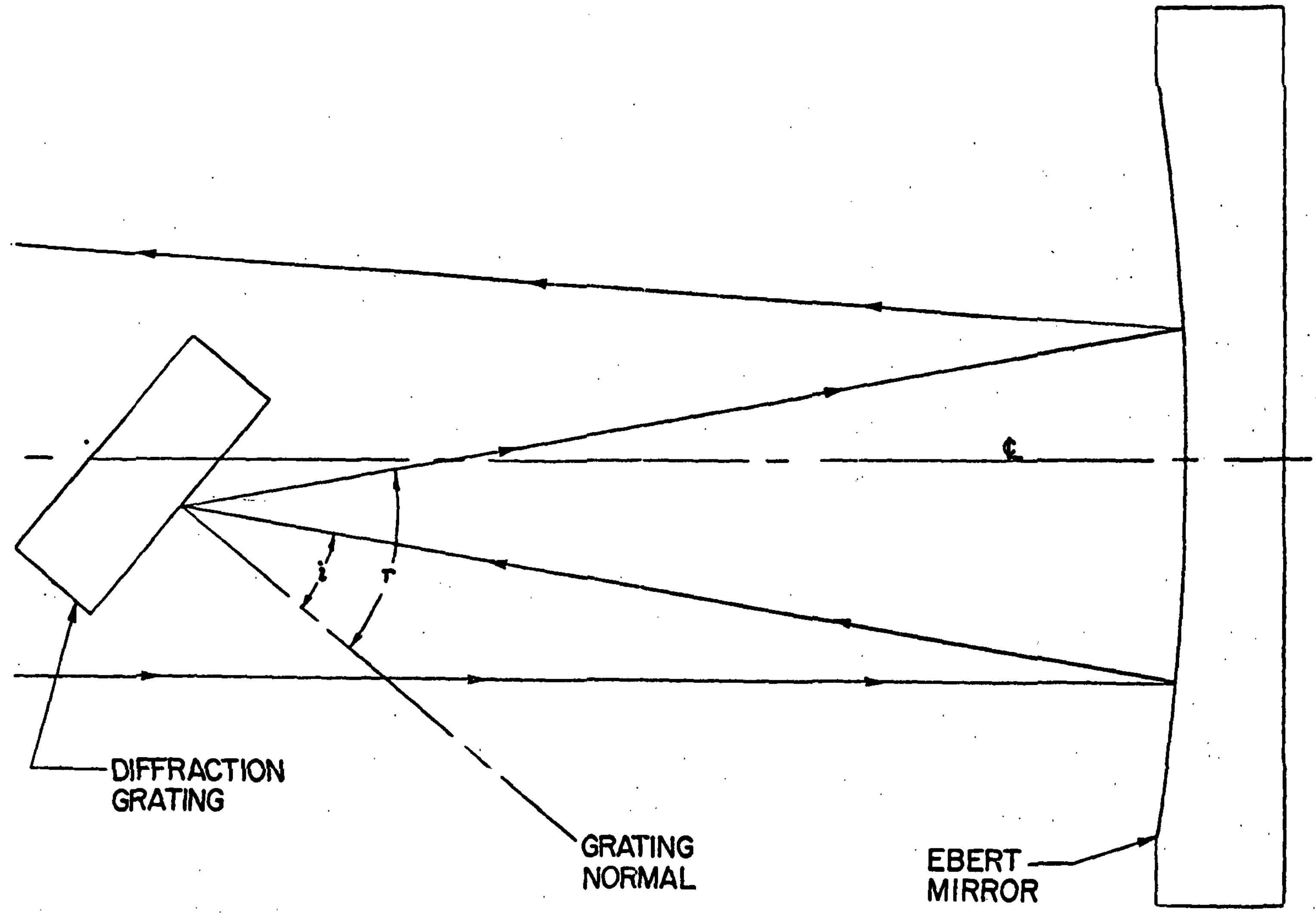
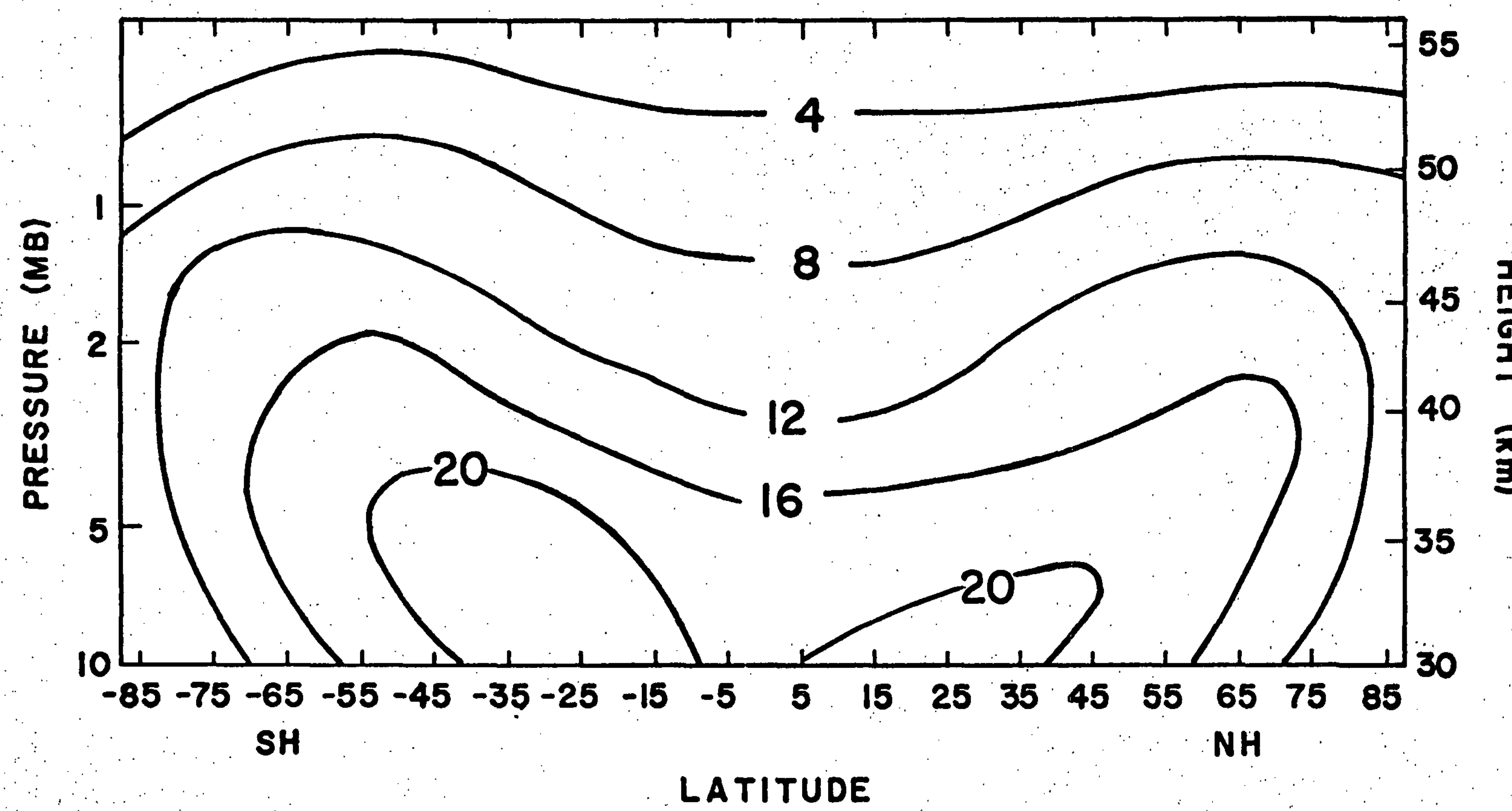


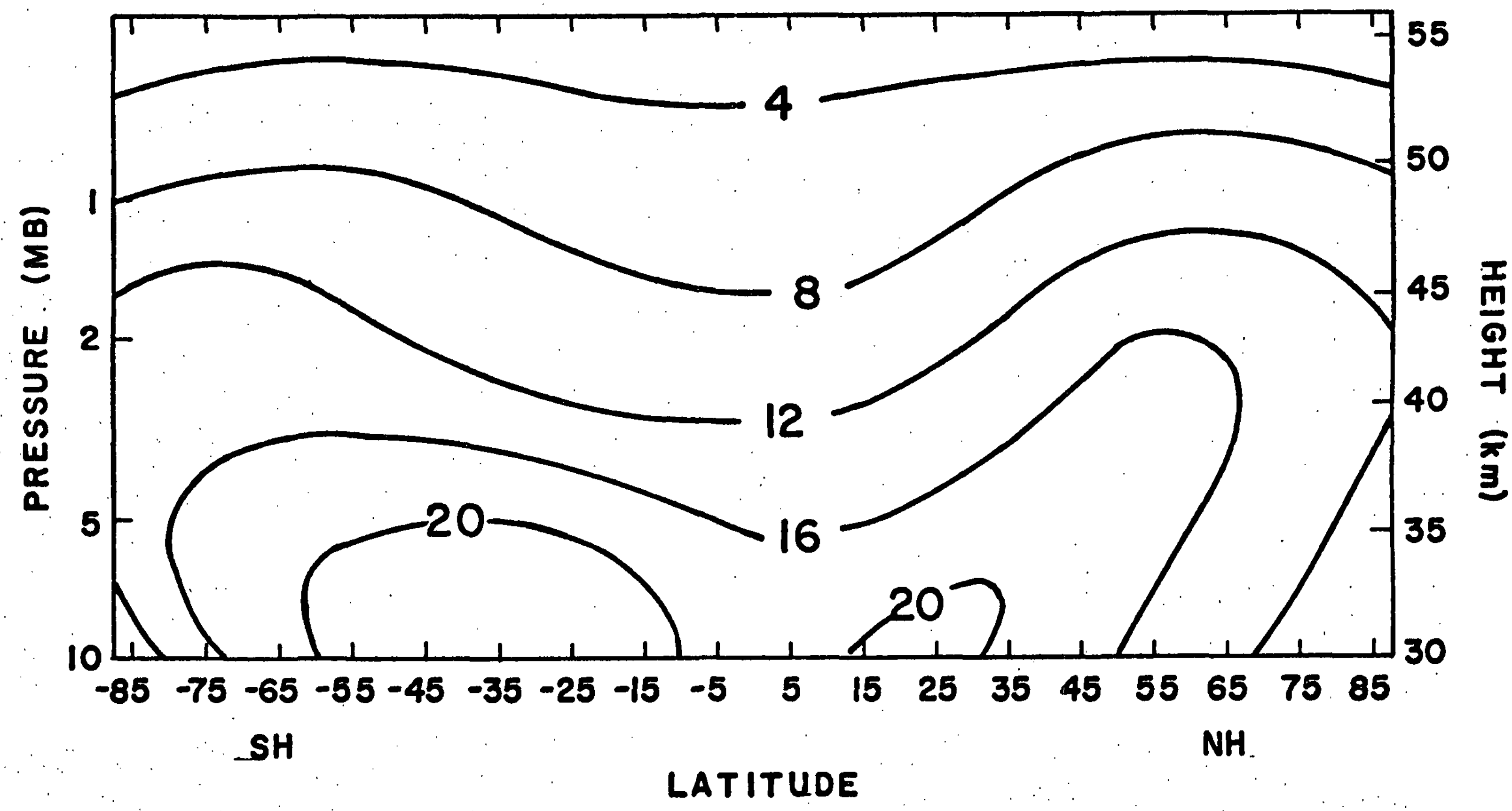
FIG. NO. 6



CROSS SECTION OZONE MIXING RATIO ($\mu g/g$)

SEPTEMBER 1967

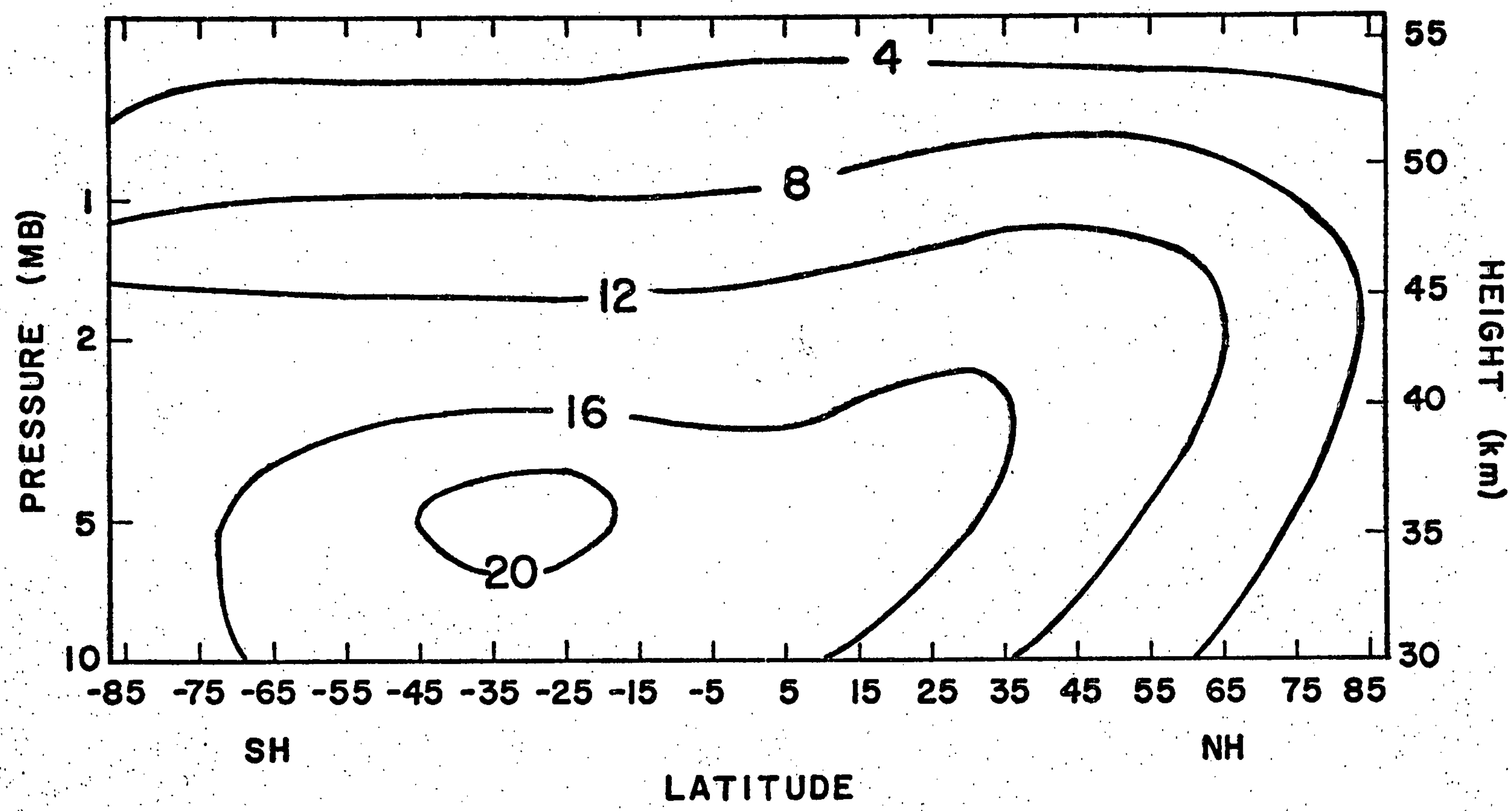
FIG. NO. 7



CROSS SECTION OZONE MIXING RATIO ($\mu g/g$)

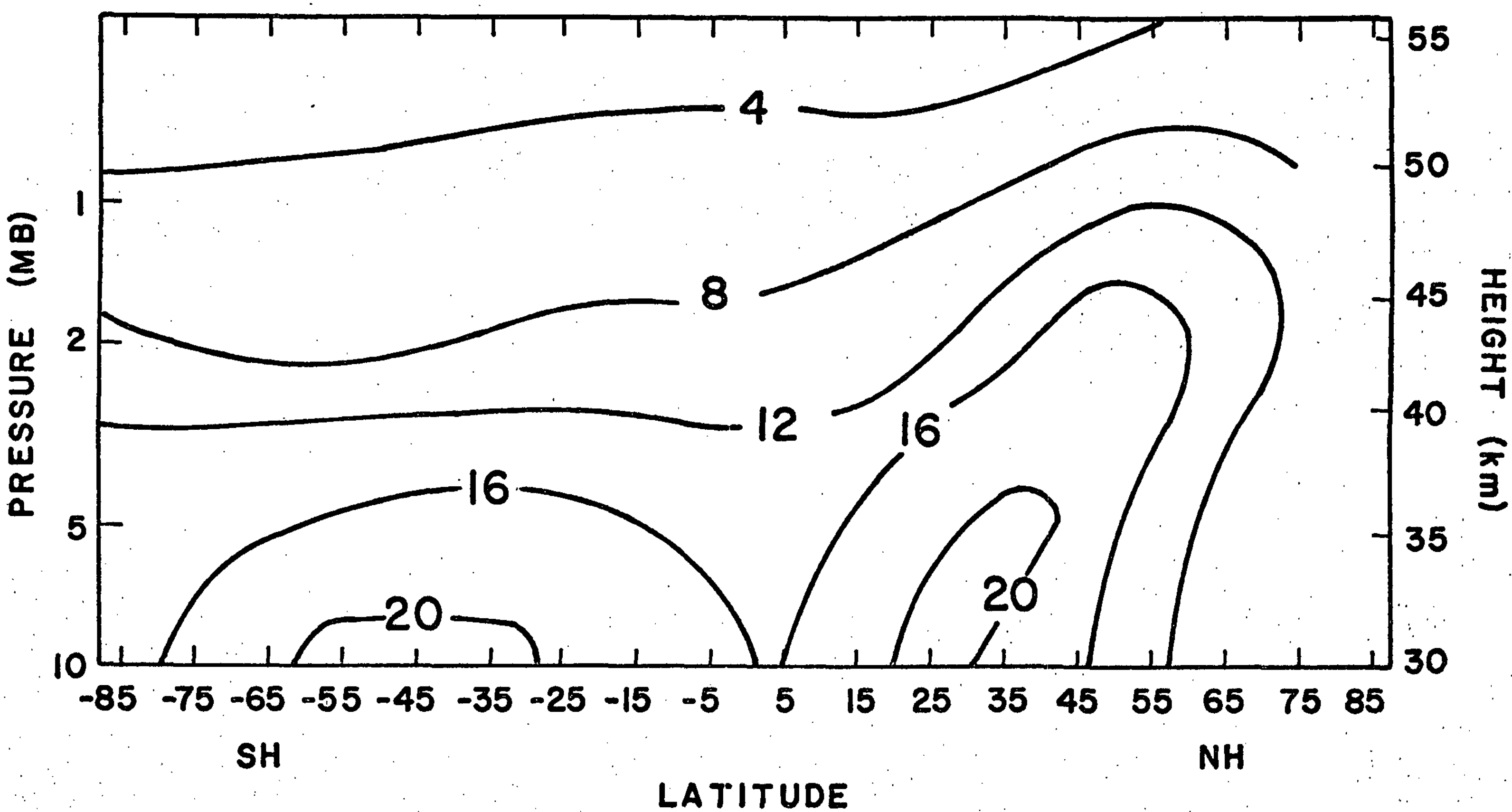
OCTOBER 1967

FIG. NO. 8



CROSS SECTION OZONE MIXING RATIO ($\mu g/g$)

FIG. NO. 9 NOVEMBER 1967



CROSS SECTION OZONE MIXING RATIO ($\mu g/g$)

FIG. NO. 10

JANUARY 1968

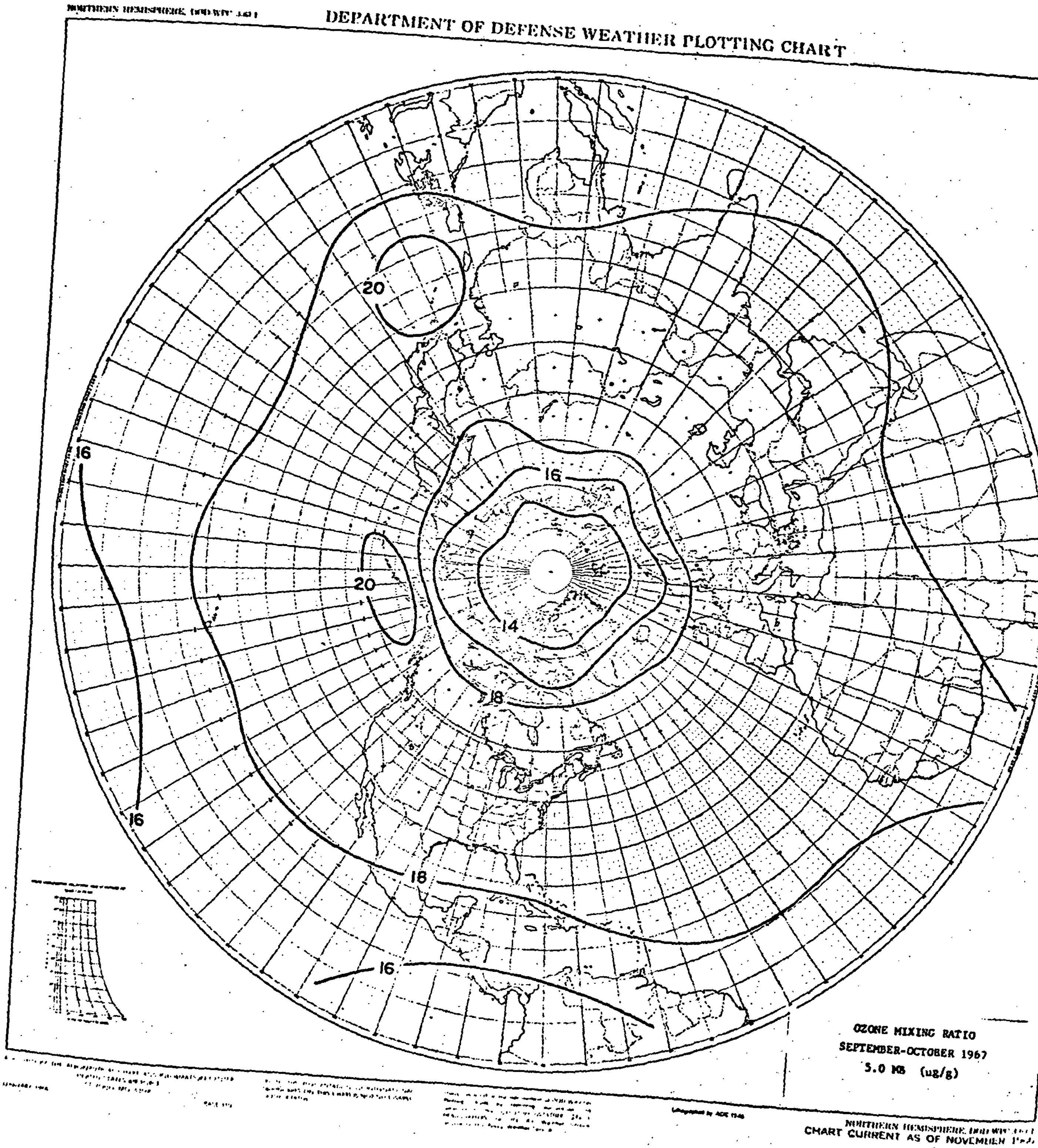

DEPARTMENT OF DEFENSE WEATHER PLOTTING CHART
20
16
20
14
16
18
16
18
16
OZONE MIXING RATIO
SEPTEMBER-OCTOBER 1967
5.0 MB (ug/g)
CHART CURRENT AS OF NOVEMBER

FIG. NO. 11

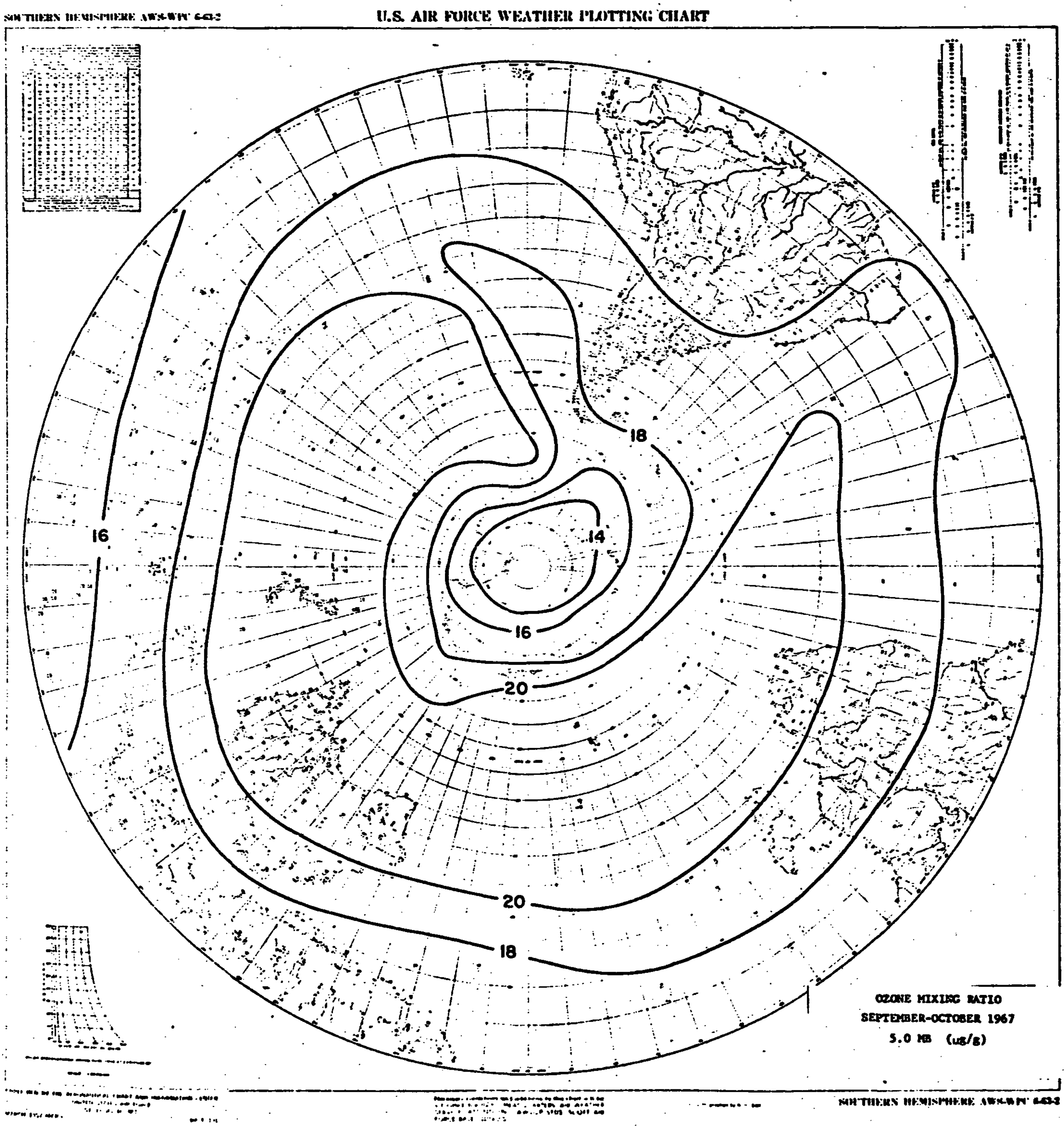

SOUTHERN HEMISPHERE AWS-WPC 6-63-2
U.S. AIR FORCE WEATHER PLOTTING CHART
16
18
14
16
20
20
18
OZONE MIXING RATIO
SEPTEMBER-OCTOBER 1967
5.0 MB (ug/g)
SOUTHERN HEMISPHERE AWS-WPC 6-63-2

FIG. NO. 12

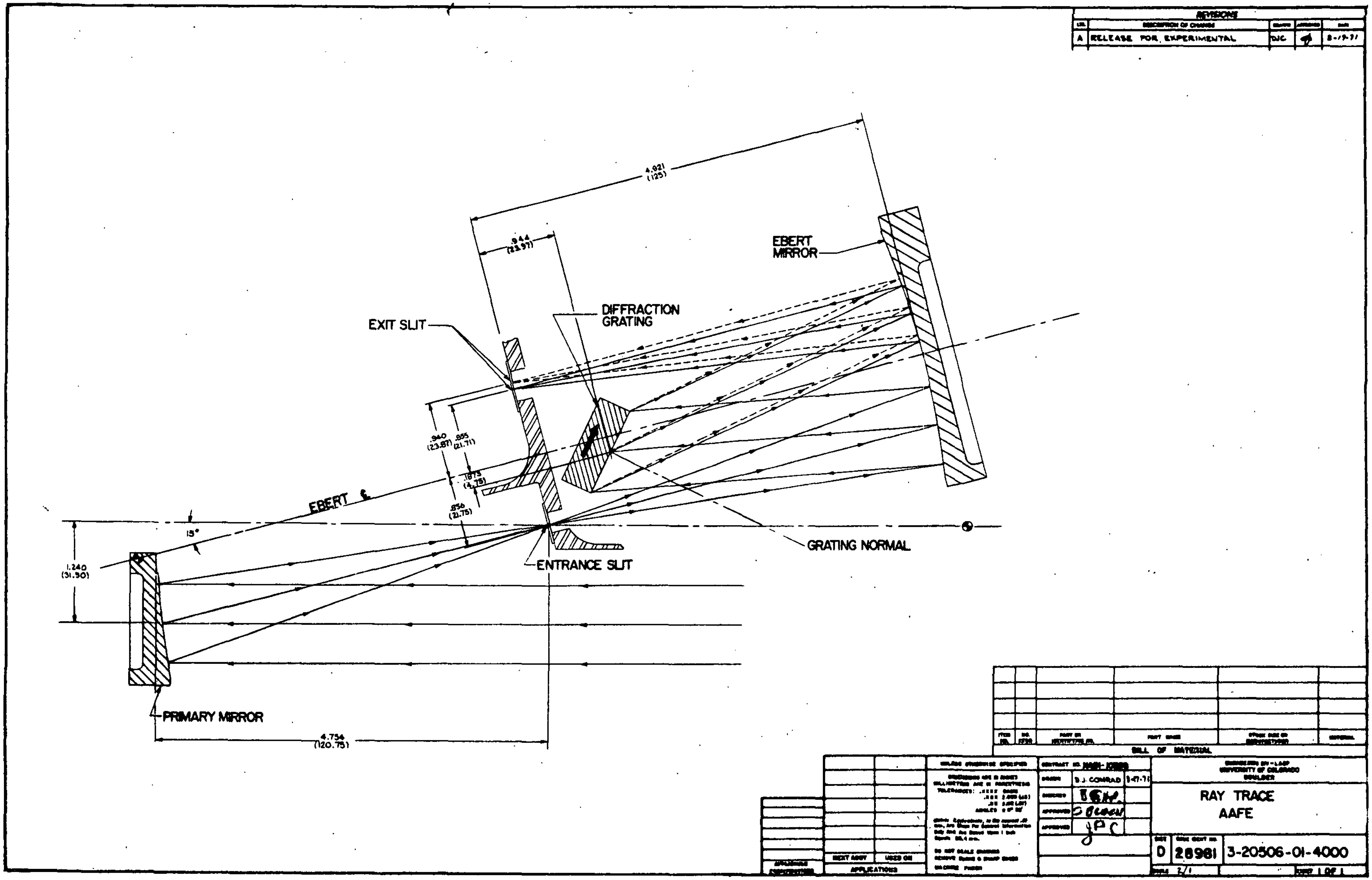
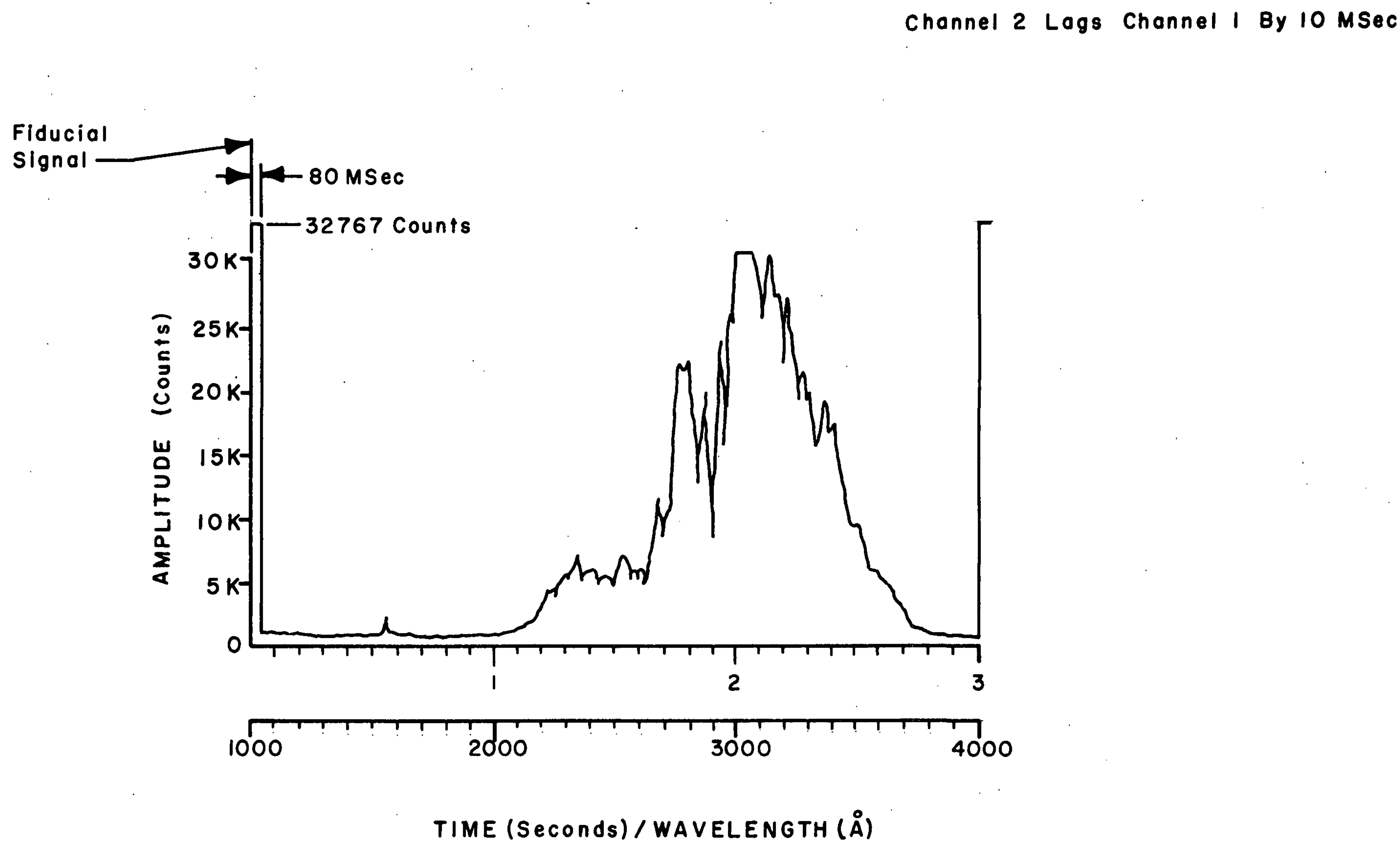

REVISIONS
A RELEASE FOR EXPERIMENTAL DJC 8-19-71
EBERT MIRROR
DIFFRACTION GRATING
EXIT SLIT
4.921 (125)
.944 (23.97)
.940 (23.87)
.855 (21.71)
.1873 (4.75)
.856 (21.75)
EBERT ℄
15°
1.240 (31.50)
ENTRANCE SLIT
GRATING NORMAL
PRIMARY MIRROR
4.754 (120.75)
BILL OF MATERIAL
D.J. CONRAD
RAY TRACE
AAFE
D 28981 3-20506-01-4000
APPLICATIONS

FIG. NO. 13

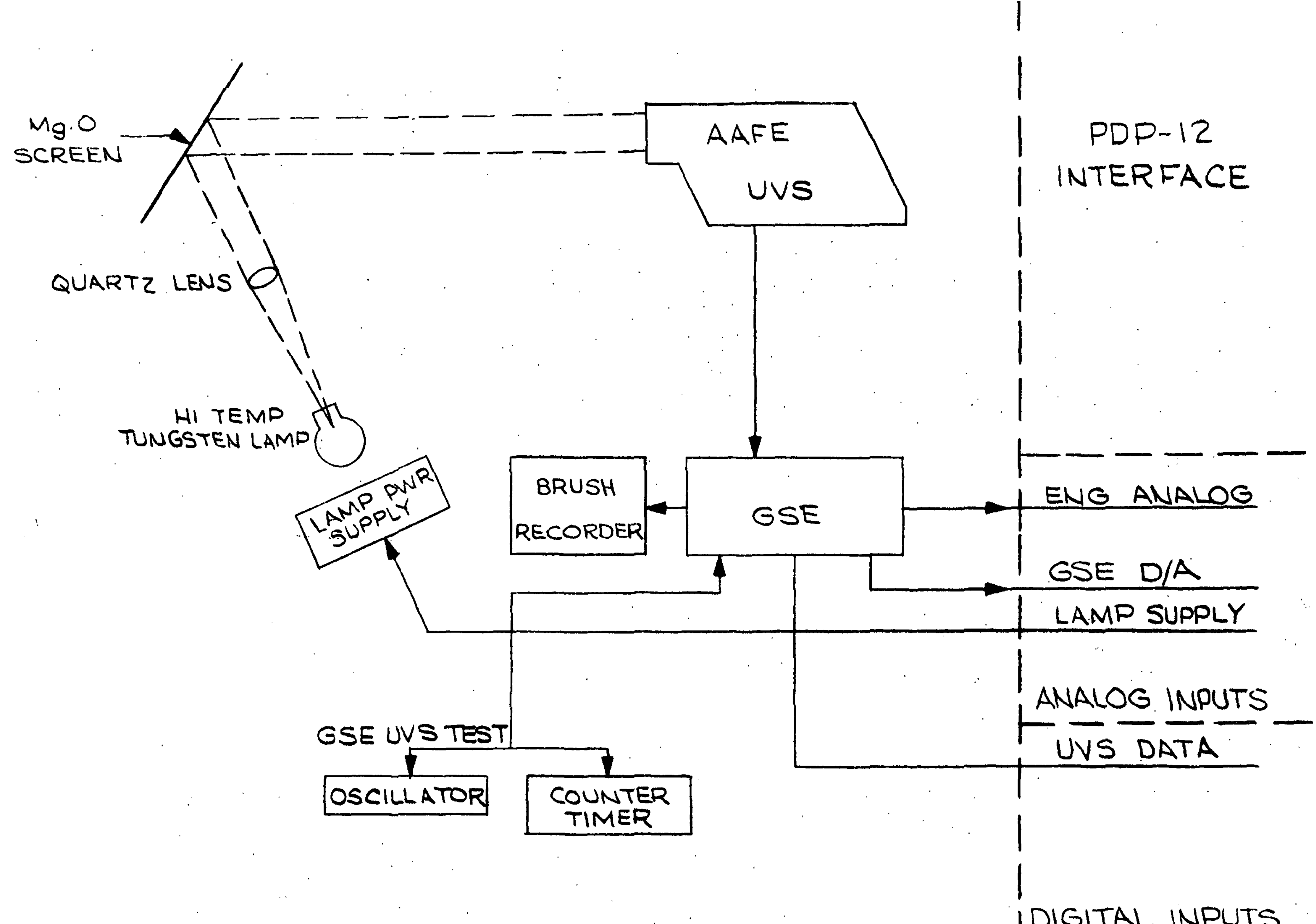
AAFE TEST DATA CHART IN FLIGHT CALIBRATION MONITORS
HVPS-1 (PMT Serial No. 17003) Level 4 = +2.33V = +2504V Actual Level 3 = +1.87V = +1987V Actual Level 2 = +1.58V = +1604V Actual Level 1 = +1.05V = +1102V Actual Off = +0.10V = + 00V Actual
HVPS-2 (PMT Serial No. 17133) Level 4 = +2.33V = +2654V Actual Level 3 = +1.85V = +2092V Actual Level 2 = +1.52V = +1656V Actual Level 1 = +0.99V = +1027V Actual Off = +0.10V = + 00V Actual
Channel-1 Cal Lamp Level 4 22528 Counts Level 3 3456 Counts Level 2 ________ Level 1 ________
Channel-2 Cal Lamp Level 4 3712 Counts Level 3 640 Counts Level 2 ________ Level 1 ________
+10V Monitor +3.51V = +10.02 Actual
-10V Monitor +2.62V = -10.00 Actual
Motor Monitor +2.00V = 14.00 V RMS Actual
Pre Regulator Monitor +3.14V Nominal
Main Frame Word 8 32767 Counts
Channel Identifier 0.00V = Word 72 is Channel-2 4.90V = Word 72 is Channel-1
Channel-1 & Channel-2 Dark Counts 0 to 4

FIG. NO. 14



TYPICAL SCAN PROFILE

FIG. NO. 15

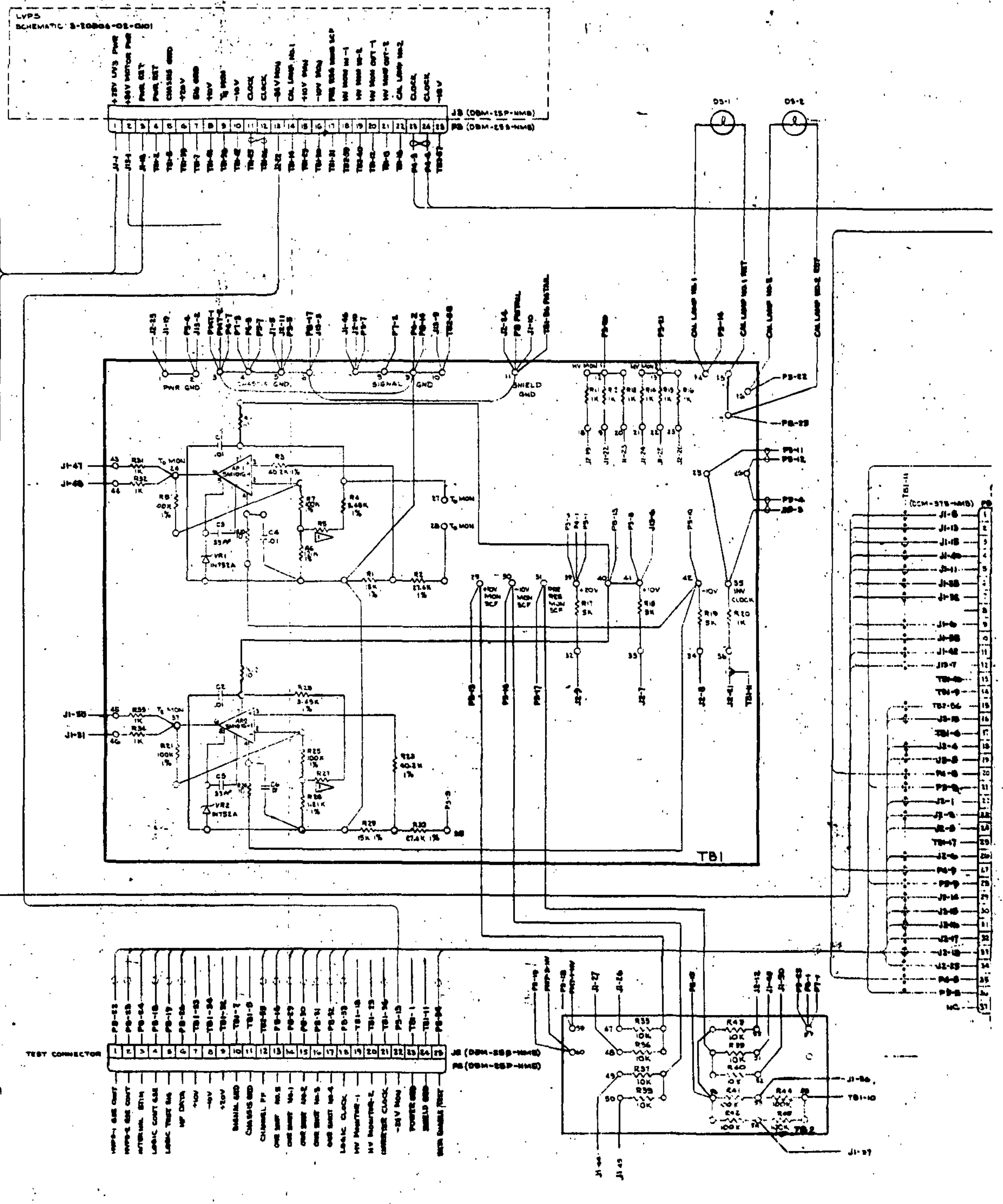


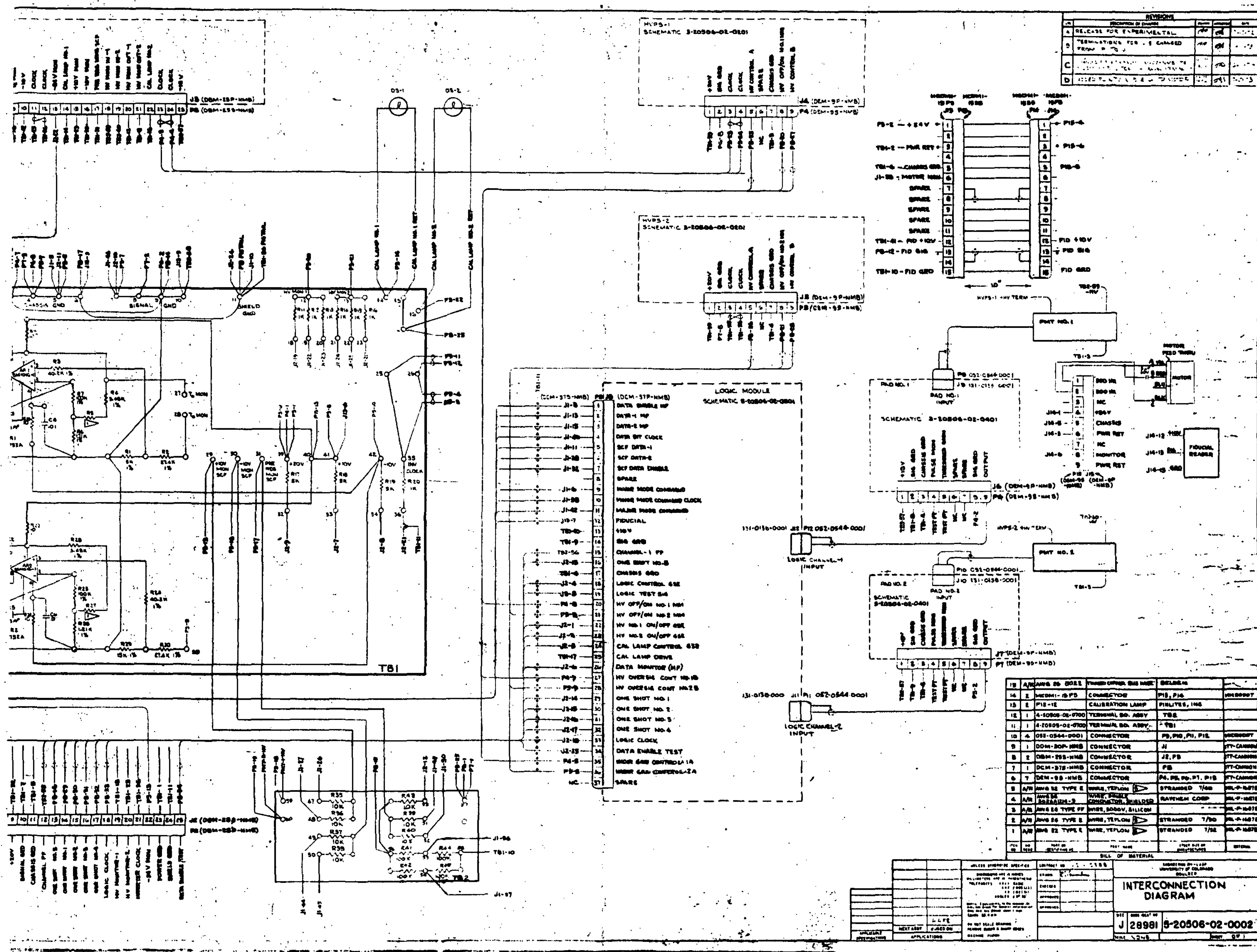
TYPICAL CALIBRATION ARRANGEMENT

FIG. NO. 16

GENERAL NOTES UNLESS OTHERWISE SPECIFIED

1. SELECT FOR REQUIRED OFFSET.
2. RESISTOR VALUES ARE IN OHMS, $\frac{1}{4}$W, 5%
3. CAPACITOR VALUES ARE IN μF
4. FOR WIRING LIST SEE DOC. NO. 20506-02-2012
5. FOR WIRE COLORS SEE DOC. NO. 20506-02-2012



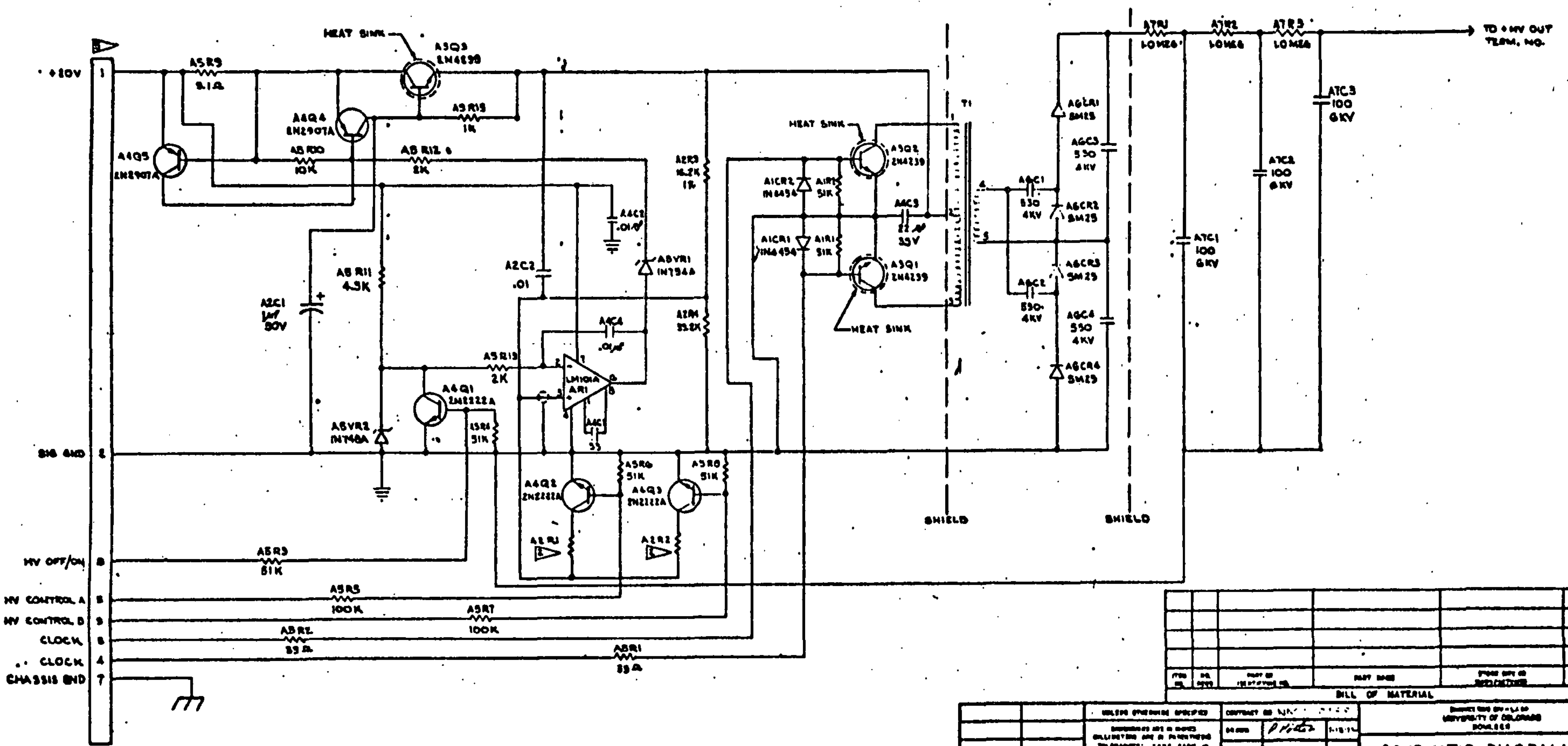


INTERCONNECTION DIAGRAM
J 28981 8-20506-02-0002
LOGIC MODULE
SCHEMATIC 8-20506-02-0801
HVPS-1
SCHEMATIC 3-20506-02-0201
HVPS-2
PMT NO. 1
PMT NO. 2
PAD NO. 1
PAD NO. 2
SCHEMATIC 3-20506-02-0401
LOGIC CHANNEL-1 INPUT
LOGIC CHANNEL-2 INPUT
MOTOR
FIDUCIAL READER
TB1
TB2
CAL LAMP NO. 1
CAL LAMP NO. 2
BILL OF MATERIAL
REVISIONS
RELEASE FOR EXPERIMENTAL

GENERAL NOTES UNLESS OTHERWISE SPECIFIED

1. SELECT FOR DESIRED HIGH VOLTAGE MIN OUTPUT; USE 1/10 W, 1%.
2. SELECT FOR DESIRED HIGH VOLTAGE LEVELS AFTER DETERMINING SELECT VALUES PER NOTE 1; USE 1/10 W, 1%.
3. RESISTANCE VALUES ARE IN OHMS, 1/4 W, 5%.
4. CAPACITANCE VALUES ARE IN PF.
5. J4 IS ASSIGNED TO HVPS-1 AND J5 IS ASSIGNED TO HVPS-2. HVPS-1 AND HVPS-2 ARE IDENTICAL EXCEPT FOR NOTES 1 AND 2. (SEE INTERCONNECTION DIAGRAM 3-20506-02-0002).
7. LAST REFERENCE DESIGNATIONS USED:
   - FOR A1 - R2, CR2, E3
   - FOR A2 - R4, C2, E6
   - FOR A3 - Q3, E15
   - FOR A4 - C4, AR1, Q3, E37
   - FOR A5 - R15, VR2, E21
   - FOR A6 - C4, CR4, T1, E10
   - FOR A7 - R3, C3, E3
8. REF DESIGNATIONS NOT USED A5 R14

REVISIONS			
LTR	DESCRIPTION OF CHANGE		DATE
A	RELEASE FOR EXPERIMENTAL		



ITEM NO.	REQ	PART OR IDENTIFYING NO.	PART NAME	SPEC	MATERIAL

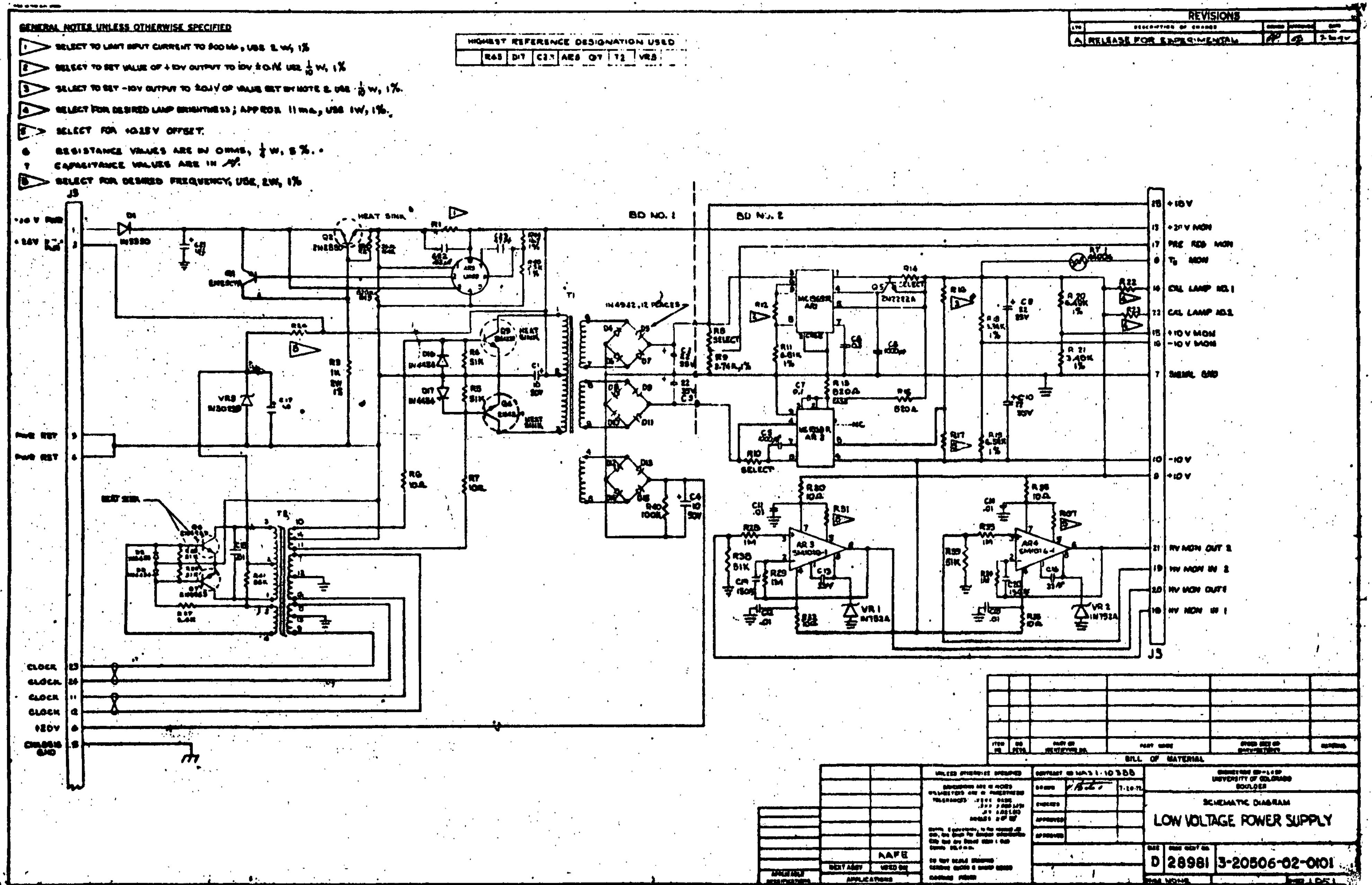
BILL OF MATERIAL

UNIVERSITY OF COLORADO BOULDER

SCHEMATIC DIAGRAM
HIGH VOLTAGE POWER SUPPLY

D 28981 3-20506-02-0201

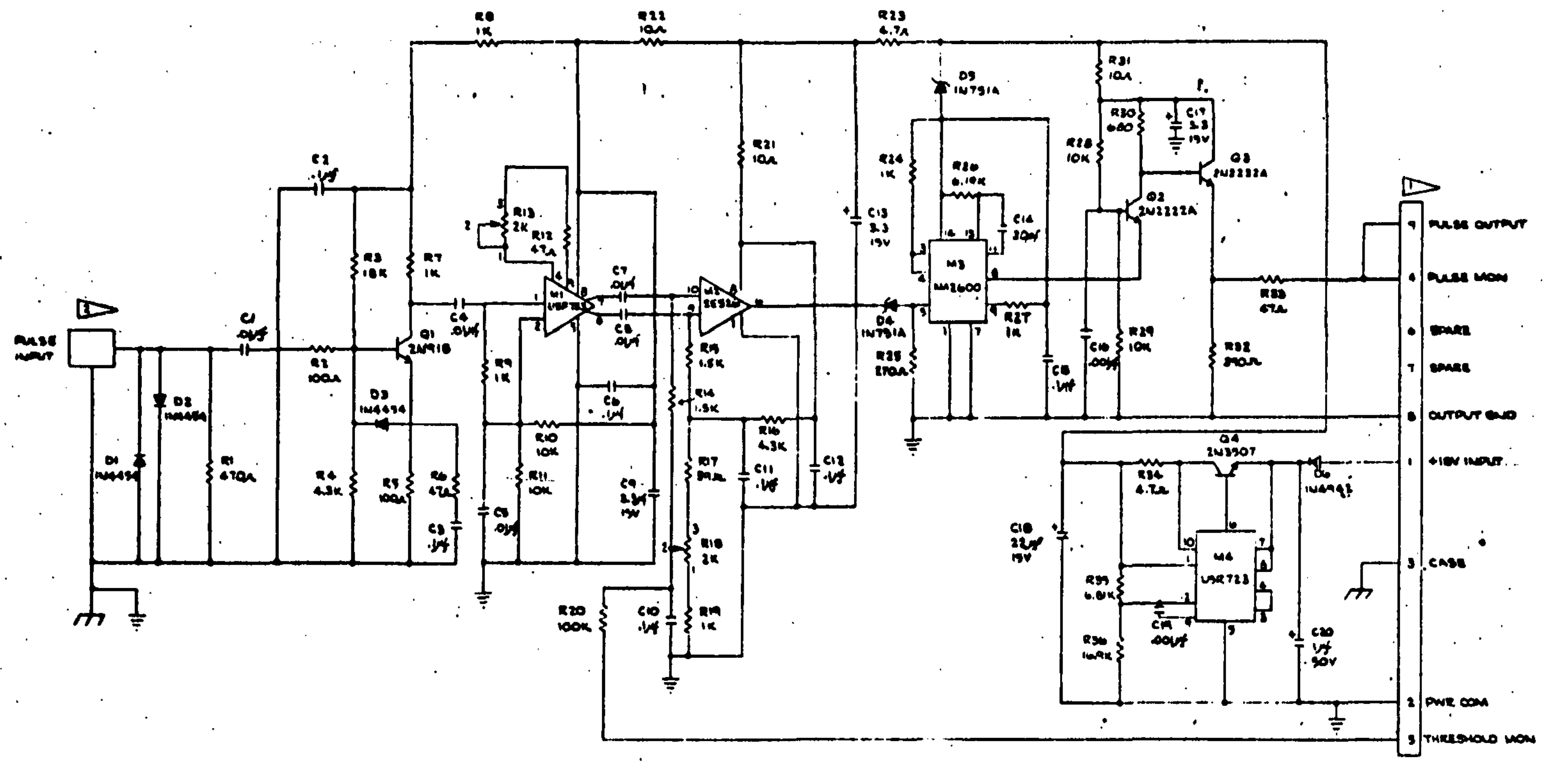
APPLICATIONS


GENERAL NOTES UNLESS OTHERWISE SPECIFIED
1. SELECT TO LIMIT INPUT CURRENT TO 500 MA, USE 2 W, 1%
2. SELECT TO SET VALUE OF +10V OUTPUT TO 10V ±0.1% USE 1/10 W, 1%
3. SELECT TO SET -10V OUTPUT TO ±0.1V OF VALUE SET BY NOTE 2. USE 1/10 W, 1%.
4. SELECT FOR DESIRED LAMP BRIGHTNESS; APPROX. 11 ma, USE 1W, 1%.
5. SELECT FOR +0.25 V OFFSET.
6. RESISTANCE VALUES ARE IN OHMS, 1/4 W, 5%.
7. CAPACITANCE VALUES ARE IN μF.
8. SELECT FOR DESIRED FREQUENCY, USE 2W, 1%
HIGHEST REFERENCE DESIGNATION USED
R43 D17 C21 AR5 Q7 T2 VR3
REVISIONS
A RELEASE FOR EXPERIMENTAL
BD NO. 1
BD NO. 2
J3
J5
+10V
+21V MON
PRE REG MON
T0 MON
CAL LAMP NO. 1
CAL LAMP NO. 2
+10V MON
-10V MON
SIGNAL GND
-10V
+10V
HV MON OUT 2
HV MON IN 2
HV MON OUT 1
HV MON IN 1
PWR RET
PWR RET
CLOCK
CLOCK
CLOCK
CLOCK
±20V
CHASSIS GND
HEAT SINK
1N4942, 12 PLACES
BILL OF MATERIAL
SCHEMATIC DIAGRAM
LOW VOLTAGE POWER SUPPLY
D 28981 3-20506-02-0101

GENERAL NOTES UNLESS OTHERWISE SPECIFIED

1. J6 AND J7 ARE ASSIGNED TO PAD-1 AND PAD-2 RESPECTIVLY. PAD-1 AND PAD-2 ARE IDENTICAL. SEE INTERCONNECT DIAGRAM 9-20506-02-0002
2. J9 AND J10 ARE ASSIGNED TO PAD-1 AND PAD-2 RESPECTIVLY. SEE NOTE 1.

REVISIONS	
A	RELEASED FOR EXPERIMENTAL



ITEM NO	NO REQD	PART OR IDENTIFYING NO	PART NAME	STOCK SIZE OR SPECIFICATION	OPTIONAL

BILL OF MATERIAL

CONTRACT NO NAS1-10988

DRAWN 7-19-72

LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
UNIVERSITY OF COLORADO
BOULDER

SCHEMATIC DIAGRAM

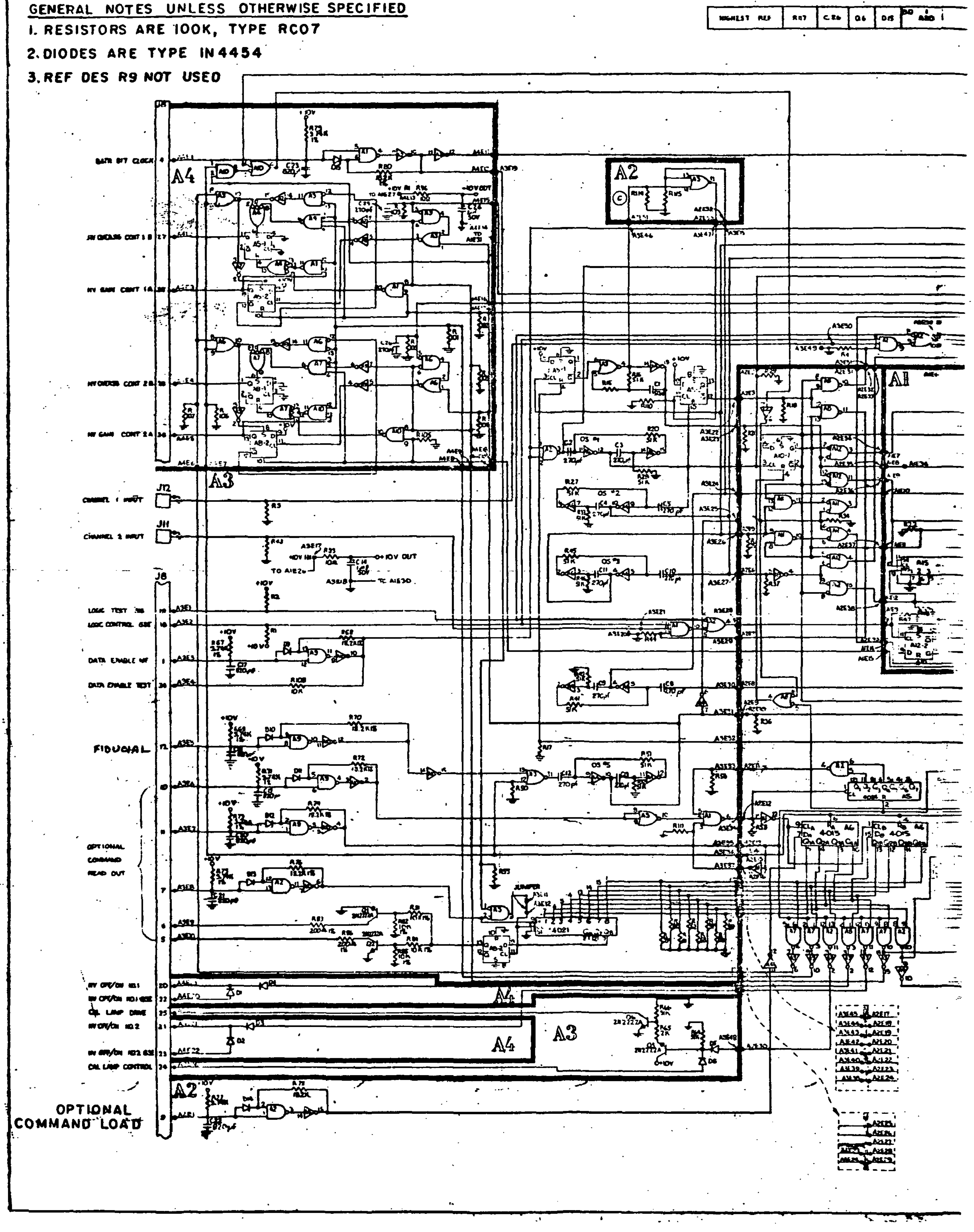
PULSE AMPLIFIER DISCRIMINATOR
SPACOM SE135HR

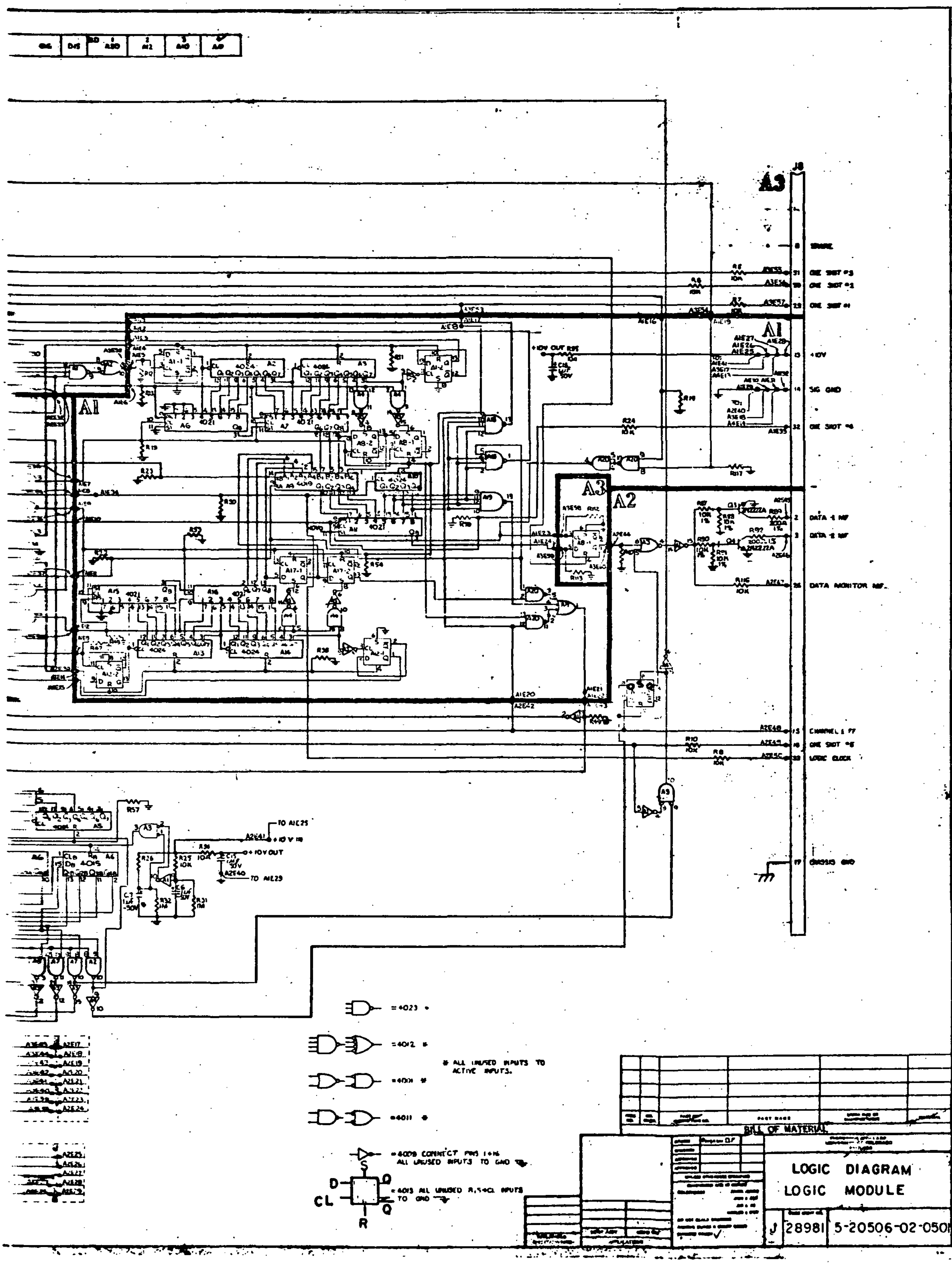
D 28981 3-20506-02-0403

AAPE
NEXT ASSY USED ON
APPLICATIONS

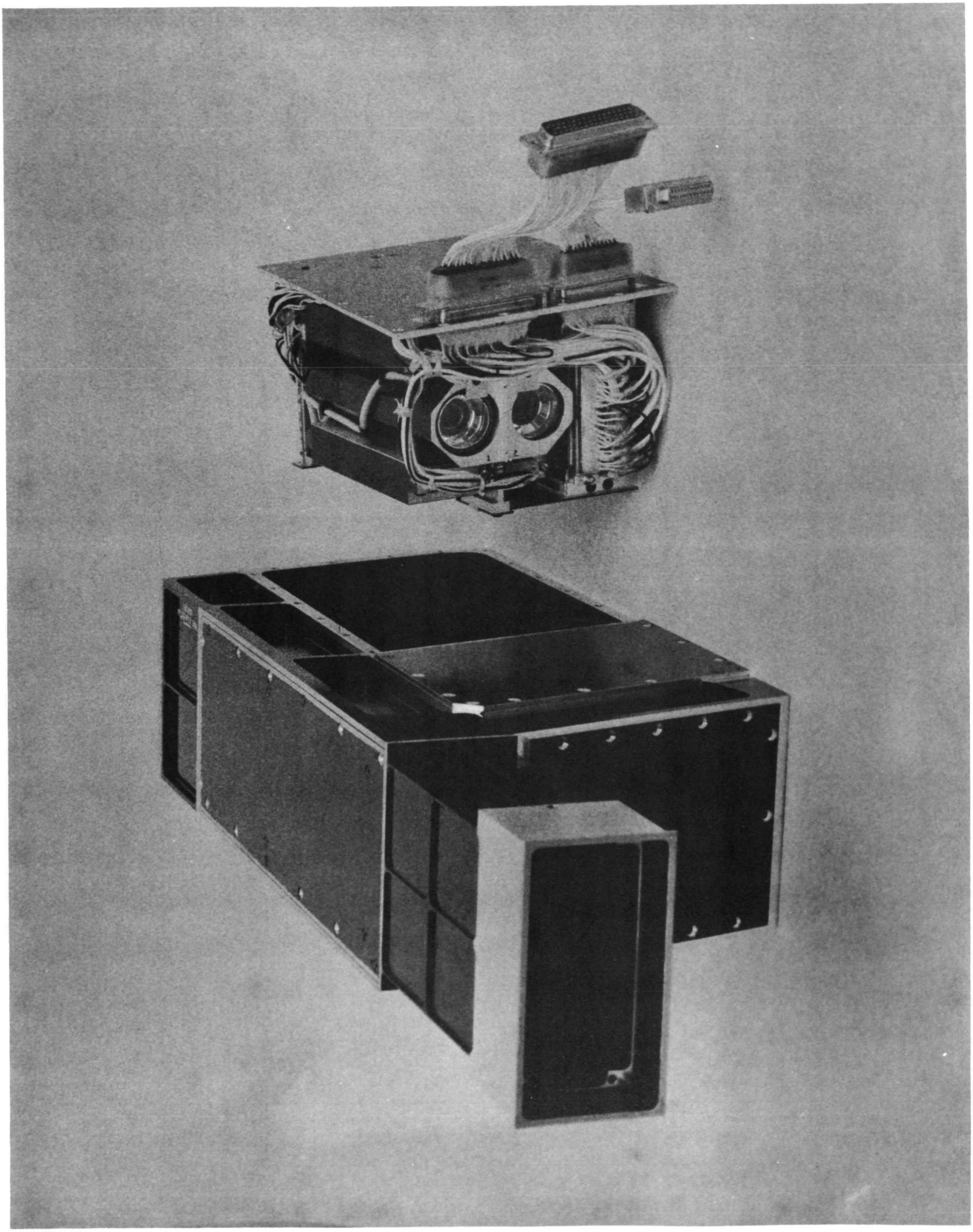
GENERAL NOTES UNLESS OTHERWISE SPECIFIED

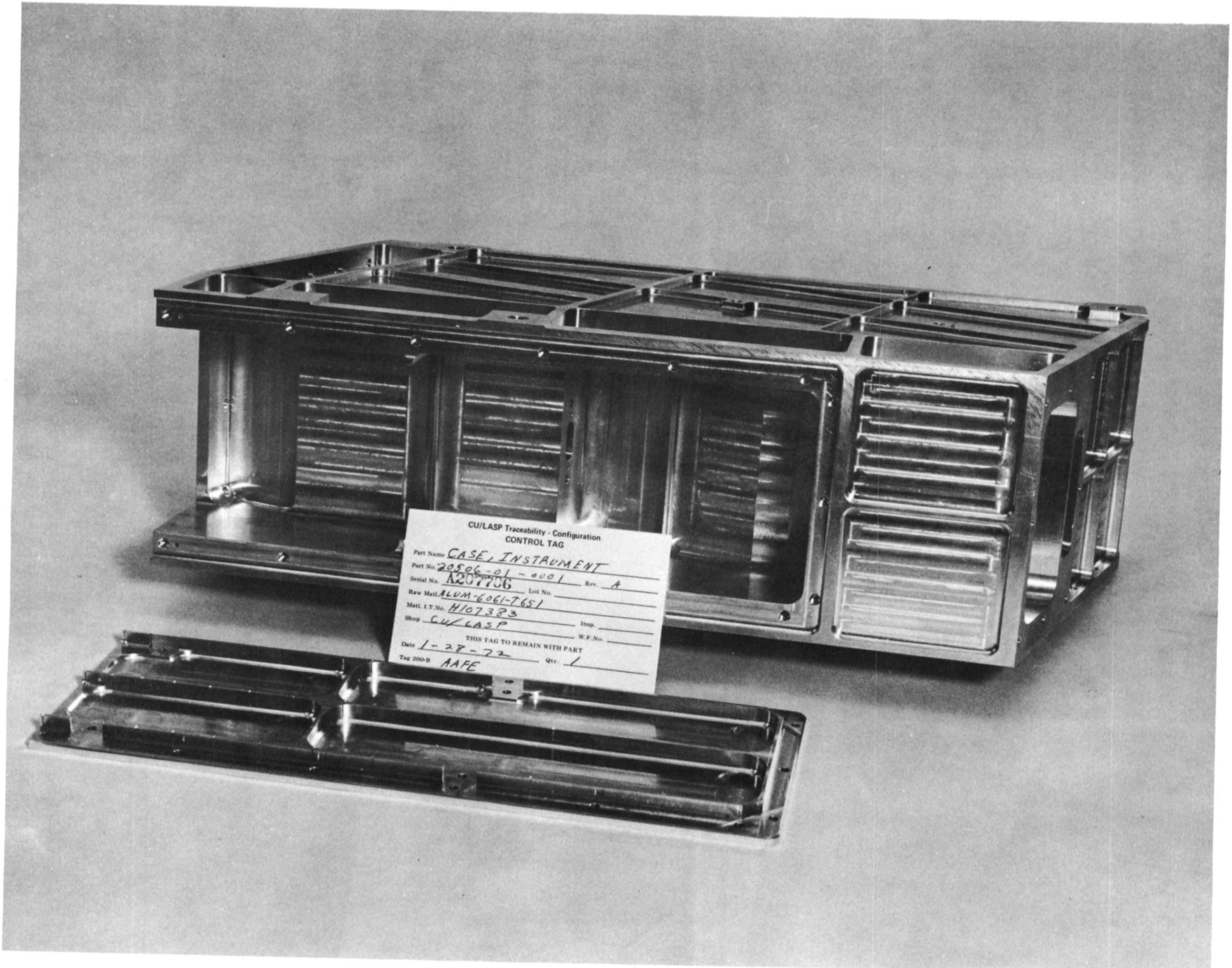
1. RESISTORS ARE 100K, TYPE RC07
2. DIODES ARE TYPE IN4454
3. REF DES R9 NOT USED

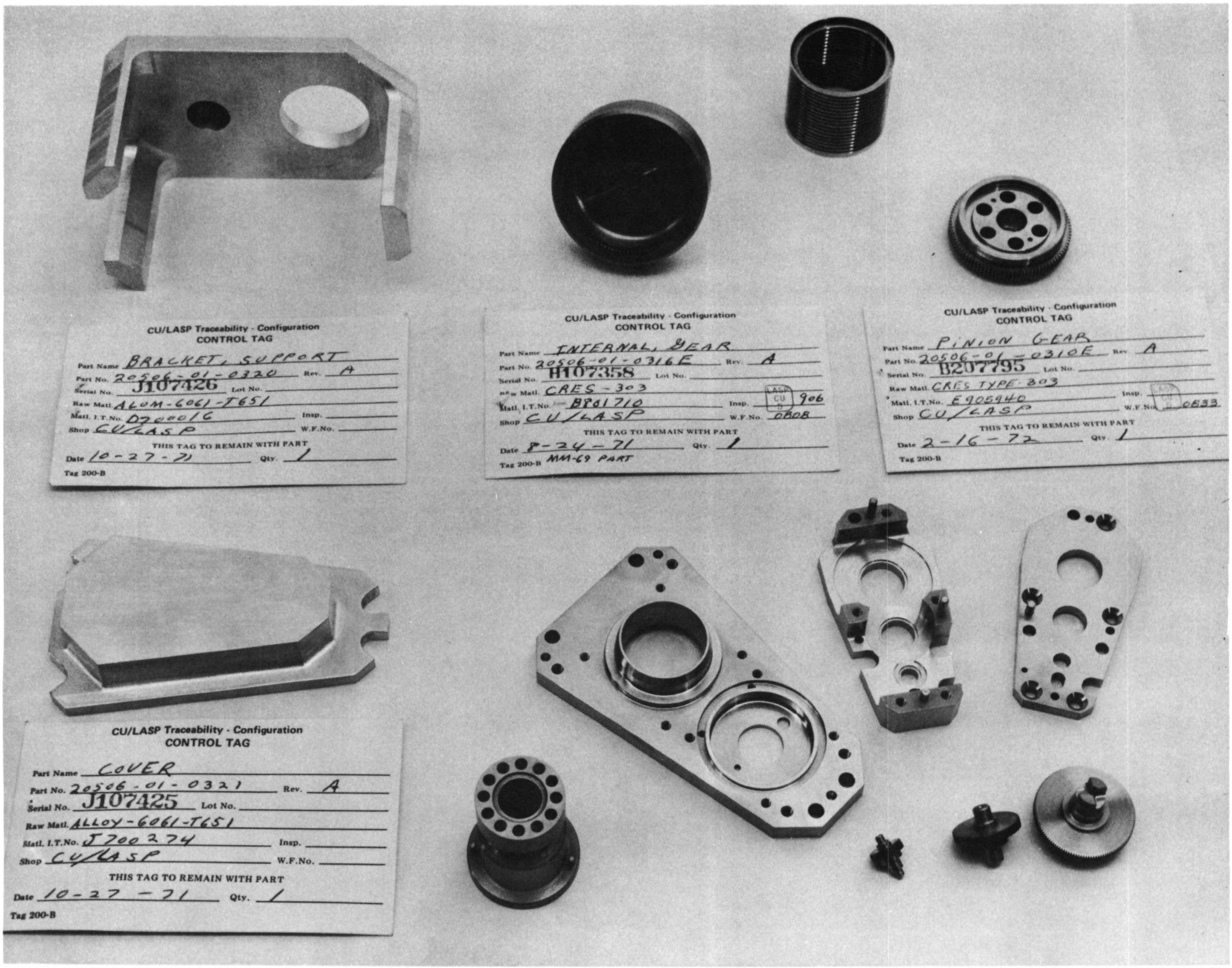


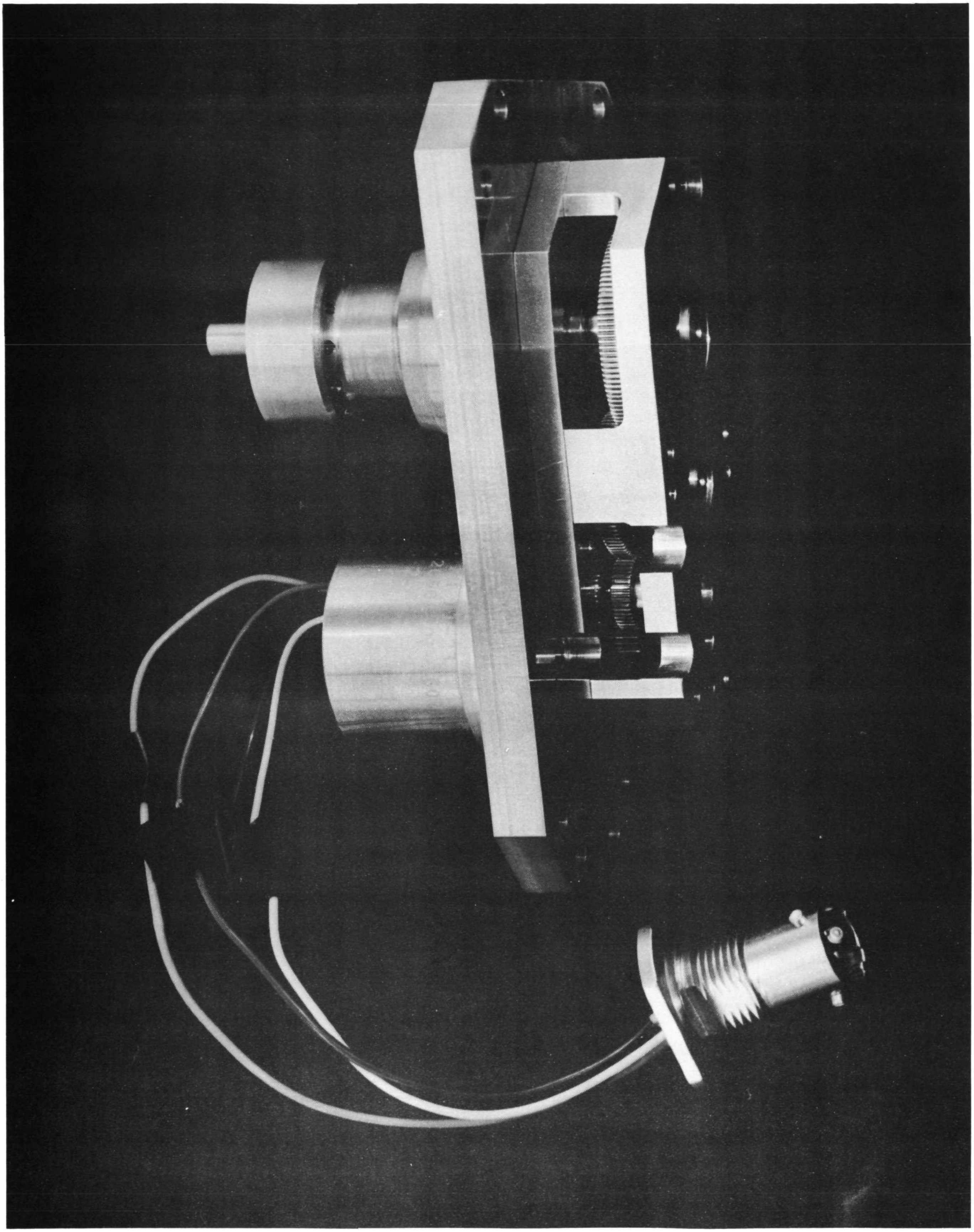


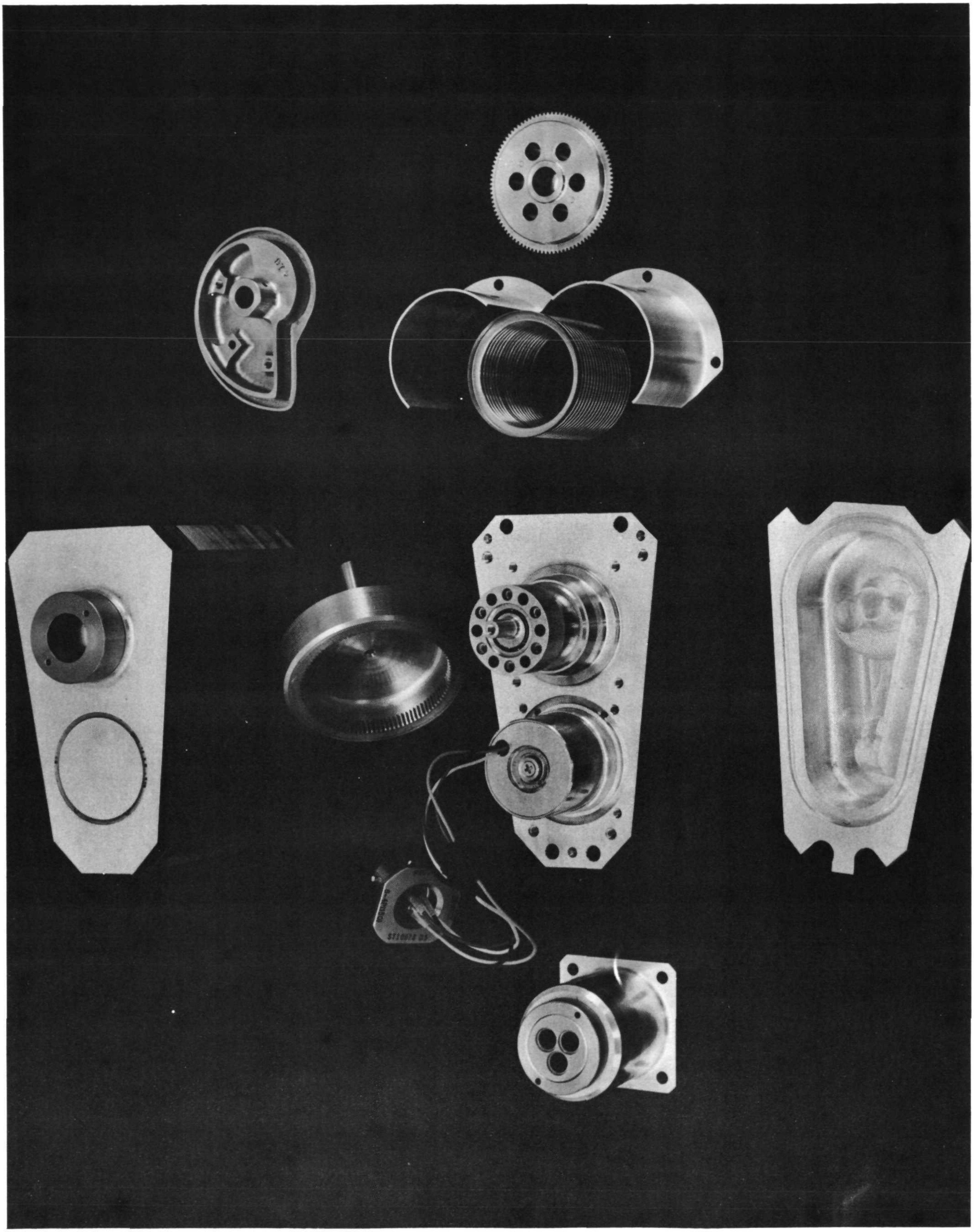
A1
A2
A3
= 4023 *
= 4012 *
= 4001 *
= 4011 *
* ALL UNUSED INPUTS TO ACTIVE INPUTS.
= 4009 CONNECT PINS 1 & 16 ALL UNUSED INPUTS TO GND
= 4013 ALL UNUSED R, S & CL INPUTS TO GND
BILL OF MATERIAL
LOGIC DIAGRAM
LOGIC MODULE
J
28981
5-20506-02-0501

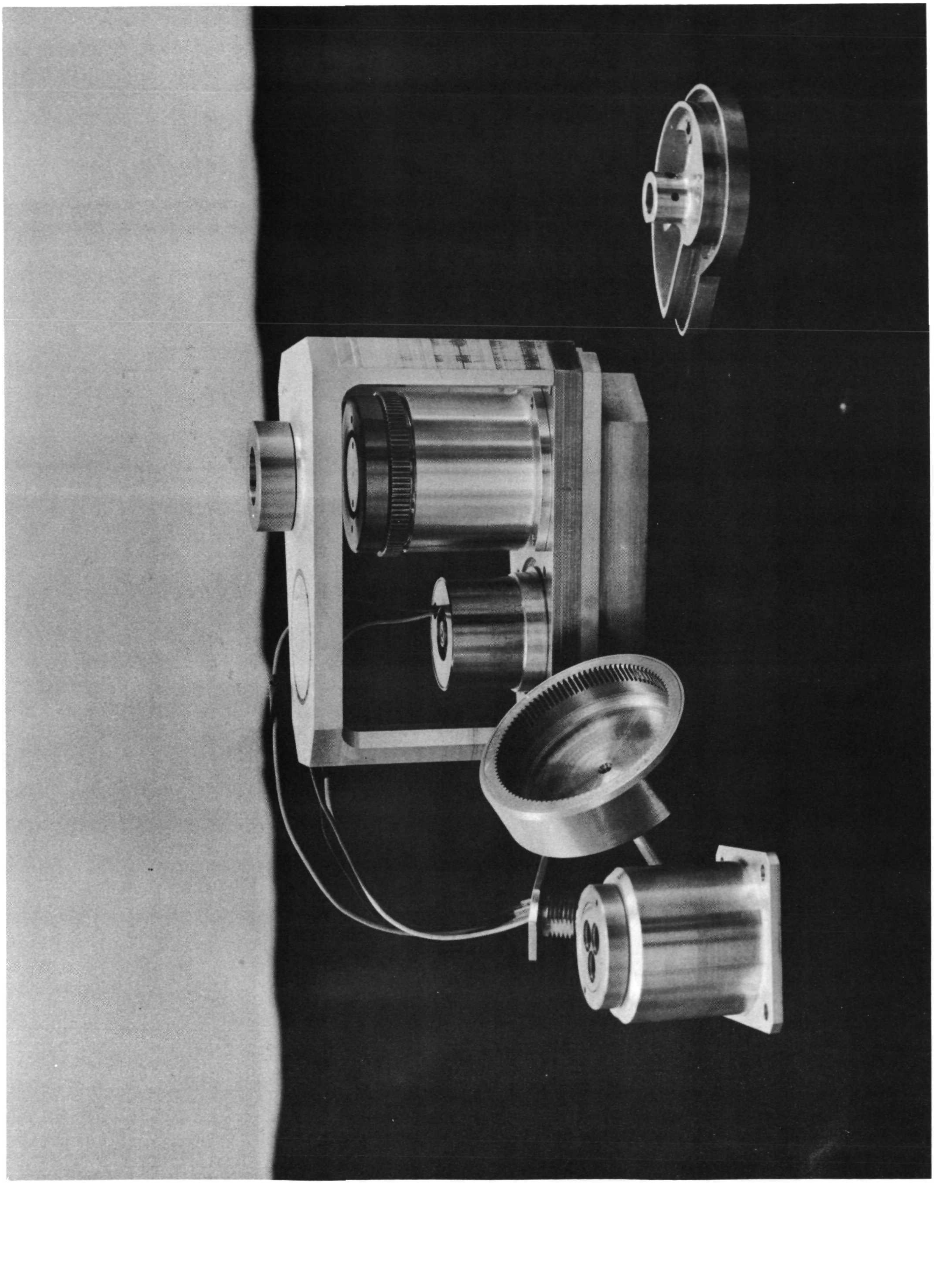


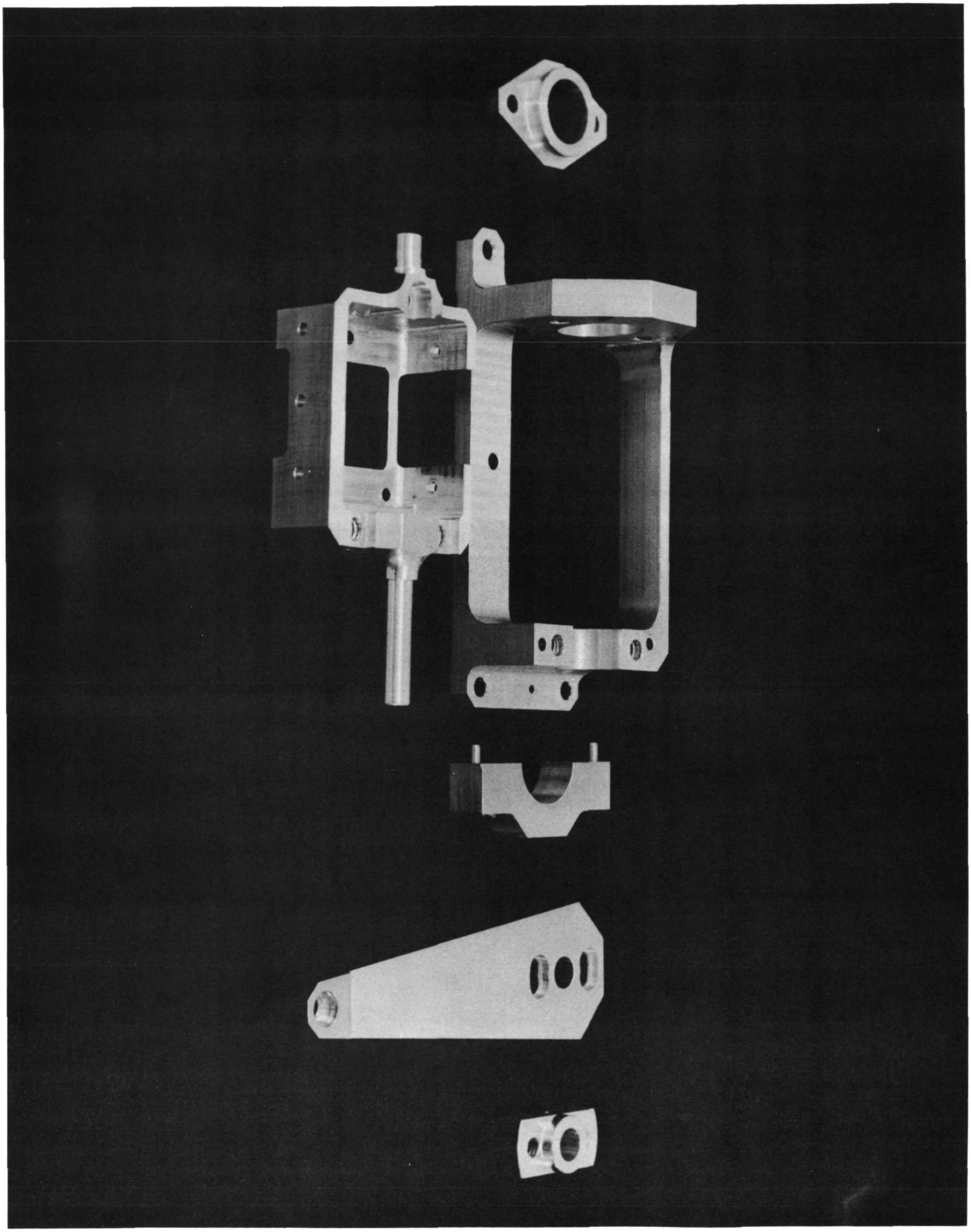

CU/LASP Traceability - Configuration
CONTROL TAG
Part Name CASE, INSTRUMENT
Part No. 20506-01-0001
Serial No. A207756 Lot No. Rev. A
Raw Matl. ALUM-6061-T651
Matl. I.T. No. H107383
Shop CU/LASP Insp.
W.F. No.
THIS TAG TO REMAIN WITH PART
Date 1-28-72
Tag 200-B AAFE Qty. 1

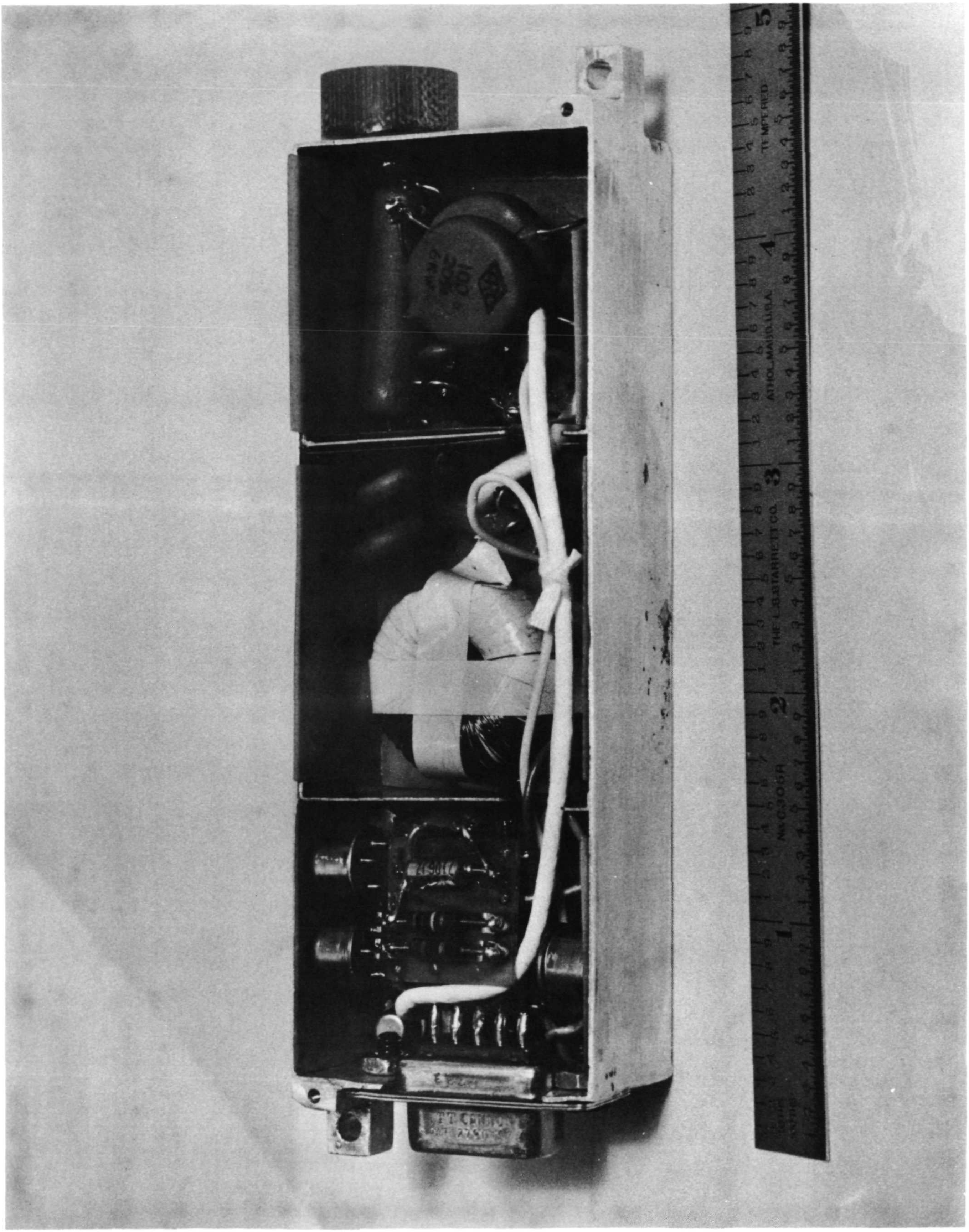

CU/LASP Traceability - Configuration
CONTROL TAG
Part Name BRACKET, SUPPORT
Part No. 20506-01-0320 Rev. A
Serial No. J107426 Lot No.
Raw Matl. ALUM-6061-T651
Matl. I.T.No. D700016 Insp.
Shop CU/LASP W.F.No.
THIS TAG TO REMAIN WITH PART
Date 10-27-71 Qty. 1
Tag 200-B
CU/LASP Traceability - Configuration
CONTROL TAG
Part Name INTERNAL GEAR
Part No. 20506-01-0316E Rev. A
Serial No. H107358 Lot No.
Raw Matl. CRES-303
Matl. I.T.No. B801710 Insp. 906
Shop CU/LASP W.F.No. 0808
THIS TAG TO REMAIN WITH PART
Date 8-24-71 Qty. 1
Tag 200-B MM-69 PART
CU/LASP Traceability - Configuration
CONTROL TAG
Part Name PINION GEAR
Part No. 20506-01-0310E Rev. A
Serial No. B207795 Lot No.
Raw Matl. CRES TYPE 303
Matl. I.T.No. E905940 Insp.
Shop CU/LASP W.F.No. 0833
THIS TAG TO REMAIN WITH PART
Date 2-16-72 Qty. 1
Tag 200-B
CU/LASP Traceability - Configuration
CONTROL TAG
Part Name COVER
Part No. 20506-01-0321 Rev. A
Serial No. J107425 Lot No.
Raw Matl. ALLOY-6061-T651
Matl. I.T.No. J700274 Insp.
Shop CU/LASP W.F.No.
THIS TAG TO REMAIN WITH PART
Date 10-27-71 Qty. 1
Tag 200-B










THE L.S.STARRETT CO.
ATHOL, MASS. U.S.A.