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**AEROSOL PHYSICAL PROPERTIES IN THE
STRATOSPHERE (APPS) RADIOMETER DESIGN
SUMMARY REPORT**

by

**Carlton R. Gray, E. Albert Woodin, Thomas J. Anderson,
Robert J. Magee and George W. Karthas**

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16. Abstract This report presents the measurement concepts and radiometer design developed to obtain earth-limb spectral-radiance measurements for the Aerosol Physical Properties in the Stratosphere (APPS) measurement program. The measurements made by a radiometer of this design can be inverted to yield vertical profiles of Rayleigh scatterers, ozone, nitrogen dioxide, aerosol extinction, and aerosol physical properties, including a Junge size-distribution parameter, and a real and imaginary index of refraction. The radiometer design provides the capacity for remote sensing of stratospheric constituents from space on platforms such as the Space Shuttle and satellites, and therefore provides for global measurements on a daily basis.					
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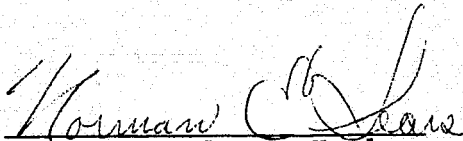
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SECTION 1

INTRODUCTION

There is growing scientific opinion that physical processes in the earth's stratosphere are of vital importance to man and the biosphere, and that very little is understood of these processes. The Aerosol Physical Properties in the Stratosphere (APPS) measurement program of remote sensing of the stratosphere has recently demonstrated^{(1,2)*} its unique capability for monitoring the atmospheric state and interactions in this region, thus improving man's knowledge of the stratosphere.

The APPS measurement program is designed to invert earth-limb radiance measurements (see Figure 1-1) to obtain vertical profiles of atmospheric state parameters in the stratosphere. The inverted atmospheric state parameters are Rayleigh scatterers, ozone, nitrogen dioxide, aerosol extinction, and aerosol physical properties, including a Junge size-distribution parameter, and a real and imaginary index of refraction.

Simultaneous measurement of more than one atmospheric state parameter in the stratosphere has for years been virtually impossible. More recently, as the scientific community has focused increasing interest on the physical processes, experimental techniques capable of more adequately monitoring this region have evolved. Limb inversion is one of the more promising techniques, with the unique capability of establishing aerosol physical properties which existing remote measurement techniques cannot. In addition, global coverage is extended with the APPS measurement program, as the scan geometry is not tied to a single sun-spacecraft geometry.

Reported herein is the APPS radiometer design (see Figures 1-2 and 1-3), which meets the design requirements for stratospheric monitoring by remote sensing of the limb. Special design features of the APPS radiometer are its dual in-line direct solar calibration, its optical characteristics including off-axis radiation rejection, and its information-processing characteristics for the Space Shuttle and/or sun-synchronous

* Superscript numerals refer to similarly numbered references in the List of References.

satellite configurations. These design features classify the instrument as a state-of-the-art radiometer design (see Table 1-1).

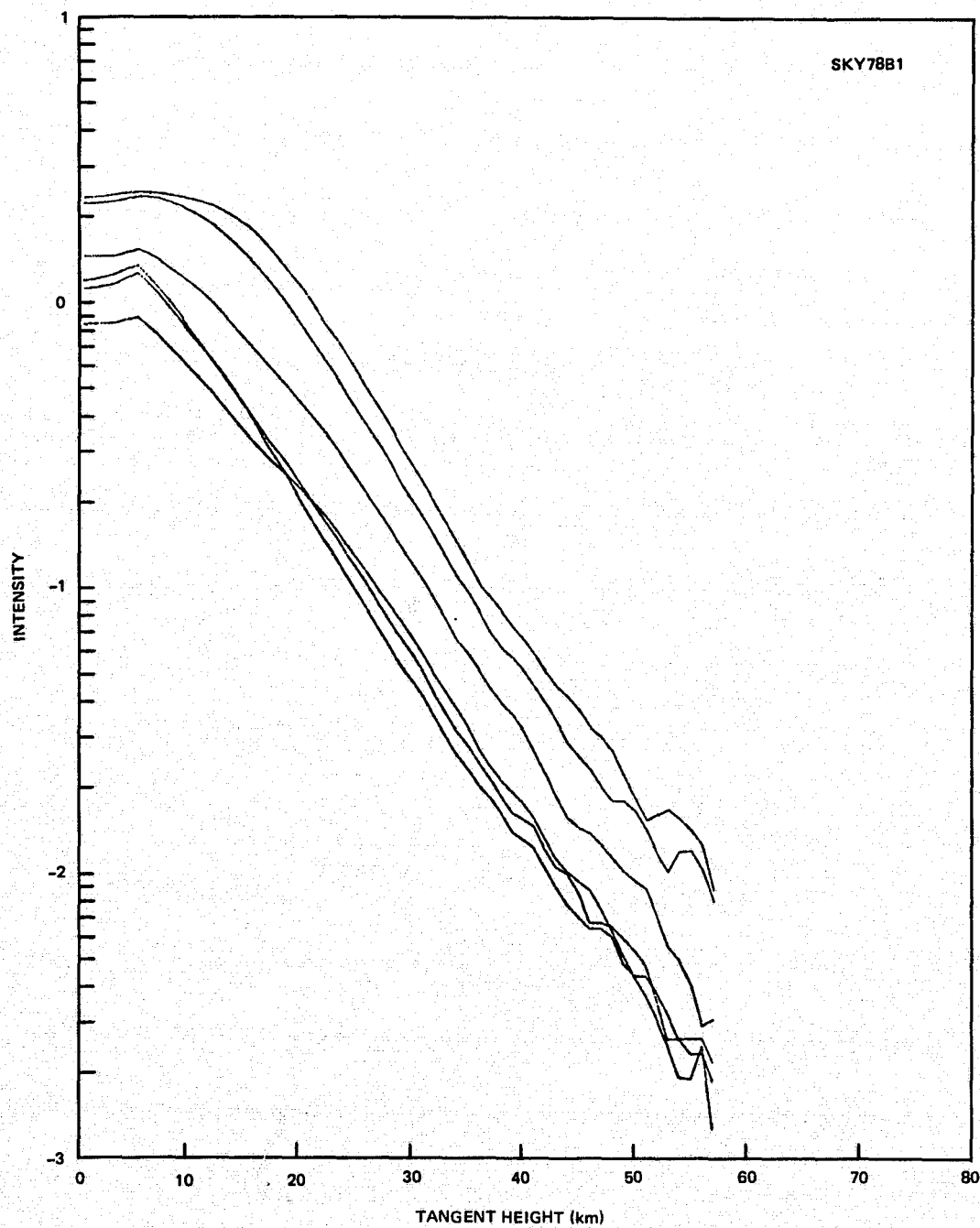


Figure 1-1. Earth-limb spectral radiance data.

10-15-76

Table 1-1. NASA/JPL FLIGHT INSTRUMENTS CATALOG

1. INSTRUMENT NAME: (APPS) Aerosol Physical Properties in the Stratosphere		INSTRUMENT CLASS	CATALOG NO.	PAGE 1 OF 4
2. GENERAL: TYPE <u>Spectral Radiometer</u>				
PURPOSE <u>Global measurements of spatial and temporal variations in Aerosol</u> <u>Physical Properties in the Stratosphere and Mesosphere.</u>				
PRINCIPLE OF OPERATION <u>The radiometer measures the scattered solar radiation from</u> <u>the earth's limb in selected spectral bands with a single line-of-sight and a</u> <u>finite field of view. Scans of the earth's horizon are obtained from the shuttle</u> <u>or satellite. The measured horizon intensities are encoded on board and telemetered</u> <u>to the ground for inversion processing of aerosol physical properties, ozone</u> <u>density, molecular density and NO₂.</u>				
3. RESPONSIBLE INDIVIDUALS:				
PRINCIPAL INVESTIGATOR <u>Carlton R. Gray</u>			TELEPHONE <u>(617) 258-1549</u>	
- ORGANIZATION <u>C. S. Draper Laboratory, Inc.</u>				
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- FUNDING ORGANIZATION <u>NASA - Langley (AAFE)</u>				
THIS DATA SHEET PREPARED BY <u>Carlton R. Gray</u>			TELEPHONE <u>(617) 258-1549</u>	
- ORGANIZATION <u>C. S. Draper Laboratory, Inc.</u>				
4. MISSION:				
SPACECRAFT/AIRCRAFT/OTHER <u>TBD - Shuttle</u>				
ORBIT/TRAJECTORY PARAMETERS _____				
* Potential for outer planet studies and spin stabilized satellites				
5. PERFORMANCE:				
PARAMETER(S) OBSERVED	<u>Spectral Radiance</u>			
MEASUREMENT LIMITS	<u>Daylight</u>			
ACCURACY	<u>Intensity, 0.006% relative, 5.0% absolute</u>			
RESOLUTION	<u>Angular 0.2 mr</u>			
OBSERVATION RATE	<u>592.6/sec. for 0.9 sec., 50 limbs per orbit typical</u>			
DESIGN LIFE <u>two (2) years</u>	DUTY CYCLE <u>< 1 minute per orbit</u>			
REDUNDANCY <u>System backup modes</u>				
NOTES: The inverted quantities are aerosol physical properties (density, size, index of refraction - real and imaginary), ozone density, molecular density and NO ₂ .				

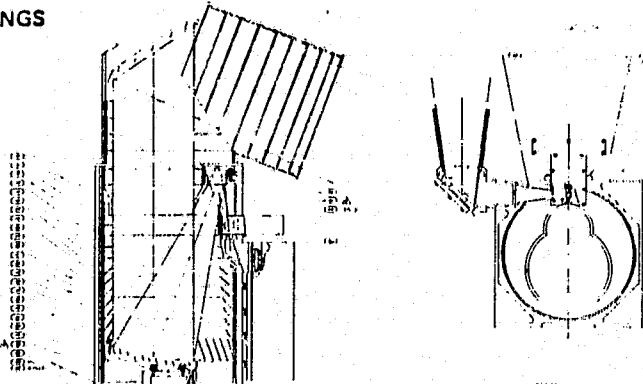
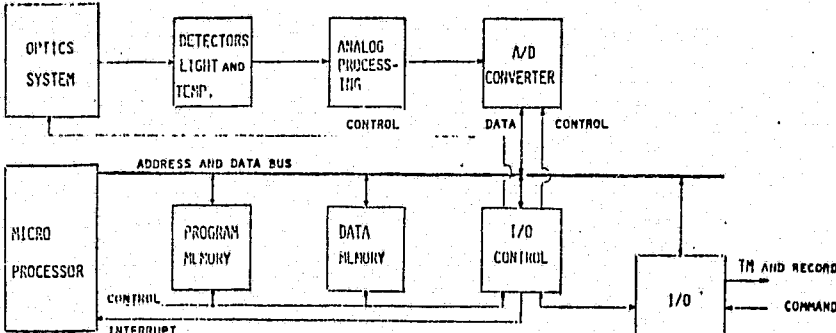
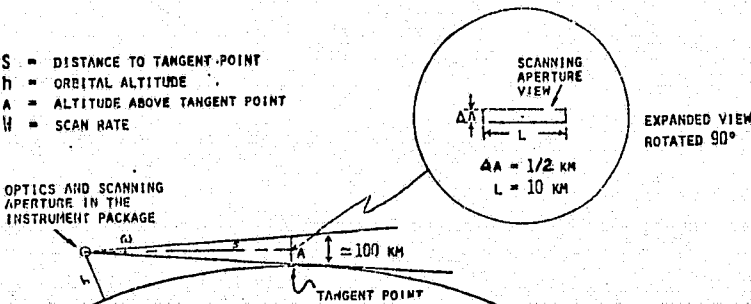
Table 1-1. NASA/JPL FLIGHT INSTRUMENTS CATALOG (Cont.)

INSTRUMENT NAME (APPS(Aerosol Physical Properties in the Stratosphere)	INSTRUMENT CLASS	CATALOG NO.	PAGE 2 OF 4
6. STATUS: OPERATIONAL DATE <u>TBD</u> UNITS BUILT (YEAR) <u>--</u> MISSIONS FLOWN (YEAR) <u>--</u> UNITS TO BE BUILT (YEAR) <u>TBD</u> INSTRUMENT HERITAGE <u>Based on (MIT/IL, X-15-1) and (LES 8/9) optical design concepts and Apollo Sextant</u>			
7. PHYSICAL CHARACTERISTICS: Shuttle Design MASS: <u>Beryllium 19.6 kg (43.25 lb) Beryllium/Aluminum 24.7 kg (54.42 lb)</u> DIMENSIONS: <u>~ 35.6 x 34.6 x 55.9 cm</u> ENVELOPE: STOWED <u>~35.6 x 34.6 x 55.9 cm</u> DEPLOYED <u>(same)</u> DYNAMIC <u>Unobstructed clear field of view of earth limb</u>			
8. REQUIREMENTS/INTERFACE CONSTRAINTS: INPUT POWER: <u>23.3 watts *</u> D.C., <u>uses no A.C. input</u> A.C., <u>not applicable</u> Hz TEMPERATURE <u>288°K</u> PHYSICAL LIMITS: VIBRATION <u>15 G. random < 2000 Hz</u> SHOCK <u>50 G, 1/2 cycle, sine 0.2 ms</u> ACOUSTIC <u>TBD</u> RADIATION <u>Shuttle orbital conditions</u> MAGNETIC SUSCEPTIBILITY <u>TBD</u> ATTITUDE (POSITION/RATE): PITCH <u>1.0°/.02°</u> ROLL <u>1.0°/.1°</u> YAW <u>1.0°/.1°</u> ATTITUDE DETERMINATION: PITCH <u>.02°</u> ROLL <u>.1°</u> YAW <u>.1°</u> IN-FLIGHT CALIBRATION <u>Built in solar calibration, requires < 1 second, automatic or upon command.</u> NOTES: * Electronic 11.1 watts Scanning Motor 5.2 Thermal Control 6.1 Expansion .9 <u>23.3 watts</u>			
9. COMMUNICATIONS: DOWNLINK: TYPE <u>Bi-Phase L</u> FREQUENCY <u>S-Band</u> BANDWIDTH _____ INFORMATION RATE <u>128 KBPS</u> DYNAMIC RANGE _____ UPLINK: TYPE <u>Discrete</u> FREQUENCY _____ BANDWIDTH _____ INFORMATION RATE <u>TBD</u> COMMANDS/GROUND CONTROLLABLES: <u>13 commands</u> GROUND STATION NETWORK <u>TBD</u> THROUGHPUT/PROCESSING TIME <u>TBD</u> SIGNAL PROCESSING: ONBOARD <u>Scheduling</u> GROUND <u>Inversion of horizon intensity data - ephemeris data</u> NOTES:			

Table 1-1. NASA/JPL FLIGHT INSTRUMENTS CATALOG (Cont.)

INSTRUMENT NAME (APPS) Aerosol Physical Properties in the Stratosphere	INSTRUMENT CLASS	CATALOG NO.	PAGE 3 OF 4
10. SENSOR: SPECTRAL RANGE <u>300 nm to 850 nm</u> SPECTRAL RESOLUTION <u>10 nm at eight (8) discrete wavelengths</u> DETECTOR TYPE(S) <u>Silicon</u> DETECTOR OPERATING TEMPERATURE <u>0° to 25°c</u> NEP <u>0.9×10^{-13} watts/Hz^{1/2}</u> COOLING METHOD <u>thermoelectric coolers as mission requires</u> DYNAMIC RANGE <u>10^6</u> NOTES:			
11. OPTICS: TYPE <u>Off axis cassegrain telescope</u> FOCAL LENGTH <u>45.72 cm</u> CLEAR APERTURE <u>100 cm^2</u> FIELD OF VIEW: TOTAL <u>$0.2 \times 4.0 \text{ mr}$</u> INSTANTANEOUS <u>not applicable</u> ANGULAR RESOLUTION <u>0.2 mr</u> OPTICAL ELEMENT MATERIAL <u>Beryllium</u> COATING <u>Aluminum - Nickel</u> (electrolytically deposited) NOTES:			
12. SCAN: METHOD <u>Oscillating mirror</u> PATTERN <u>Linear pitch scan</u> SCAN RATE/FRAME TIME <u>$3^\circ/\text{second}$</u> POINTING MECHANISM <u>Shuttle - attitude control of pallet</u> POINTING ACCURACY <u>$\pm 0.5^\circ$</u> STABILITY <u>$\pm .01^\circ/\text{second}$</u> NOTES:			
13. DATA OUTPUT: CONTENT <u>Limb radiance—$\mu\text{W}/\text{cm}^2\text{-srad-nm}$</u> FORMAT <u>Serial binary, 14 bit digital word</u> NOTES:			

Table 1-1. NASA/JPL FLIGHT INSTRUMENTS CATALOG (Cont.)

INSTRUMENT NAME (APPS) Aerosol Physical Properties in the Stratosphere	INSTRUMENT CLASS	CATALOG NO.	PAGE 4 OF 4
OUTLINE DRAWINGS 			
BLOCK DIAGRAM <u>APPS SYSTEM BLOCK DIAGRAM</u> 			
FOOTPRINT S = DISTANCE TO TANGENT POINT h = ORBITAL ALTITUDE A = ALTITUDE ABOVE TANGENT POINT W = SCAN RATE  EXPANDED VIEW ROTATED 90°			
REFERENCES: AUTHOR(S) AND TITLE DATE <u>R. Newell and C. Gray - Meteorological and Ecological Monitoring of the Stratosphere and Mesosphere NASA-CR-2094</u> <u>August 1972</u> <u>C. Gray, H. Malchow, - Aerosol Physical Properties from Satellite</u> <u>July 1973</u> <u>D. Merritt, R. Var, Horizon Inversion NASA-CR-112311</u> <u>C. Whitney</u> <u>H. Malchow, C. Whitney - Inversion of Scattered Radiance Horizon Profiles for Gaseous Concentrations and Aerosol Parameters, December 1976.</u>			

SECTION 2

OPTICAL DESIGN

2.1 INTRODUCTION

Multispectral radiance from scattered solar radiation at the earth's limb is gathered by means of an optical system which contains a telescope with restricted field-of-view, spectral filters, and transfer optics. The telescope uses a reflective objective which focuses an image of the earth's limb onto a restricting focal-plane aperture. The optical radiation passing through the aperture is transferred by a lens into parallel beams which are cascaded down a chain of filters. Behind each filter is a lens which concentrates the image of the aperture onto detectors so that the radiance in each wavelength band may be recorded. A schematic of the optical system is shown in Figure 2-1.

2.2 OPTICS DESCRIPTION AND DESIGN

2.2.1 Objective

The collecting optics chosen for the radiometer is an unobscured (eccentric) Cassegrain telescope consisting of sections of a paraboloid (primary mirror) and a hyperboloid (secondary mirror). This configuration was chosen to obtain the highest possible rejection of off-axis radiance and to be consistent with the desired mechanical size for the APPS radiometer.

The principal dimensions of the objective are (in centimeters):

- (1) Clear aperture
 - (a) Primary diameter—11.4
 - (b) Secondary diameter—2.2
- (2) Equivalent radius of curvature
 - (a) Primary radius—61
 - (b) Secondary radius—30.5

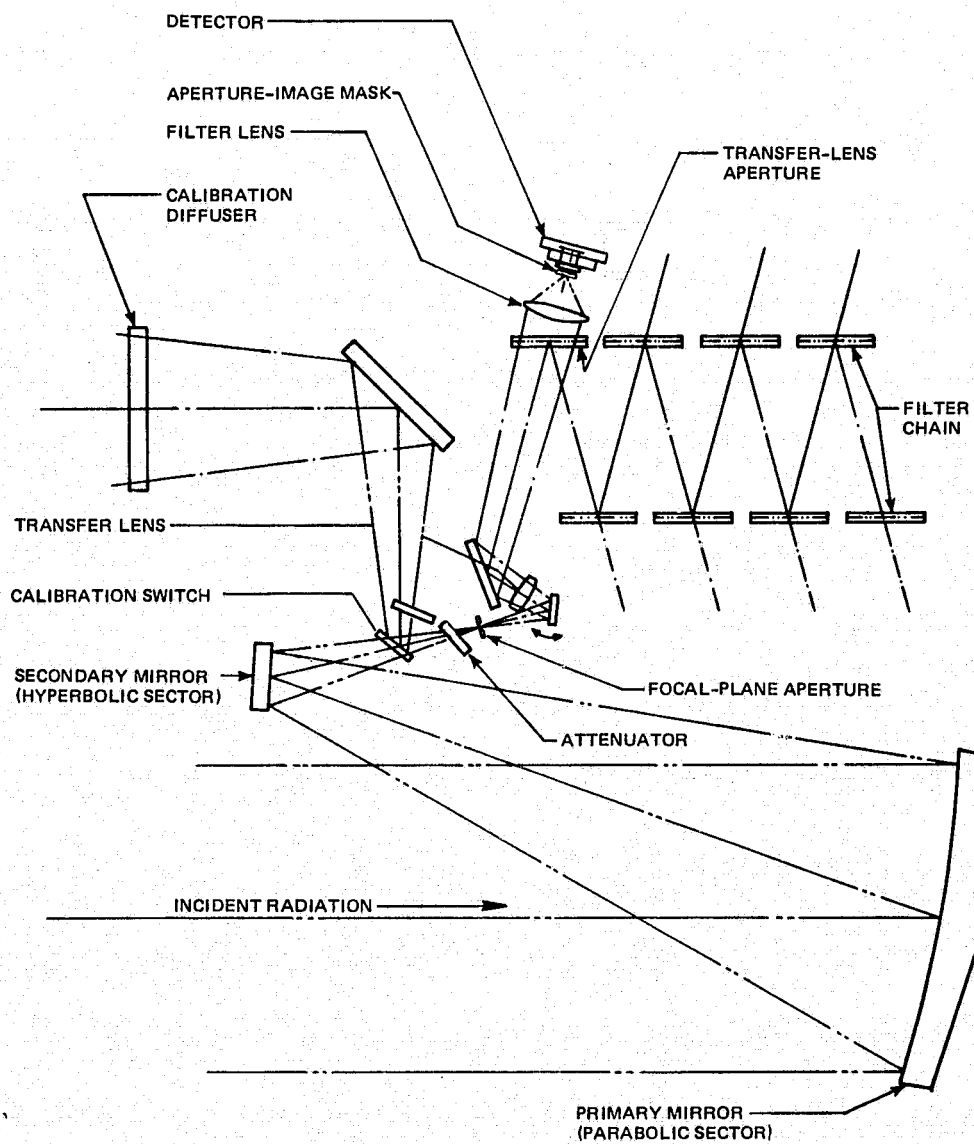


Figure 2-1. Radiometer optical train.

(3) Distance along optical axis

- (a) Primary to secondary—25.4
- (b) Secondary to focal plane—7.6

2.2.2 Transfer Lenses

Transfer lenses have been designed to provide a minimum of divergence to the filter chain of the optical radiation passing through the focal-plane aperture. To keep the number of elements small and the transmittance high, a single lens with one aspheric surface has been chosen. An image of the aperture is formed at a distance of approximately 80 centimeters so that a constant clear-aperture diameter is created throughout the filter chain. The specific image distance is thus governed by the path length required to accommodate the number of filters desired, which has been set at eight. The maximum divergence of the light rays for this optical design was set at ± 25 milliradians.

2.2.3 Filter Chain

The filter-chain assembly of the APPS design provides for up to eight spectral bands in a cascaded configuration progressing from the ultraviolet to the infrared wavelengths down the train. The mechanical design established thus utilizes a 15-degree angle-of-incidence to each filter, which results from a trade-off between minimizing path length, size, and polarization. Details of the filter characteristics are given in Section 2.5. The assembly accommodates filter discs 30 millimeters in diameter by 3 millimeters thick.

2.2.4 Detector Lens

Condensing lenses are required to minimize the size of the detectors. Behind each filter is a double convex singlet of 23-millimeter focal length, which reduces the size of the transmitted beam to fall within the detector area. The curvatures are spherical and are designed in conjunction with the transfer lens.

2.2.5 Scanning Mirror

The radiometer was originally designed for use in a spin-stabilized satellite and did not require a built-in scanning mechanism. To extend the use of the radiometer to the Space Shuttle mission, a scanning-mirror

assembly was designed at the outboard end (see Figure 1-3). It is comprised of a housing, a baffle, a plane mirror, and a drive train and motor. The mirror has a clear elliptical aperture approximately 15 centimeters by 12 centimeters, and is driven mechanically through the range ± 35 milliradians, which is optically ± 70 milliradians. The nominal line-of-sight is directed 111 degrees to the radiometer principal axis to accommodate the negative elevation of the limb from a 500-kilometer Space Shuttle orbit, and to conserve instrument-envelope dimensions.

2.2.6 Detailed Design

The performance of eccentric Cassegrain configurations was first examined using the CSDL automatic lens design programs. The specific design of the APPS optics was accomplished using the ACCOS V program system. The ACCOS V program has the coordinate transformations required to handle the decentered aperture and rotated transfer-lens optical axis, as well as provision for using aspheres of higher-than-conic order. The optical design and analysis programs provide:

- (1) Optical-surface curvatures.
- (2) Spacing and thickness of elements.
- (3) Clear-aperture requirements.
- (4) Image positions and aberrations.
- (5) Tolerances on optical parameters.

Table 2-1 is a listing of the optical parts with their approximate dimensions and forms. More details of the transfer and filter lens are shown in Figure 2-2. Tolerances for the objective components are listed in Table 2-2. Tolerances on the remaining optical elements are to be specified during the instrument-development phase.

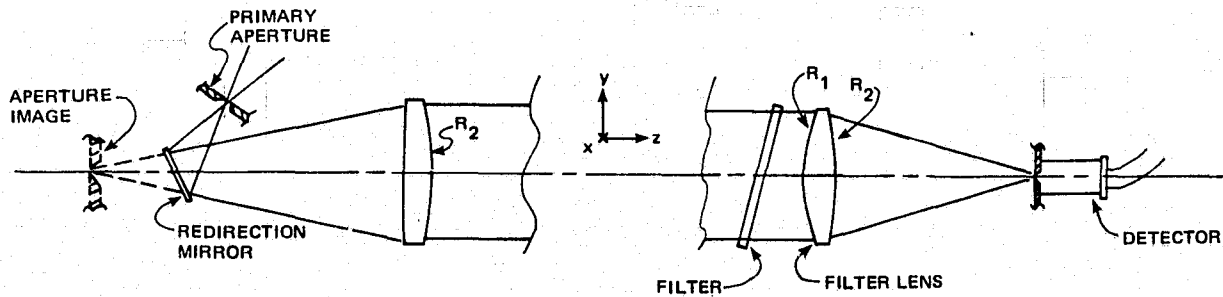
To obtain the maximum wavelength coverage, all refractive elements have ultraviolet-grade fused-silica substrates. To achieve thermal stability and to provide low mass, the reflective elements have beryllium substrates.

2.2.7 Resolution

The radiometer objective resolution is limited on-axis by diffraction, and produces images due to geometric aberrations at the edge of the field-of-view as shown in Table 2-3. Since the aperture width is much larger than the diffraction limit, only moderate tolerances are required on the optical components. In practice, however, the optical resolution will be determined by the accuracy of fabrication of the

Table 2-1. Optical parts list.

Component	Material	Approximate Size	Remarks
Primary Mirror	Beryllium	5-in. dia., 3/4-in. thick	Parabolic sector, EFL = 12 in.
Secondary Mirror	Beryllium	1-in. dia., 1/4-in. thick	Hyperbolic sector, EFL = 6 in.
Focal-Plane Aperture	Chromium on Quartz	3/8-in. dia., 1/16-in. thick	Aperture is scribed line on chromium coating protected by cover quartz plate
Attenuator Filter	Metal on Quartz	1/4-in. × 1/2-in. × 1/8-in. thick	Solar filter and compensator for direct calibration
Compensation Plate	Quartz	1/4-in. × 1/2-in. × 1/8-in. thick	Solar filter and compensator for direct calibration
Two-position Mirror	Beryllium	1/2-in. × 1/2-in. × 1/2-in. thick	Two positions — calibration or line of sight
Transfer Lens	Quartz	7/8-in. dia. × 0.3-in. thick	Single-element asphere
Flat Mirror	Beryllium	7/8-in. dia. × 0.2-in. thick	Redirection fixed mirror
Interference Filter	Multilayer on Quartz	1 1/8-in. dia. × 0.18-in. thick	Eight required — one for each waveband
Filter Lens	Quartz	7/8-in. dia. × 0.2-in. thick	Single-element spherical eight required — all identical
Scanning Mirror	Beryllium	5-in. × 7-in. × 3/4 in.	Flat



TRANSFER LENS	
SINGLE ELEMENT - ONE ASPHERIC	
MATERIAL: FUSED QUARTZ	
DIAMETER: 1.0 in.	
f/NUMBER: 2.47	
rms IMAGE RADIUS AT 0.9-degree FIELD ANGLE	
WAVELENGTH (μm)	rms RADIUS (in.)
0.31	0.00038
1.00	0.00049
NEW IMAGE DIAMETERS	

FILTER LENS	
SINGLE ELEMENT - SPHERICAL SURFACES	
MATERIAL: FUSED QUARTZ	
DIAMETER: 7/8 in.	
f/NUMBER: 1.06	
rms IMAGE RADIUS AT 0.9-degree FIELD ANGLE	
WAVELENGTH (μm)	rms RADIUS (in.)
0.31	0.018
1.00	0.022
NEW IMAGE DIAMETERS	

Figure 2-2. Transfer optics.

Table 2-2. Radiometer tolerances.

	Change in Parameter	Change in rms Image Radius
Primary Mirror to Secondary Mirror Spacing	± 0.005 in.	0.00104 in.
Secondary Mirror to Focal Plane Spacing	± 0.005 in.	0.00062 in.
Decentering of Primary Mirror to Secondary Mirror (Along y Axis)	0.005 in.	0.00051 in.
Decentering of Primary Mirror to Secondary Mirror (Along x Axis)	0.005 in.	0.00046 in.
Tilt of Primary Relative to Secondary Mirror (About x Axis)	0.05° (0.87 mrad)	0.00038 in.
Tilt of Primary Mirror Relative to Secondary Mirror (About y Axis)	0.05° (0.87 mrad)	0.00042 in.

Linear Relation Tolerance to Radius

Image Increase $\approx$ Image Diameter at Ends of Slit

Table 2-3. Radiometer specifications.

Entrance-Aperture Area	100 cm ²
Effective Focal Length of Primary Optics	45.72 cm (18 in.)
Field-of-View Through Primary Focal-Plane Aperture	0.2 mrad × 4 mrad (0.0036 in.) × (0.072 in.)
Radiometer Transmission (Up to and Including Transfer Lens)	22% - 47%
rms Image Radius of Primary Optics at 0.12 degree (Approx. Ends of Focal Plane Aperture)	0.023 mrad (0.00041 in.)
rms Image-Radius Transfer Optics at 0.9 degree (Approx. Ends of Focal Plane Aperture)	0.0005 in.

mirrors and alignment of the components. Figure 2-3 shows the optical transfer function of the radiometer comparing the objective and aperture over the first cycle. It can be seen from the curves that the response of the objective optics has a very small effect on the aperture response. The aperture-limited resolution is discussed further in Section 4.

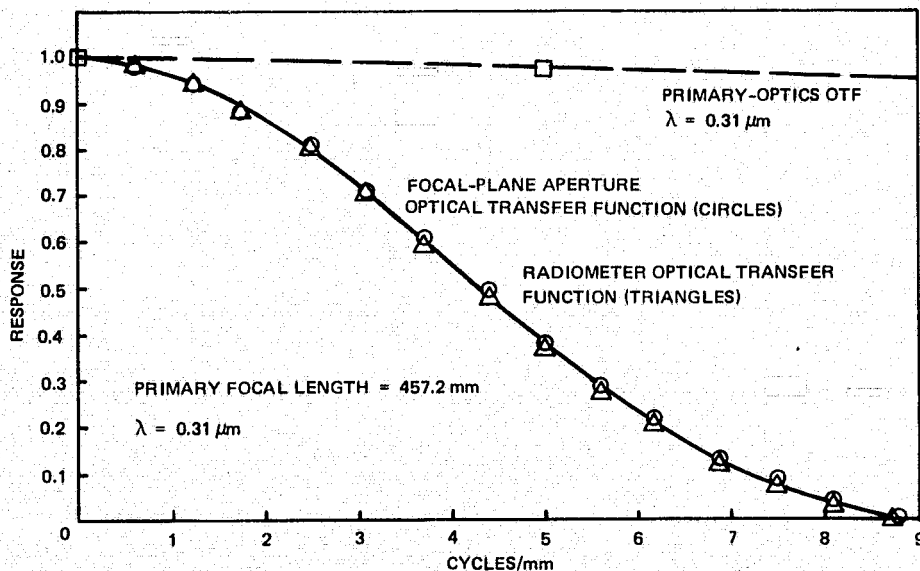


Figure 2-3. Radiometer optical transfer function.

2.3 APERTURES AND FIELD STOPS

2.3.1 Entrance Aperture

The diameter of the radiometer entrance aperture is chosen to give a 100-centimeter² collecting area. The position of the aperture stop is placed at the surface of the primary mirror to minimize its exposure to off-axis radiation. With the use of the scanning-mirror assembly, however, a more optimum position for the stop would be approximately 30 centimeters in front of the primary vertex. However, such a change would require a repositioning of the transfer-lens-aperture stop to a less desirable location.

2.3.2 Focal Plane and Transfer Lens

The field-of-view of the radiometer is defined and limited by a rectangular aperture at the focal plane. It is constructed by etching away material from chromium film deposited on the fused-silica plate. The aperture is protected by a fused-silica cover plate. The width of the aperture, the larger rectangular dimension, is limited to a 4-milliradian field-of-view by the desired solar-calibration technique, by the desired limb-spatial resolution, and by the mechanical size of the filter train. The height of the aperture has the same maximum limitation. The minimum height, however, is limited to 0.1 milliradian because of diffraction. Smaller apertures will cause the transmitted beam to increase beyond the clear aperture of the transfer lens.

The transfer lens produces an image of the objective-aperture stop approximately 8 centimeters beyond the lens. The redirection mirrors are configured to place this image at the first filter in the chain, so that a restricting aperture can be placed at this point to block light scattered by the objective aperture from reaching the detectors.

2.3.3 Detector

The condensor lenses are configured to place an image 0.4 times the focal-plane aperture on the detectors. This arrangement provides the smallest detector size requirement. However, in the case where the detector's area is large enough, the placement of the image slightly beyond the focus of the condensor lenses is desirable to minimize the effect of nonuniform sensitivities within the detector-active area.

2.3.4 Calibration Path

The diffuse calibration path is designed to permit an unvignetted view of a fused-silica diffuser by the transfer optics, filter train, and detectors. This is accomplished by the introduction of a redirection mirror between the secondary mirror and the focal-plane aperture. To duplicate the f/number of the objective, which is set at 4, the transmission diffuser ends up approximately 5 centimeters in diameter, at a location in the radiometer which permits its exposure to direct sunlight.

2.4 BAFFLE STRUCTURES

2.4.1 Objective Cavity

The objective-housing assembly is designed with baffles and light traps to minimize the illumination of the primary and secondary mirrors by optical radiation outside the field-of-view scattered from the housings. The design, as shown in Figure 2-4, represents an effective rejection system. For the Space Shuttle configuration, with the scanning-mirror assembly attached, it may be possible, after scattered-light tests are run, to eliminate some or all of the objective-cavity baffles to reduce the mass of the radiometer. Figure 2-4 shows the criteria lines used to establish the angles and depths of the baffle fins. The design goal was to require the equivalent of three specular reflections of an incoming ray before it arrived at either mirror, for a solar-exclusion angle of 20 degrees. The surface treatment of the baffles is discussed in Section 2.6

2.4.2 Transfer Region

The aperture plate is to be coated with a chromium film and black oxidized on the transfer-lens side. The radiation incident on the objective side of the aperture plate will be reflected against the internal baffles (between the secondary mirror and the focal plane). Special baffles beyond the focal-plane aperture are not required. All optical-cavity walls should be etched, sand-blasted, or serrated and blackened as defined in Section 2.6.

The third aperture stop, located at the first filter, should be machined during assembly to guarantee its function excluding an image of the illuminated primary-mirror aperture.

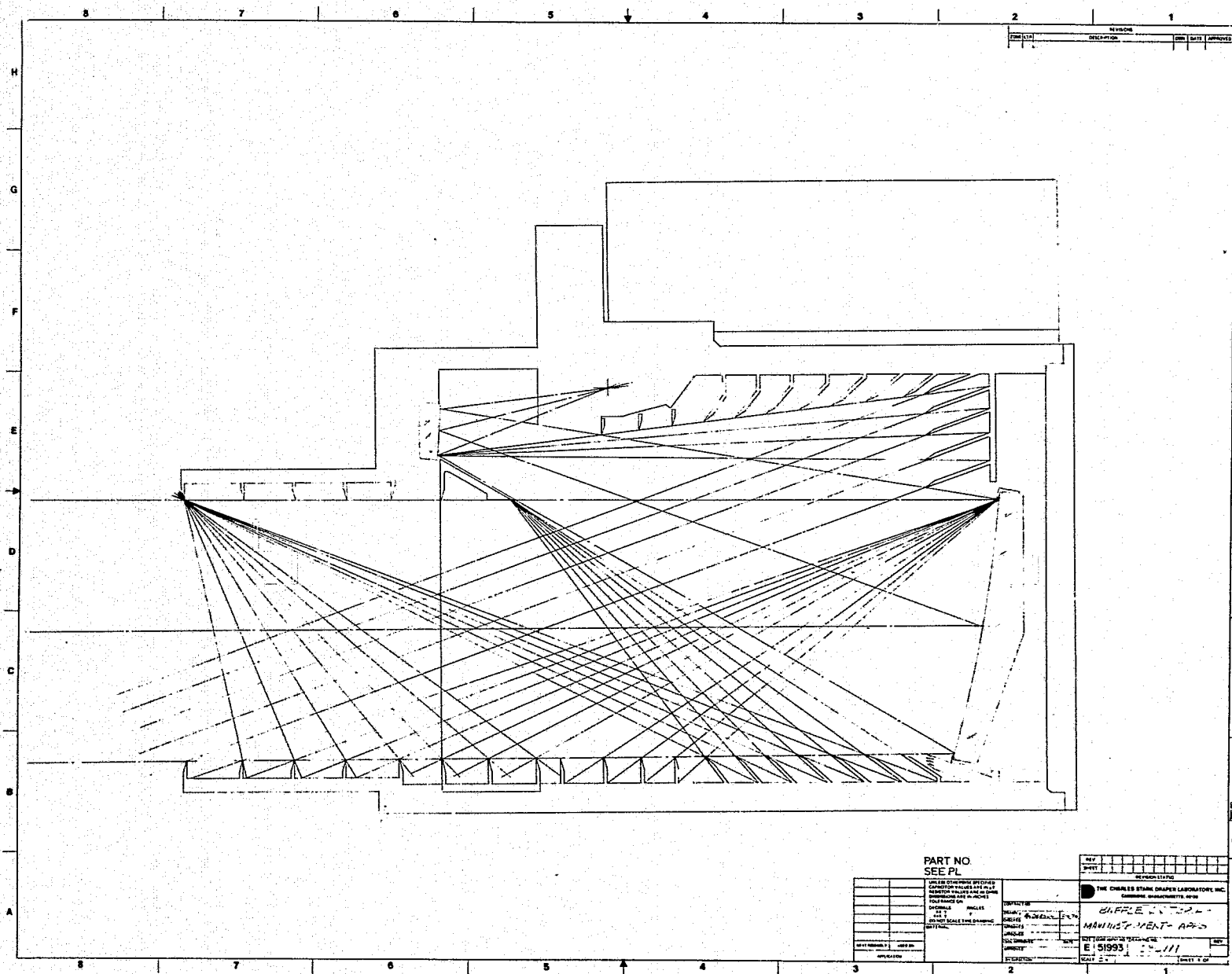


Figure 2-4. Baffle design criteria—objective cavity.

2.4.3 Filter Chain

A special light trap is located at the end of the filter chain. The design of this light trap aids in preventing a reflection of spectral radiation not sampled at each discrete filter. This reduces the general illumination of all channels from a large percentage of the reflected solar radiation lying between the filter bandpasses.

2.4.4 Scanning-Mirror Assembly

The design criteria for setting up the baffle positions for the scanning-mirror assembly are shown in Figure 2-5. The baffle length is arbitrarily terminated to keep the dimensions of the radiometer compact. The design allows a 25-degree sun-angle constraint.

2.5 FILTER CHARACTERISTICS

2.5.1 Transmission

The filter type chosen for use on the radiometer is a Fabry-Perot design with fused-silica substrates. Each filter consists of a blocker and a selector. Figure 2-6 shows the transmission bandpasses of a set of typical filters tested during the development of the instrument design. The equivalent integrated bandpasses vary from 10 to 20 nanometers. Both the bandpass and the center wavelength can be chosen to suit the radiometer design and inversion requirements between wavelengths of 250 and 2000 nanometers.

2.5.2 Reflection

The use of interference filters, as opposed to a prism or grating, is made efficient because most of the optical radiation not transmitted by the filters is specularly reflected. The order of the filters, from the ultraviolet to infrared, is chosen because a silver coating, which is preferred for its high reflectance, does not transmit well below 400 nanometers. Therefore, the first one or two filters will employ an aluminum coating to increase the system throughput for the ultraviolet filters. Table 2-4 shows the reflectances of a similar set of interference filters with aluminum coatings. The production filters are expected to have approximately 5-percent-higher reflectances outside their bandpasses.

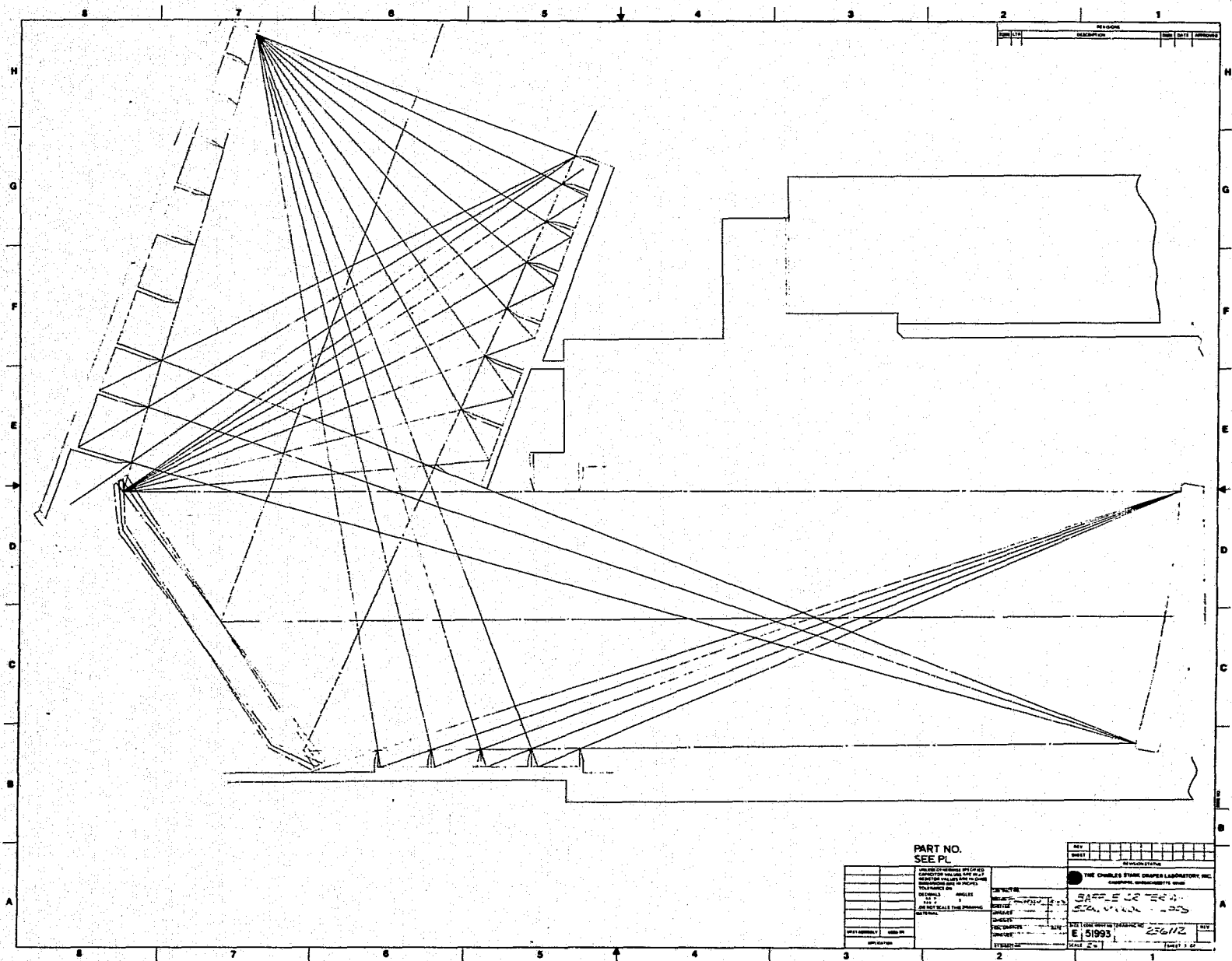


Figure 2-5. Baffle design criteria—scanning mirror assembly.

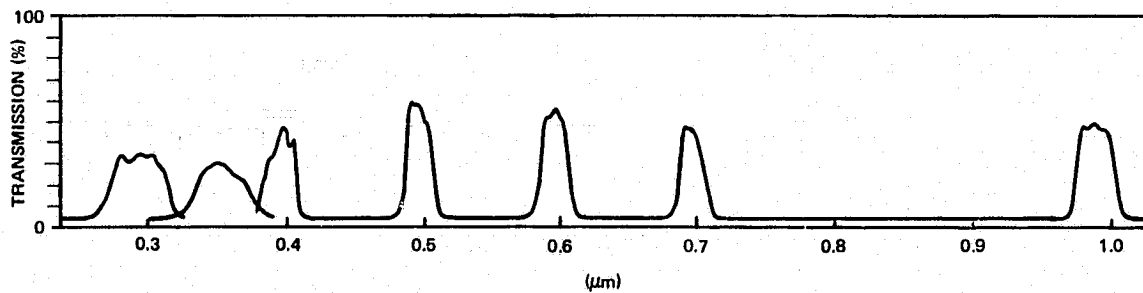


Figure 2-6. Typical interference filters—spectral bandpass characteristics.

Table 2-4. Percent reflectance values of Schott interference filters at 10-degree angle-of-incidence.

Measurement Wavelength (nm)	Filter Type				
	403 nm	420 nm	502 nm	596 nm	693 nm
400	28.5	28.5	86	86	86
500	87	86	64.5	89.5	86
600	92	92	92	79	92
700	94	92.5	91.5	91	84
800	95	95	92	89	89
900	95	95	92	89	89

2.5.3 Polarization

Optimization studies were performed at CSDL to establish the polarization properties of sample interference filters as a function of angle-of-incidence. A study was made to determine the approximate effects and variability of the polarization of the transmitted beam (see Figure 2-7). The values varied widely depending on the coating and material thickness chosen by the vendor. Table 2-5 shows the measured values at a 15-degree angle-of-incidence for the set of typical interference filters. The polarization values are well within the 10 percent criterion established as an upper limit for the present design. The reflected beams remained essentially unpolarized.

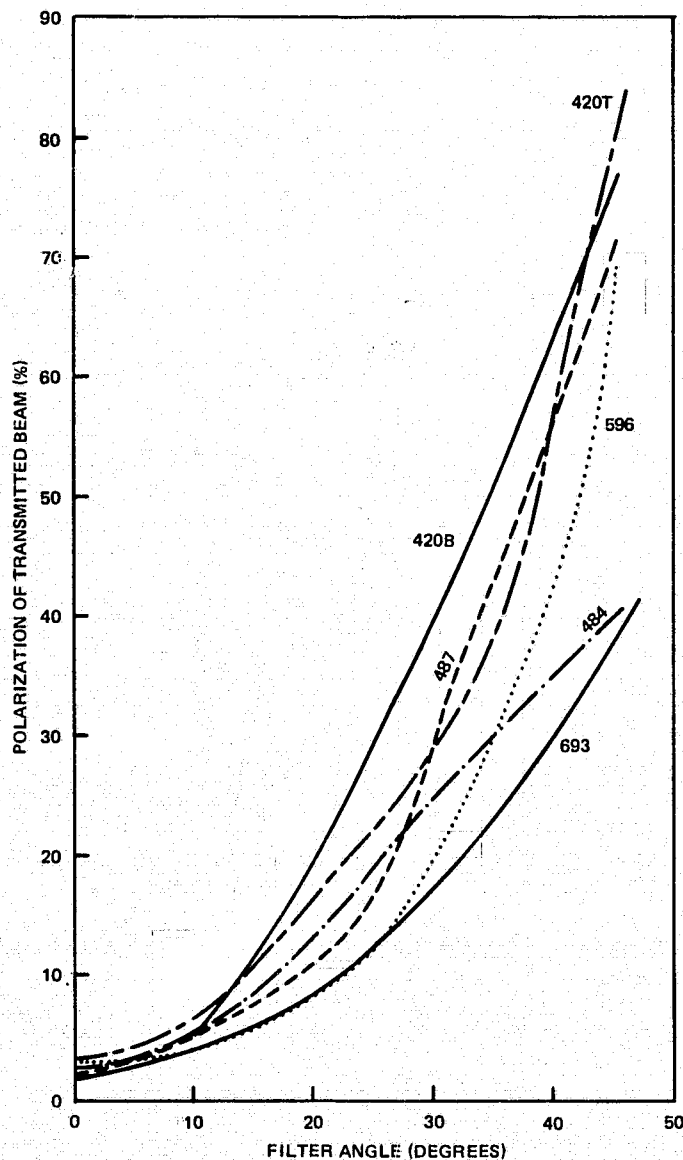


Figure 2-7. Interference filters—polarization characteristics.

Table 2-5. APPS interference filters - polarization characteristics at 15-degree angle-of-incidence.

λ (nm)	% (Vendor)	% (CSDL)
300	3.37	3.5
350	0.47	1
400	4.39	4.5
500	3.48	4
600	2.25	4
700	5.77	6
1000	8.85	9.5
1000	5.57 Rerun	

Reflection path <2% (CSDL).

2.6 COATINGS

2.6.1 Mirrors

The properties of the coatings chosen for the reflective components of the radiometer should have the following features:

- (1) Broad-spectral-band reflection.
- (2) Low diffuse scattering.
- (3) Durability.
- (4) Radiation hardness.

To preserve reflectance down to 300 nanometers, vacuum-deposited aluminum with a 1000-angstrom protective coat of magnesium fluoride is chosen. Figure 2-8 shows a comparison of the reflectance of different metals before oxidation, and includes an estimate for the protected aluminum. Higher efficiency multilayer reflective coatings are available, but the bandpass is sacrificed, and higher scattering is usually exhibited. The most advantageous alternative is the use of protected silver, which would provide a gain of approximately 10 percent per surface in reflectance. However, due to its sharp ultraviolet cut-off, the 300-nanometer channel would have to be sacrificed.

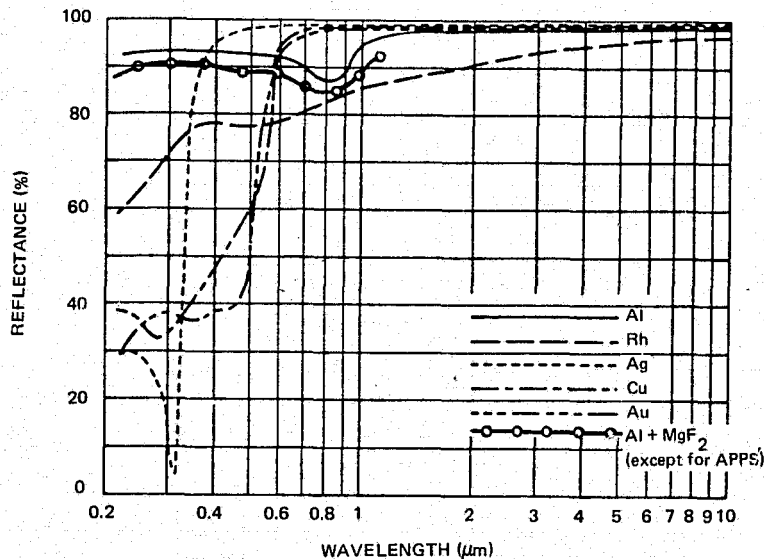


Figure 2-8. Reflectance of freshly deposited films.

2.6.2 Lenses

A similar compromise situation prevails with reflection-reducing coatings for the transmissive elements of the radiometer. High-efficiency coatings for lenses are available which reduce the average reflectance by a factor of 10 over an uncoated surface, but only over a maximum bandwidth of 400 nanometers. A protective coating of magnesium fluoride is advisable, however, to prevent staining of the elements during construction. Figure 2-9 shows the transmission-wavelength trade-off with antireflection coatings. The magnesium-fluoride thickness should be less than 1000 angstroms to enhance the ultraviolet region where both source power and detector sensitivity are low.

2.6.3 Throughput

To calculate the power losses through the radiometer, the most conservative coating performance was assumed: aluminum on mirrors, and uncoated lenses and windows. Table 2-6 shows the percentage of the input power leaving each element of the optical train at the center wavelengths of the filter bandpasses. The detector lenses are shown before the filter chain to simplify the tabulation. A gain in throughput of a factor of 2 for most wavelengths is possible with the use of higher efficiency coatings.

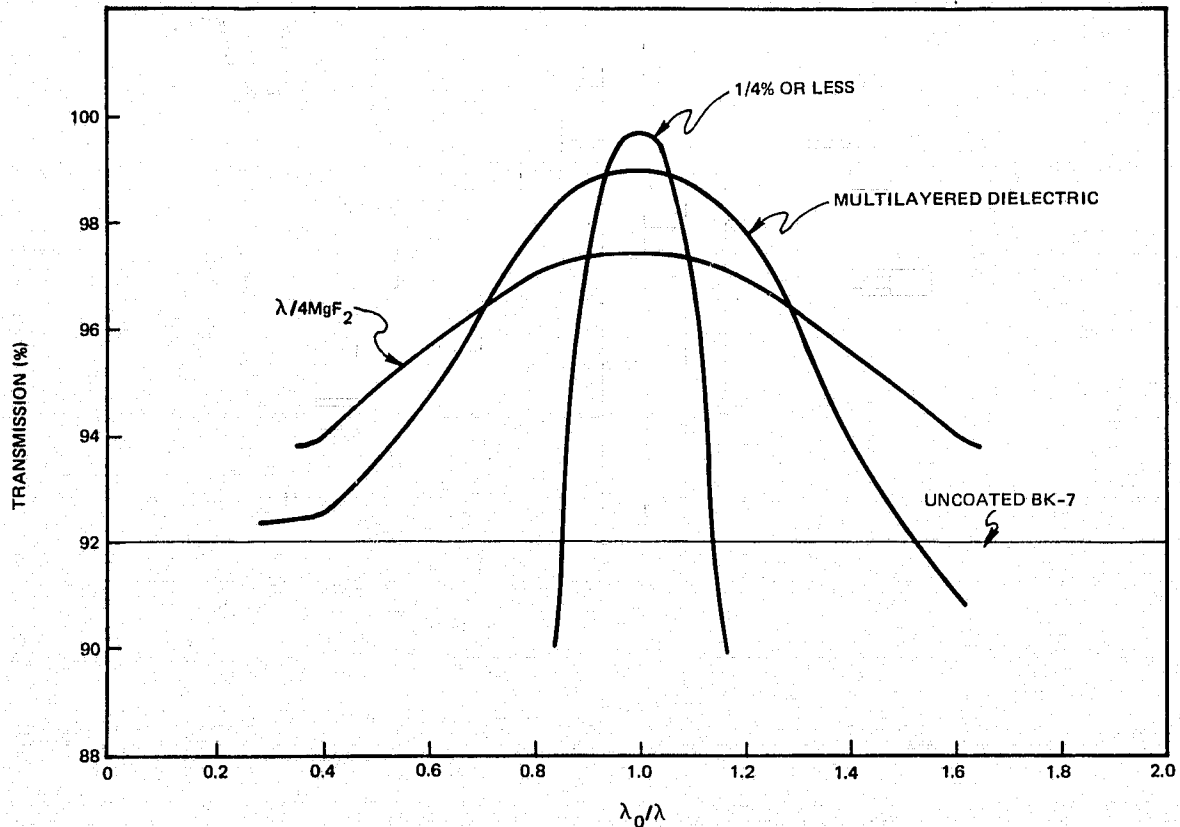


Figure 2-3. Antireflection coatings on BK-7 substrate.

2.6.4 Housings

From extensive scattered-light studies, two surface treatments have been found to be suitably low in scattering in the ultraviolet, visible, and near-infrared spectrum:

- (1) 3M Brand Black Velvet 100 Series paint (with zinc-chromate primer).
- (2) Black oxide of electroplated copper.

Although the paint has superior absorptions, it is difficult to apply to small cavities, and cannot be used on critical-fit interfaces. The paint treatment has previously been space-qualified and used successfully on telescopes. Specifically, it is recommended that the scanning-mirror-assembly baffles and spacers be painted. The objective-cavity baffles and spacers should be painted if the scanning-mirror assembly is not employed; otherwise, the surfaces should be electroplated. All other surfaces bordering the optical path should have the electroplate

Table 2-6. Percent throughput of APPS radiometer.

Element	Wavelength (nm)							
	300	350	400	500	600	700	850	1000
Nodding Mirror	R 90	90	89	88	87	85	84	90
Primary	R 81	81	79	78	76	72	71	81
Secondary	R 73	73	70	69	66	61	60	73
Focal Plane	T 67	67	64	64	61	57	56	69
First Redir.Mirror	R 61	61	57	56	53	48	47	62
Transfer Lens	T 56	56	52	52	49	45	44	58
Second Redir.Mirror	R 50	50	46	46	43	38	37	52
Detector Lens	T 46	46	42	43	40	36	35	49
1st Filter	R 30/T 15	39	36	38	37	34	33	47
2nd Filter	↓	27/12	32	33	34	32	32	44
3rd Filter	↓	↓	15/14	29	31	33	30	42
4th Filter	↓	↓	↓	12/17	29	28	28	39
5th Filter	↓	↓	↓	↓	12/16	25	25	35
6th Filter	↓	↓	↓	↓	↓	13/11	22	31
7th Filter	↓	↓	↓	↓	↓	↓	11/11	27
8th Filter	↓	↓	↓	↓	↓	↓	↓	13/14
Trap	12	11	7	7	10	10	10	13

R: Reflection

T: Transmission

treatment. The diffuse reflectance of the 3M paint is between 2 and 4 percent from 300 to 1000 nanometers, and for the oxide of copper, it is between 4 and 6 percent.

2.7 ALIGNMENT OF OPTICS COMPONENTS

2.7.1 Objective

The focal-plane-aperture assembly is rigidly mounted to the filter-chain assembly, and no adjustment is intended to be provided. The focal-plane-aperture assembly itself acts as a reference for adjustment of focus and alignment of the objective mirrors and transfer lens. The primary and secondary mirrors both have adjustable shims between their mounts and the main housings. The shims are machined for thickness and are tapered to make the aperture appear on-axis and focused at infinity as viewed from the outside by a collimator. These assembly adjustments are provided so severe mechanical tolerances of the primary- and secondary-mirror mounting surfaces are not required.

2.7.2 Transfer Lens

The transfer lens is provided with centering and focus shims to permit the accurate projection of the transferred beam along the desired optical path of the filter train and to set the proper divergence of the beam. The angle can be checked by removing the last filter and observing if the beam is centered. The focus is set to produce an image of the focal-phase aperture approximately 25 centimeters beyond the last filter position.

2.7.3 Detectors

The detector assemblies are adjustable in two directions perpendicular to the optical axis, to guarantee that the sampled radiation is collected by the detector's active area.

2.8 CALIBRATION

2.8.1 Switching Assemblies

Between the secondary mirror and the focal plane is located a calibration-switching assembly, which allows for two modes of direct solar calibration to establish the absolute and relative spectral responses of the radiometer. The solar-calibration technique uses a transmission diffuser or an attenuator. Mechanically, two separate

solenoids are designed to pivot either of the calibration arms, and to place a redirectional mirror and diffuser or an attenuator into the line-of-sight.

2.8.2 Diffuser Path

The redirectional mirror provides a view by the transfer lens and detectors of a transmission-diffusing disc located at the periphery of the housing which can be directly exposed to sunlight. The diffuser is a fused-silica disc opal fired on both sides (by the Kodak process), which is 50 millimeters in diameter by 6 millimeters thick. Figure 2-10 shows the diffusing characteristics of a single opal-fired surface in comparison to fine-ground glass. The double-sided version behaves so similarly to a Lambertian surface that it should provide a variation of signal to the detectors accurately proportional to the cosine of the sun angle from the zenith axis of the disc. It is intended for use at least once each orbit. When the scanning-mirror assembly is employed, a 15-degree restricting cone is placed over the diffuser path and oriented according to the mission profile to optimize the diffuser's exposure to the sun.

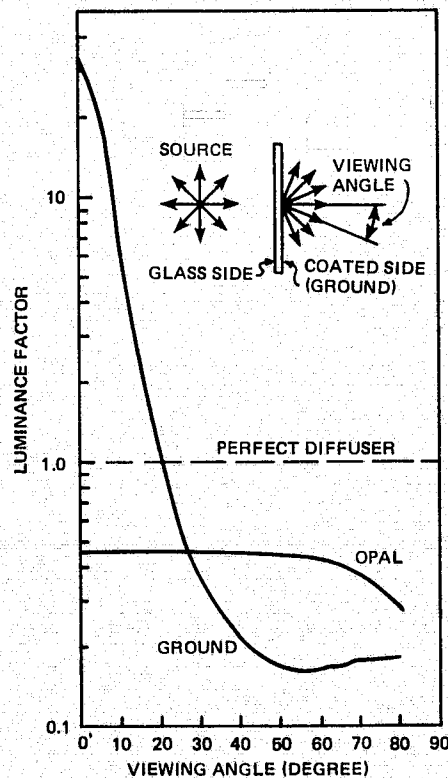


Figure 2-10. Comparison of flashed opal and fine-ground glass from Kodak brochure.

2.8.3 Direct Path

The second arm of the switching assembly contains a neutral-density filter, an attenuator, of the reflection type, with an attenuation coefficient of 10^5 , and a positive-meniscus lens to compensate for the focus shift caused by the thickness of the filter. The sun's disc can be viewed directly by the radiometer when the attenuator is in place without damage to the detectors. The attenuated signal is approximately the same value as the maximum limb radiance observable. This mode of calibration is required for certain orbital configurations where the sun is viewed only near the terminator. It also provides the capability for making extinction measurements at sunrise or sunset. The neutral-density filter (attenuator) is mounted diagonally to the optical axis to reflect the major part of the solar radiance through a port onto the objective wall and baffles.

SECTION 3

MECHANICAL DESIGN

3.1 GENERAL DESCRIPTION

The APPS radiometer mechanical design is based upon an off-axis Cassegrain telescope with a scanning mirror, discrete wavelength detectors, and support electronics that meet the optical and electronic requirements set forth for a Space Shuttle mission. The radiometer's overall dimensions for this specific design are 56 centimeters (22.0 inches) high, 36 centimeters (14.0 inches) deep, and 35 centimeters (13.6 inches) wide with an estimated weight of approximately 19.6 kilograms (43.25 pounds). In the Space Shuttle configuration, the radiometer is designed to be mounted vertically (see Figure 1-2) on a spacecraft pallet, and to scan the earth's limb between -17 and -25 degrees below the local horizontal.

3.2 MECHANICAL-DESIGN REQUIREMENTS

The initial constraints governing the mechanical design were:

- (1) 100-cm² entrance aperture.
- (2) 45.72-cm (18.0 inches) effective focal length of primary optics.
- (3) 0.2-milliradian $\times$ 4-milliradian instantaneous field-of-view.
- (4) Eight wavelength channels in a cascaded optical filter system.
- (5) Dual in-line solar calibration.
- (6) Provisions for scanning the optical line-of-sight ± 4 degrees.

Other design considerations were:

- (1) Minimum weight and size.
- (2) Space qualification.

- (3) Minimum number of reflective surfaces in the optical train.
- (4) Parallel processing of radiance data.

3.3 OPTICAL PATH

The optical path of the APPS radiometer is first considered to illustrate the major design features (see Figure 2-1). Collimated energy first enters the forward section of the scanning-mirror assembly, then passes through the forward baffle system and onto the scanning mirror. From there it is redirected through the rear baffle system of the scanning-mirror assembly and the baffle system of the main housing, and onto the primary mirror. The energy collected at the primary mirror is focused towards the front of the instrument and off-axis to the secondary mirror. From the secondary mirror, the energy is reflected back toward the rear of the instrument through the calibration-switch assembly to the focal-plane aperture.

The radiance passing through the focal-plane aperture is then reimaged with the transfer lens, and redirected with mirrors to the first of eight cascaded interference filters. The sampled radiance that then passes through each filter is focused onto a detector with a filter lens. The radiance not sampled by the previous filter is reflected to the next interference filter and detector combination throughout the filter chain at an incident angle of 15 degrees to the normal. The radiance which is not selected is removed at the end of the chain with a light trap.

The calibration-switch assembly permits two modes of direct solar calibration. In the primary calibration mode, a shutter prevents energy from entering through the main path, and accepts energy only through the transmission diffuser which is directed into the focal-plane aperture. The second direct solar-calibration mode is initiated when the calibration-switch assembly activates a mechanical arm with filter (attenuator) attached, thereby placing this attenuator in the main line-of-sight just before the focal-plane aperture.

3.4 MAJOR SUBASSEMBLIES

A description of each of the major subassemblies and subsystems will serve to illustrate the specific APPS radiometer mechanical design.

3.4.1 Main Housing (P/N 236117) *

The main housing serves as a foundation of the APPS radiometer upon which the various subassemblies are attached. The main housing is to be machined from a beryllium billet with an initial weight of about 25.4 kilograms (56 pounds). After machining, the estimated weight of the main housing is about 4.1 kilograms (9 pounds). The end flanges are square to provide mounting lands for the electronic assemblies. The exterior shape between these end flanges is essentially octagonal, with raised bosses for mounting the various subassemblies. These octagonal shapes are used for the large assemblies to optimize weight reduction while maintaining mechanical rigidity through fairly simple machining techniques. Points of attachment are placed at 45-degree intervals near the vertices of the octagon. The spacecraft mounting interface is perpendicular to the end faces and is relieved to accept the three kinematic ball mounts (see Section 3.4.11). The main interior cavity consists of a $19.063^{+0.013}_{-0.000}$ centimeter ($7.505^{+0.005}_{-0.000}$ -inch) diameter bore in the rear section of the housing. A second bore, $14.618^{+0.013}_{-0.000}$ centimeters ($5.755^{+0.005}_{-0.000}$ inches) in diameter, eccentric to the first bore by 2.222 centimeters (0.875 inch), is in the forward section of the housing. This smaller bore is concentric with the main line-of-sight and accepts the forward baffles. The larger bore accepts the rear baffles, and provides additional volume for the baffles near the primary mirror. A cutout in the surface opposite the mounting plane accepts the filter assembly and the focal-plan assembly.

3.4.2 Primary-Mirror Assembly (P/N 236148)

The primary-mirror assembly consists of the primary mirror, primary-aperture stop, support structure, and machined spaces used for mounting and aligning the primary mirror to the main housing. The primary mirror is an off-axis segment of a parabolic mirror. Three pads are machined and lapped on each of the mating surfaces between the mirror and its supporting structure to provide a three-point mounting system with minimum distortion. In addition to the three attaching screws, there are two dowel pins, one in a hole and the other in a slot, to provide locational accuracy. The supporting structure (P/N 236118) pilots accurately in the main housing, and also serves as a retainer for the rear baffle system. Cemented to the outside of the primary mirror is the primary-aperture stop — a cylindrical component machine with a stop diameter of 11.430 ± 0.013 centimeters (4.500 ± 0.005) inches.

* Drawings referenced by P/N number are included in Section 3.7.

3.4.3 Secondary-Mirror Assembly (P/N 236149)

The secondary-mirror assembly consists of the secondary mirror, support structure, and machined spacer used for mounting and aligning the secondary mirror to the main housing. The secondary mirror is an off-axis segment of a hyperbolic mirror. A single pad is machined and lapped on each of the mating surfaces between the mirror and its support to minimize distortion. A double-dowel pin system provides locational accuracy in a manner similar to that of the primary mirror. The supporting structure (P/N 236146) pilots accurately in the main housing, and is mounted in conjunction with a machined spacer on the assembly to provide the proper axial location.

3.4.4 Calibration-Switch Assembly (P/N 236115)

The calibration-switch assembly consists of a machined housing with integral mounting pads and provisions to accept the components that permit two modes of direct solar calibration. The housing is open on both sides, so that the components may be assembled and calibrated in an exposed state. Closeout panels are added prior to assembly in the instrument. There are two arm assemblies, each actuated by a pull-type solenoid. Each arm is preloaded in the "off" position by an extension spring, and when actuated, rotates 15 degrees about a cantilever-type flexural pivot into a stop on the housing at the "on" position.

The geometry of the system depends on the following design goals:

- (1) Solenoid travel - Minimum travel near the end of the stroke to provide the maximum force.
- (2) Flexural pivot rotation - Minimum angular rotation to provide maximum life of pivot.
- (3) Extension spring force - Enough force to retrain the arms during launch loads, but less than the solenoid actuating force.
- (4) Physical size - Proper size to meet component requirements of the mirrors, filters, and assembly clearances.

A model of the salient design feature of the calibration-switch assembly has been fabricated (P/N 236107) and tested to optimize the factors mentioned previously.

In addition to the design requirements and constraints listed, control of incoming radiation must be regulated in the normal mode of operation and each of the two solar-calibration modes. During normal operation, there is a linkage and shutter mechanism attached to the end

of the arm containing the diffuser mirror, which prevents energy from the diffuser path from entering the housing. Also, there is a shutter attached to the attenuator arm, which prevents radiation from entering the line-of-sight from the forward baffles in the main housing via the attenuator's exit pupil. Each of these shutters is designed to be closed during the "off" cycle of each switch.

3.4.5 Calibration-Diffuser Assembly (P/N 236114)

This calibration-diffuser assembly consists of a machined housing which contains a redirection mirror, shroud, and a quartz transmission-diffusing disc. The assembly pilots into the main housing, and is attached by means of two indexing brackets. Normally, the direction of the line-of-sight of the calibration-diffuser assembly is parallel to the radiometer's line-of-sight, which is 21 degrees below local horizontal. However, this assembly may be rotated in increments of 15 degrees pitch angle. The calibration diffuser itself is located against an O-ring when the shroud is attached to the main housing. The inside conical surface of the shroud is serrated to minimize the effect of scattered radiation. A flat redirection mirror is attached to the support structure through three lapped pads on each component to minimize distortion.

3.4.6 Filter Assembly (P/N 236170)

The filter assembly is the mechanical housing where sampled radiation from the earth's limb is separated into discrete spectral wavelengths and detected. In the initial design stages, the filter-chain configuration was investigated quite thoroughly, because the design of the radiometer depends heavily on the filter chain. At first, a carousel arrangement was considered. In this configuration, the filters were placed in a circular pattern with the reflecting light paths lying in a single plane. Another configuration considered was that similar to the strings on a toy drum. The filters were placed in a circular pattern at each end of the "drum," and the light path ran back and forth between filters along the outside cylindrical surface of the drum. In each of these two configurations, even though the total path length was relatively small, it was felt that the difficulty in machining the parts and assembling them accurately far outweighed the advantages of a short-path-length design.

It was then determined that a cascaded arrangement between two parallel rows of filters would be the simplest to machine and assemble accurately. Other factors within this configuration had to be considered, however. Two basic restraints were:

- (1) Minimum total-path length -- The size and weight of the assembly was directly related to the path length, as the diverging beam required larger components with increased path lengths.
- (2) Minimum angle-of-incidence -- Polarization effects were of concern to the optical designers, and it was stressed that the incident angle should be kept small to minimize these effects. As the angle decreases, however, the path length increases due to the filter-spacing requirements.

Several designs were made using incident angles of 10, 12.5, 15, and 22.5 degrees. Parameters considered were filter diameter, filter spacing, path length, lens focal length, size, and weight. An incident angle of 15 degrees was chosen as being optimum, and subsequently the polarization effects were verified as acceptable by means of a test fixture (P/N 219927).

The present filter-assembly design consists of four machined blocks sandwiched between two cover plates. The two inner blocks house the filters, lenses, and retainers, and the two outer blocks house the detectors and wire harnessing. The two opposing filter blocks are kept parallel by aligning and pinning them to the cover plates. Each filter recess is spaced accurately in the block, and the filters are kept parallel by a ganged retainer which indexes the filters to the interior faces of the parallel blocks. This method of mounting provides for minimum misalignment by relatively simple machining and assembly procedures.

Other notable design features of the filter assembly are:

- (1) The flat redirectional mirror used to align the radiation from the focal-plane assembly to the filter-assembly optical axis is mounted to the left-hand filter block on three lapped pads. The mirror's compound angle is controlled by machining the mounting surface on a rotary table. The desired compound angle can be obtained accurately with basic 15- and 45-degree angular rotations.
- (2) The transfer lens located between the focal-plane assembly and the filter-assembly redirectional mirror is retained against an O-ring and spacers which are to be machined at assembly for alignment.

- (3) The upper and lower cover plates are machined from 0.952- and 0.635-centimeter (0.375- and 0.250-inch) thick plates, respectively. The stock is relieved to provide an isometric plate construction with 0.318-centimeter- (0.125-inch-) thick webs and ribs. Additional bases are provided for mounting screws.
- (4) Six mumetal 0.081-centimeter-(0.032-inch-) thick cover plates enclose the entire assembly to provide magnetic shielding.
- (5) Thermal control is provided by eight thermoelectric elements located between the filter assembly and the main housing. Thermal isolation is obtained by the use of four titanium standoffs, each having an outside diameter of 0.508 centimeter (0.200 inch) and a wall thickness of 0.102 centimeter (0.040 inch).

3.4.7 Focal-Plane Assembly (P/N 236189)

The focal-plane assembly is actually a subassembly of the filter assembly, however it is discussed as a separate assembly. The essential parts of the focal-plane assembly are a machined housing, a focal-plane-aperture transfer lens, and a redirectional mirror. The aperture consists of a masked opening 0.0091-centimeter (0.0036-inch) high by 0.183-centimeter (0.072-inch) wide on a coated disc of quartz 0.157-centimeter- (0.062-inch-) thick and protected by a 0.157-centimeter- (0.062-inch-) thick cover plate. This element is mounted in the housing between two retainer shims. These shims are machined at assembly to provide precise axial position of the focal-plane aperture. A flat redirectional mirror is mounted to its support through three lapped pads. The angle of redirection is controlled by machining the mating surfaces. However, more precise location could be obtained, if required, by using an adjustable mounting plate. The housing is indexed to the filter assembly by positioning one edge against the filter-assembly housing and pinning.

3.4.8 Scanning-Mirror Assembly (P/N 236211)

The scanning-mirror assembly is the mechanical housing where radiation from the earth's limb is optically scanned to obtain vertical-radiance profiles. The scanning-mirror assembly, which is specifically designed for Space Shuttle applications, is attached externally to the main housing of the radiometer. The housing is machined from a beryllium billet to a shape that is essentially two intersecting octagons, 19.05 centimeters (7.50 inches) across the flats. Two intersecting bores of 18.427^{+0.013}_{-0.000} centimeters (7.255^{+0.005}_{-0.000} inches) in diameter accommodate the baffles. End plates serve as a baffle retainer and are fastened near the

vertices of the octagon. Two slots 18.098 ± 0.002 centimeters (7.125 ± 0.001 inches) apart are milled in the side walls to accept the mirror supports. Two holes 0.7963 ± 0.0013 centimeter (0.3135 ± 0.0005 inch) in diameter are line bored in each side of the housing to provide an accurate location for the rotational axis of the mirror. The mirror, 12.70 centimeters (5.00 inches) by 15.24 centimeters (6.00 inches) by 1.27 centimeters (0.50 inch), is relieved on the back side to reduce weight and provide mounting lands for the supports.

The mirror is supported on one side by a cantilever-type flexural pivot in a bracket which mounts directly to the housing. On the other side, which is the driver side, a yoke-bracket is used to support the mirror with a second flexural pivot. The mirror is driven by a bracket which is attached to the motor and, in turn, is attached to the mirror through the yoke, thus bypassing the flexural pivot. In this manner, the bearings in the motor-gearhead assembly are relieved of mirror loads.

The assembly procedure for mounting the mirror in the scanning-mirror housing is as follows: The mirror and brackets are assembled so that the stacked height is about 0.013 centimeter (0.005 inch) less than the distance between the milled slots on the housing. This sub-assembly is then inserted, rotating the mirror about 10 degrees for housing clearance, into the milled slots. The stack is then extended to a snug fit with the housing by adjusting the axial location of one of the pivot members. Close-fitting alignment pins are inserted into the line-bored locating holes in the housing, and the mirror supports are fastened to the housing. The alignment pins are then removed, and the motor-gearhead assembly is attached to the mirror bracket and is fastened to the housing. By using this procedure, misalignment between the motor shaft and the axis of the flexural pivot is minimized. The effect of misalignment is further reduced by the fact that the amount of mechanical rotation involved is only ± 2 degrees. The mirror is pre-loaded by means of two extension springs attached to each side of the mirror.

Completing the assembly is a back cover plate which encloses the mirror mechanism after assembly. Attachment to the main housing is accomplished through an interface plate which fastens to the main housing.

3.4.9 Baffles

Throughout the radiometer, baffles are used extensively to reduce off-axis scattered radiation. A discussion of the radiometer-baffle system will serve to define its mechanical design, location, and fabrication requirements. For considerations of optical criteria of the baffle system, see Section 2.4. In general, the design features for the baffles are:

- (1) Baffle thickness = 0.127 centimeter (0.050 inch).
- (2) Spacer-wall thickness = 0.254 centimeter (0.100 inch) relieved to 0.127 centimeter (0.050 inch).
- (3) Diametrical clearance between baffle, spacer, and housing = 0.013 to 0.038 centimeter (0.005 to 0.015 inch).
- (4) Chamfer angle = 15 degrees.
- (5) Diametrical clearance between baffle point diameter and theoretical aperture = 0.013 to 0.038 centimeter (0.005 to 0.015 inch).

The baffles and spacers are restrained in rotation by a series of dowel pins and slots. Series of baffles and spacers are restrained rotationally by their respective end caps attached to the housing.

A description of the baffles along the line-of-sight, starting from the entrance of the scanning-mirror assembly to the primary mirror, is:

- (1) P/N 236151, -152, -153, -154, -156, -157, -158 - The first several baffles in the scanning-mirror assembly are a combination baffle and spacer, cylindrical in form. From where the two housing bores intersect, the baffles are chamfered to prevent interference. This occurs on each side of the scanning mirror.
- (2) P/N 236128 - The first baffle in the main housing is cylindrical with a circular cutout concentric to the outer diameter.
- (3) P/N 236120 - The secondary baffle consists of a cylinder with cutouts representing the intersection of a cylinder and two cones. The inside surfaces are serrated to minimize stray-light effects.
- (4) P/N 236132 and 236133 - The next five baffles are flat with cutouts for the calibration-switch assembly and the filter assembly. The optical cutouts in these baffles are the intersections of two circles.
- (5) P/N 236140 - The next seven baffles are conical in shape with varying cone angles.

- (6) P/N 236123, -124, -138, -139 - The end-baffle assembly consists of five conical baffles eccentrically positioned so that the lower edges are in mutual contact. This group is then brazed in place to a cylindrical housing to form the primary-mirror baffle assembly.

3.4.10 Electronics Assemblies

The design, as presented, does not include mechanical drawings of the electronics assemblies which are to be specified during the instrument-development phase. Provisions for electronic-component mounting plates have been incorporated into the design of the housing.

3.4.11 Mounting and Interface System

Definition of Space Shuttle mounting and interface system has not been finalized. However, the mounting system has been designed and may be retrofitted as required. The kinematic mounting system consists of three balls, 1.905 centimeter (0.750 inch) in diameter, mounted in conical seats on one side of the interface. On the other side of the interface, there are three different types of seats: conical, which is the fixed position; V-groove, which allows movement in one direction; and a plane surface, which allows movement in any direction in the mounting plane. The three bolts through each of the balls are preloaded by means of conical spring washers, fixing the instrument position. If any distortion occurs on the mounting plate, either due to thermal effects or dynamic loading, two of the three balls are free to move without loading the optical structure. When the loads are removed, the system will return to its original position.

3.5 MATERIALS

In general, the materials used in this mechanical design are:

- (1) Quartz optical elements (except mirrors).
- (2) Beryllium mirrors.
- (3) Beryllium large housings and parts critical to optical alignment.
- (4) Aluminum alloy remaining parts, including baffles, spacers, and brackets.

3.6 FINISHES

All surfaces exposed to the optical path will be blackened, either by applying a treatment of black oxide of electroplated copper or 3M

Brand Black Velvet Series paint, over a zinc-chromate primer (see Section 2). Specific surfaces to be treated are defined in the component and assembly drawings.

3.7 MECHANICAL DRAWINGS

This section contains reduced prints of the mechanical drawings, details, and assemblies.

NOTES:

1. MATERIAL: ONE OF THE FOLLOWING MAY BE USED:
A. BERYLLIUM OPTICAL GRADE 3 TO A MANUFACTURED BY PRUSH WELLMAN INC., FARMER, N.Y.
B. BERYLLIUM GRADE 981 MANUFACTURED BY KAWESKI RECYCLED ALUMINUM INC., WILKES-BA, PA.

2. ORDER OF OPERATIONS:

- A. MACHINE AS REQ'D, TYPICAL DIMENSIONS VACUUMED TO .010/.020 OF FINISHED PART
- B. STRESS RELIEVE AT 1450°F ± 25°F FOR 1 HOUR 1 MIN. IN VACUUM OR OTHER PROTECTIVE ATMOSPHERE COOL TO 700°F AT A RATE NOT TO EXCEED 100°F PER HOUR, COOL IN STILL AIR FROM 700°F TO ROOM TEMPERATURE (VACUUM OR OTHER PROTECTIVE ATMOSPHERE NOT NEEDED BELOW 700°F)
- C. FINISH MACHINE
- D. STABILIZE AT 200°F ± 10°F FOR 10 MINUTES ± 1 MINUTE, COOL TO 200°F TEMPERATURE AND HOLD FOR 10 MINUTES ± 1 MINUTE, COOL TO -100°F ± 10°F AND HOLD FOR 10 MINUTES ± 1 MINUTE, REPEAT STABILIZING PROCEDURE FOR A TOTAL OF 5 Cycles
- E. SURFACES A-A-C TO BE SELECTLESS NICKEL COATED PER MIL-C-26274 CLASS 2, .004/.006 THICK. ALL OTHER SURFACES OPTIONAL
- F. ORDER OF OPERATIONS OF THIS NOTE OPTIONAL
 1. INSTALL HELICAL COIL INSERTS
 2. PERFORM FINISH OPERATIONS TO SURFACES A-A-C AS REQ'D PER NOTES 4 AND 5
 3. NICKEL COATING SHALL NOT BE REDUCED TO LESS THAN .001 IN. THICK
 4. REPEAT STABILIZATION CYCLES PER NOTE 2D FOLLOWING EACH FINISHING OPERATION OR SEQUENCE UNTIL DIMENSIONAL STABILITY IS ACHIEVED

3. SURFACE A-A TO BE ALUMINIZED PER MIL-M-1350B, PROTECTIVE COATING SHALL BE MIN. 100 NM ± 25 NM THICK OVER CLEAR APERTURE.

4. SURFACE A-A TO BE A SECTION OF PARABOLOID, WITH VERTICALITY ± .001/D

WHERE $C = 1/R_e$
 $R_e = \text{EFFECTIVE RADIUS}$
 $= 24.000 \pm .020 \text{ INCHES}$

5. SURFACE IRREGULARITY SHALL BE $\leq \lambda$ AT 633 NM OVER THE CLEAR APERTURE

6. SURFACE QUALITY OF SURFACE A-A TO BE 10/20 PER MIL-Q-13830 OVER THE CLEAR APERTURE

7. SPECULAR REFLECTANCE OF SURFACE A-A ALONG CENTER AXIS SHALL BE NO LESS THAN 88% FROM 300 TO 1000 NM WAVE LENGTH

8. CLEAR APERTURE OF SURFACE A-A ABOUT CENTER AXIS ± .025 INCHES

9. ALL DIMENSIONS APPLY AFTER COATING

NOTES: (CONTINUED)

10. RESOLUTION TEST

WITH THE 2 V-SHED M-200'S ARRANGED IN THE CONFIGURATION OF DETAIL A, A COLLOCATED VISUAL POINT SOURCE RESPONDING UNIFORM ILLUMINATION TO F15 OVER THE CLEAR APERTURE OF THE PRIMARY MIRROR AND ALIGNED PARALLEL TO THE AXIS OF SYMMETRY, SHALL FORM AN IMAGE AT THE FOCUS POINT WITH 50% OF ITS POWER WITHIN A .0005" DIAMETER. THE TOTAL POWER IN THE IMAGE SHALL BE DETERMINED BY MEASURING THE LIGHT THAT PASSES THROUGH A 0.5 INCH DIA HOLE PLACED AT THE FOCUS POINT.

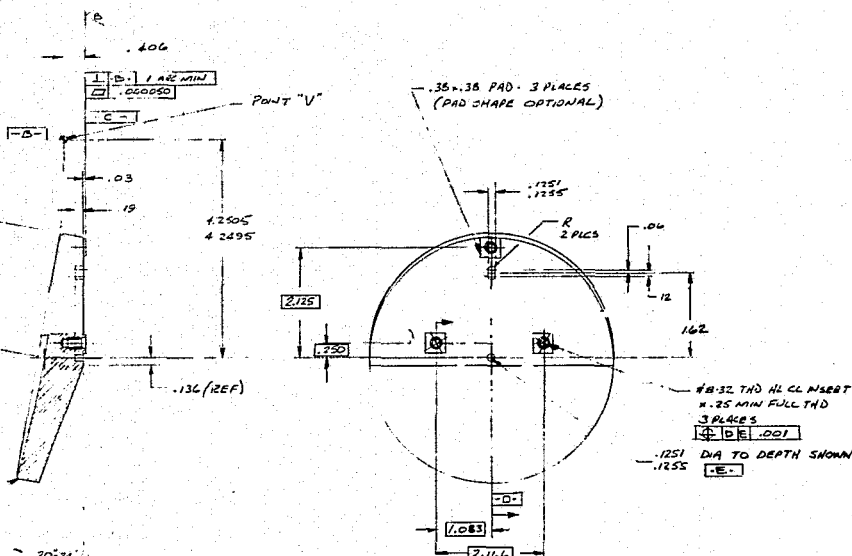
24.000 ± .020
EFFECTIVE RADIUS
SEE NOTE 4

AXIS OF SYMMETRY

10" DIA
1072" REF

03-45° HAMMER
2 PLACES

10" DIA



PART NO. SEE PL

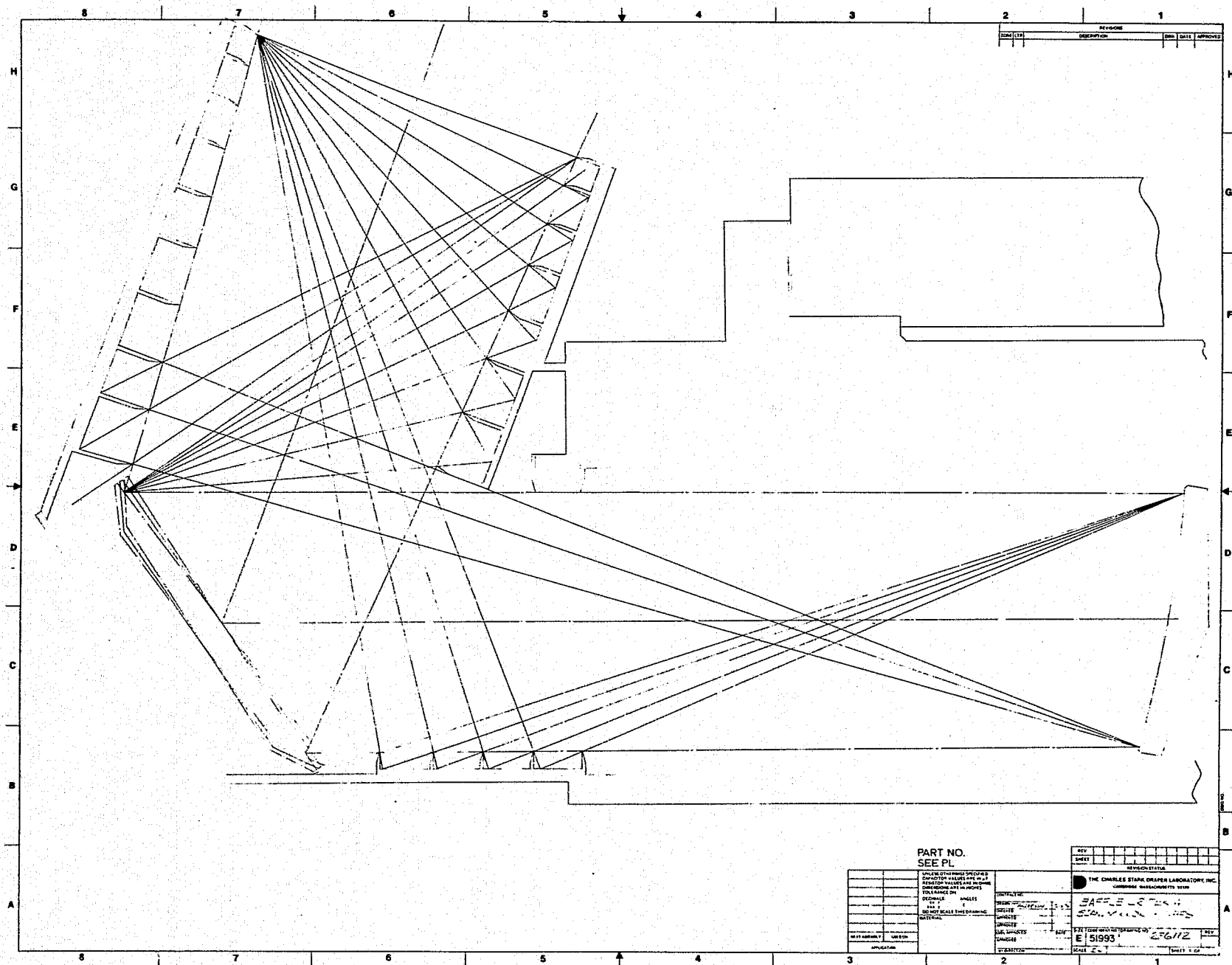
UNLESS OTHERWISE SPECIFIED
CAPACITOR VALUES ARE IN P.P.
RESISTOR VALUES ARE IN OHMS
DIMENSIONS ARE IN INCHES
TOLERANCE ON
DECIMALS ANGLES
± .01 ± 1°
DO NOT SCALE THIS DRAWING
MATERIAL
SEE NOTE 1

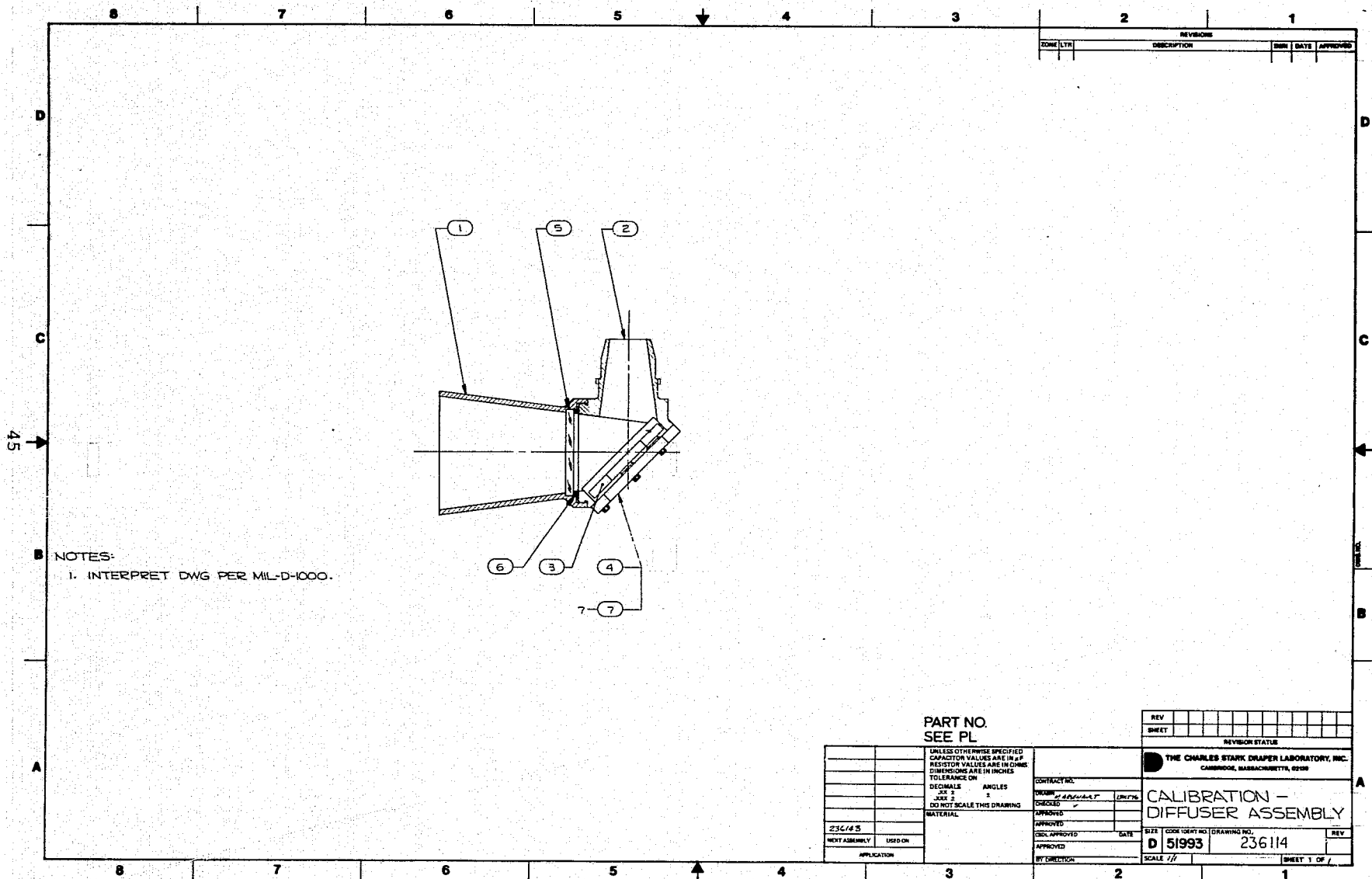
CONTRACT NO.
DRAWN: T. H. HARRIS 9/23/76
CHECKED: [initials]
APPROVED: [initials]
DATE: [blank]
BY: [blank]

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99	REVISION
100	REVISION

THE CHARLES STARK DRAPER LABORATORY, INC.
CAMBRIDGE, MASSACHUSETTS 02139
MIRROR, PRIMARY -
APP
(PRELIMINARY)
SIZE: 51993
DRAWING NO.: 236109
SCALE: FULL
SHEET 1 OF 1

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



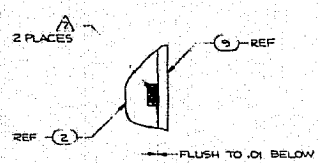


PART NO.
SEE PL

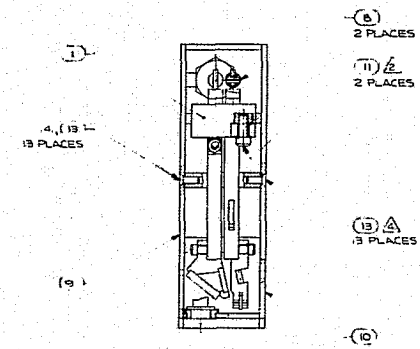
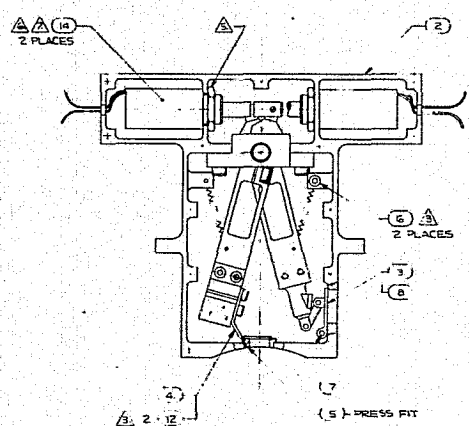
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VIEW Z-Z
SCALE: 4/1
2 PLACES

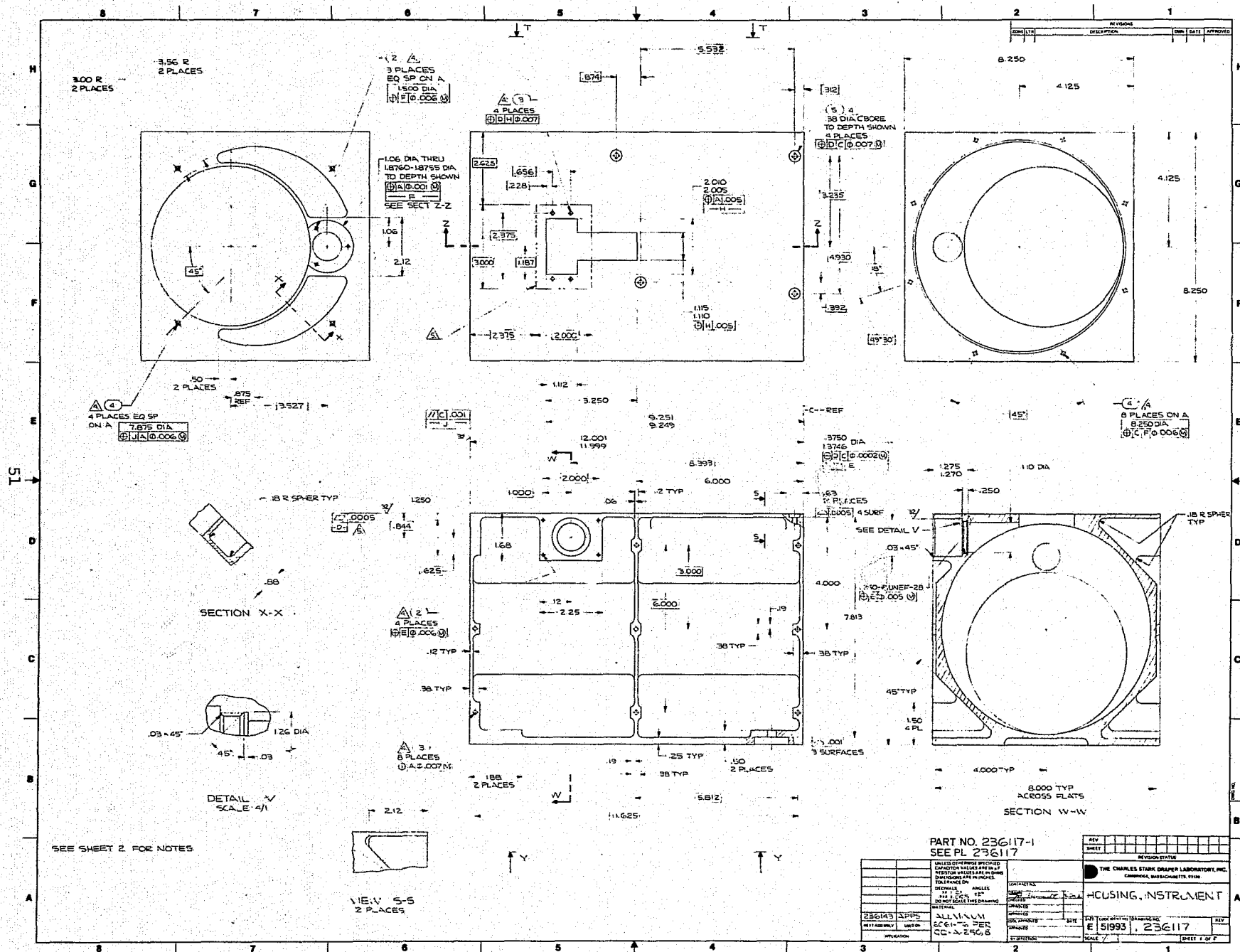


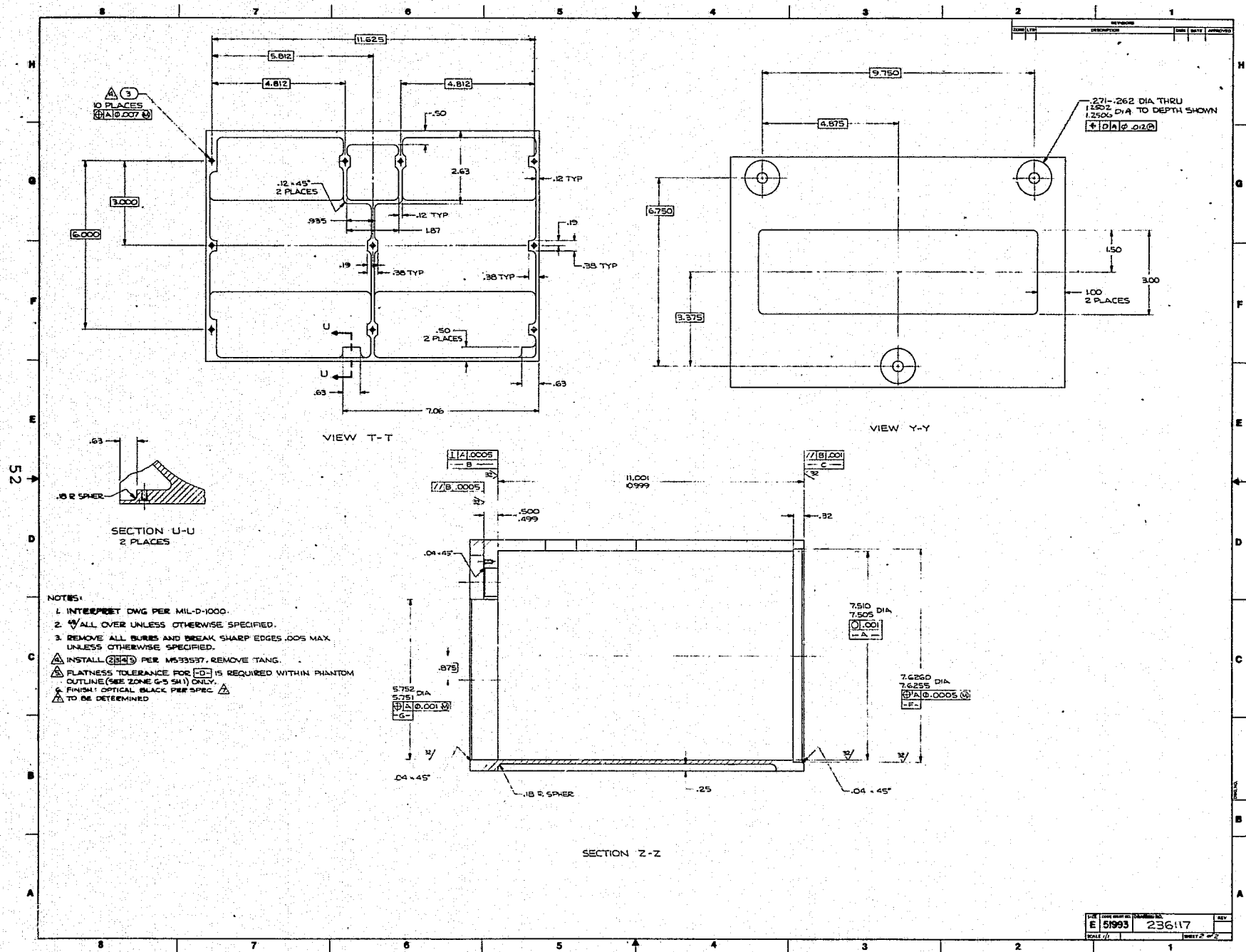
- NOTES:
1. INTERPRET DWG PER MIL-D-1000.
- △ TORQUE TO ~~△~~
- △ TORQUE TO △
- △ TORQUE TO △
- △ TORQUE TO △
- △ ROT LEADS OF (R) IN APPROX POSITION SHOWN WITH (S)
- △ LEADS OF (S) SHALL BE SUITABLY PROTECTED DURING MANUFACTURE, STORAGE AND SHIPMENT
2. IDENTIFY PER MIL-STD-130. BAG AND TAG. DO NOT MARK PART.
- △ TO BE DETERMINED

PART NO. 236115-1 SEE PL 236115		REV 1	RESPONSE
SAMPLES OF FIBRE SPECIFIED CAPACITOR VALUES ARE IN CAPACITOR CASES. IF THE CAPACITORS ARE IN PACKS FOR FANCTON ON VECTORS		THE CHARLES STONE DRAPER LABORATORY, INC. COMMERCIAL AND INDUSTRIAL RESEARCH	
ANGLES 45° 90° 135° 180° 225° 270° 315° 360° 405° 450° 495° 540° 585° 630° 675° 720° 765° 810° 855° 900° 945° 990° 1035° 1080° 1125° 1170° 1215° 1260° 1305° 1350° 1395° 1440° 1485° 1530° 1575° 1620° 1665° 1710° 1755° 1800° 1845° 1890° 1935° 1980° 2025° 2070° 2115° 2160° 2205° 2250° 2295° 2340° 2385° 2430° 2475° 2520° 2565° 2610° 2655° 2700° 2745° 2790° 2835° 2880° 2925° 2970° 3015° 3060° 3105° 3150° 3195° 3240° 3285° 3330° 3375° 3420° 3465° 3510° 3555° 3600° 3645° 3690° 3735° 3780° 3825° 3870° 3915° 3960° 4005° 4050° 4095° 4140° 4185° 4230° 4275° 4320° 4365° 4410° 4455° 4500° 4545° 4590° 4635° 4680° 4725° 4770° 4815° 4860° 4905° 4950° 4995° 5040° 5085° 5130° 5175° 5220° 5265° 5310° 5355° 5400° 5445° 5490° 5535° 5580° 5625° 5670° 5715° 5760° 5805° 5850° 5895° 5940° 5985° 6030° 6075° 6120° 6165° 6210° 6255° 6300° 6345° 6390° 6435° 6480° 6525° 6570° 6615° 6660° 6705° 6750° 6795° 6840° 6885° 6930° 6975° 7020° 7065° 7110° 7155° 7200° 7245° 7290° 7335° 7380° 7425° 7470° 7515° 7560° 7605° 7650° 7695° 7740° 7785° 7830° 7875° 7920° 7965° 8010° 8055° 8100° 8145° 8190° 8235° 8280° 8325° 8370° 8415° 8460° 8505° 8550° 8595° 8640° 8685° 8730° 8775° 8820° 8865° 8910° 8955° 9000° 9045° 9090° 9135° 9180° 9225° 9270° 9315° 9360° 9405° 9450° 9495° 9540° 9585° 9630° 9675° 9720° 9765° 9810° 9855° 9900° 9945° 9990° 10035° 10080° 10125° 10170° 10215° 10260° 10305° 10350° 10395° 10440° 10485° 10530° 10575° 10620° 10665° 10710° 10755° 10800° 10845° 10890° 10935° 10980° 11025° 11070° 11115° 11160° 11205° 11250° 11295° 11340° 11385° 11430° 11475° 11520° 11565° 11610° 11655° 11700° 11745° 11790° 11835° 11880° 11925° 11970° 12015° 12060° 12105° 12150° 12195° 12240° 12285° 12330° 12375° 12420° 12465° 12510° 12555° 12600° 12645° 12690° 12735° 12780° 12825° 12870° 12915° 12960° 13005° 13050° 13095° 13140° 13185° 13230° 13275° 13320° 13365° 13410° 13455° 13500° 13545° 13590° 13635° 13680° 13725° 13770° 13815° 13860° 13905° 13950° 13995° 14040° 14085° 14130° 14175° 14220° 14265° 14310° 14355° 14400° 14445° 14490° 14535° 14580° 14625° 14670° 14715° 14760° 14805° 14850° 14895° 14940° 14985° 15030° 			

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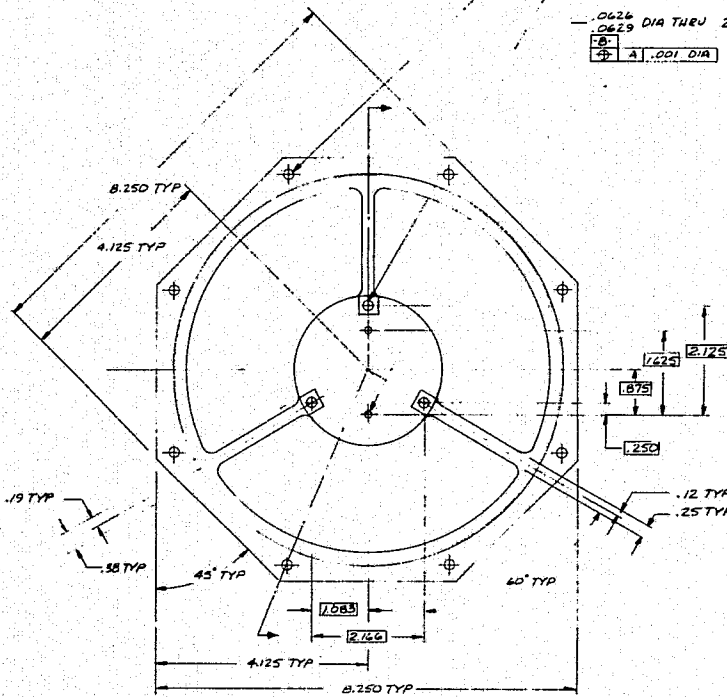
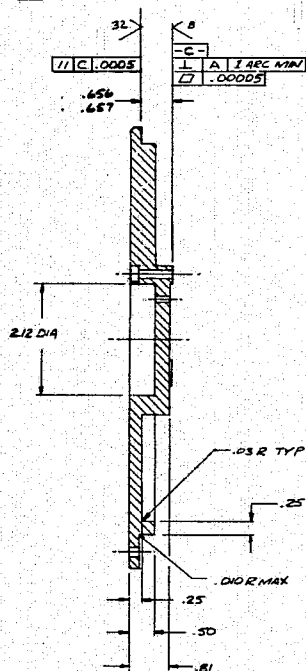
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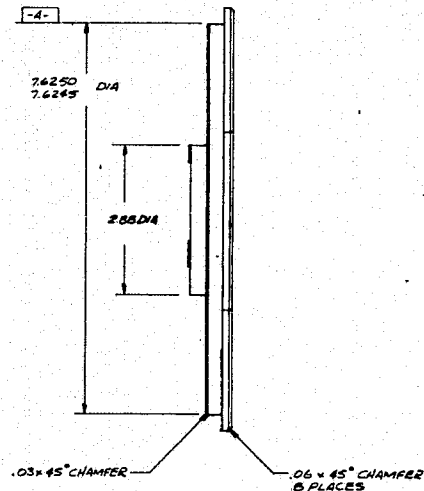
- NOTES:
1. MATERIAL: BERYLLIUM, INSTRUMENT-HIGH STRENGTH
 2. UNLESS OTHERWISE NOTED
 3. FINISH: REMOVE BURRS & BREAK SHARP EDGES
 4. ORDER OF OPERATION:
 - a. ROUGH MACHINE
 - b. STRESS RELIEVE PER SPEC. Δ
 - c. FINISH MACHINE
 - d. STABILIZE PER SPEC. Δ
 5. FINISH: OPTICAL BLACK PER SPEC. Δ TO BE DETERMINED



.171 DIA THRU 8 HOLES EQUALLY SPACED
ON 8.250 DIA Δ .001 DIA

.119 DIA THRU
.163 DIA THRU
C BORE (FAR SIDE) .285 DIA x .15 DP
3 HOLES Δ .001 DIA

.0626 DIA THRU 2 HOLES
A .001 DIA



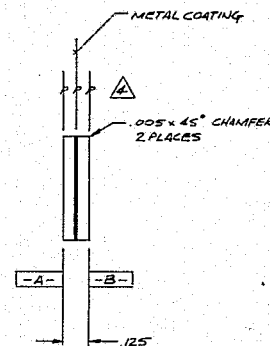
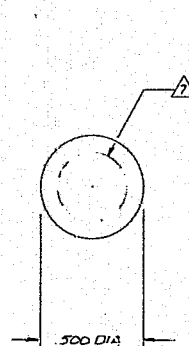
PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN P.F. RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DIMENSIONS: ANGLES X .01 1.0° 30' X .005 DO NOT SCALE THIS DRAWING		CONTRACT NO. REVISION APPROVED DATE BY	
236148	REVISION	DATE	BY
APPLICATION	USED ON	DATE	BY
SEE NOTE Δ		SCALE: FULL	

REV	DATE	DESCRIPTION	APP'D	DATE	DESCRIPTION
1					
THE CHARLES STANK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS 02139					
COVER, END - APPS					
SIZE	CODE IDENT NO.	DRAWING NO.	REV		
D	51993	236118			
SHEET 1 OF 1					

NOTES:

1. INTERPRET PER MIL-D-1000 & MIL-D-70327
2. ELEMENT IN ACCORDANCE WITH MIL-D-13830A
3. MATERIAL: SUBSTRATES - UV GRADE FUSED SILICA
SOURCE:
A. AMERSIL, INC. - SUPRASIL GRADES
B. DYNASIL CORP. - UV NO. 1000
COATING: CHROMIUM, NICKEL-CHROMIUM,
OR ALUMINUM
4. SURFACES MARKED "P" TO BE POLISHED;
ALL OTHERS FINE GROUND, BLACK
COATING OPTIONAL
5. SURFACES -A- AND -B-
TO BE PARALLEL AFTER CEMENTING TO WITHIN
15 ARC MINUTES & FLAT WITHIN $\frac{1}{4}$ λ AT 693
NM WAVE LENGTH OVER THE CLEAR APERTURE
6. SURFACE QUALITY OF SURFACES -A- & -B-
TO BE 60-40 OVER CLEAR APERTURE
7. CLEAR APERTURE - ϕ .33" DIA
8. DENSITY: FINISHED PART TO HAVE
SPECULAR TRANSMITTANCE AT 40° ANGLE
OF INCIDENCE BETWEEN 0.0004 & 0.003%
EVERY WHERE FROM 200 TO 850 NM WAVELENGTH
9. SURFACES -A- & -B- TO BE PROTECTIVE COATED
WITH MgF_2 , 100 NM THICK; DURABILITY
PER MIL-C-275A.
10. FINISHED PART TO SATISFY REQ'S OF NOTE 8
WHEN OPERATED FROM 0° TO 150° F WITHOUT
SEPARATION OF SUBSTRATES.
11. CEMENT SUBSTRATES PER MIL-D-13830 USING
ADHESIVE PER MIL-A-3920 OR EQUIVALENT

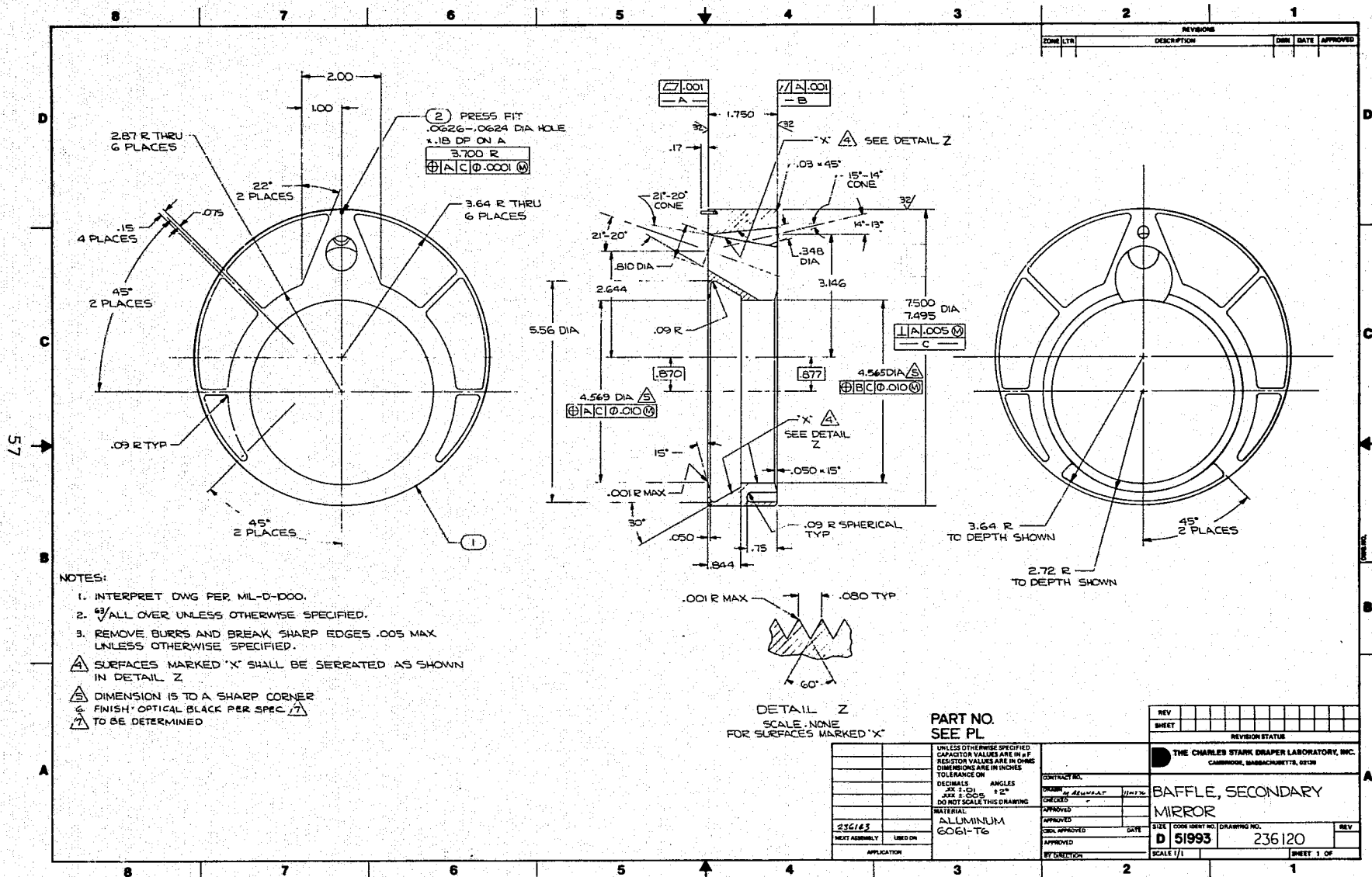


PART NO. 236119-1
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN P.F. RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON	
DECIMALS	ANGLES
$\pm .010$	$\pm .010$
DO NOT SCALE THIS DRAWING	
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236162	
NEXT ASSEMBLY	USED ON
APPLICATION	

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CHECKED	DATE
APPROVED	DATE
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ATTENUATOR (NO FILTER)		
SIZE	BOOK IDENT NO	DRAWING NO.
D 51993		236119
SCALE	#1	SHEET 1 OF





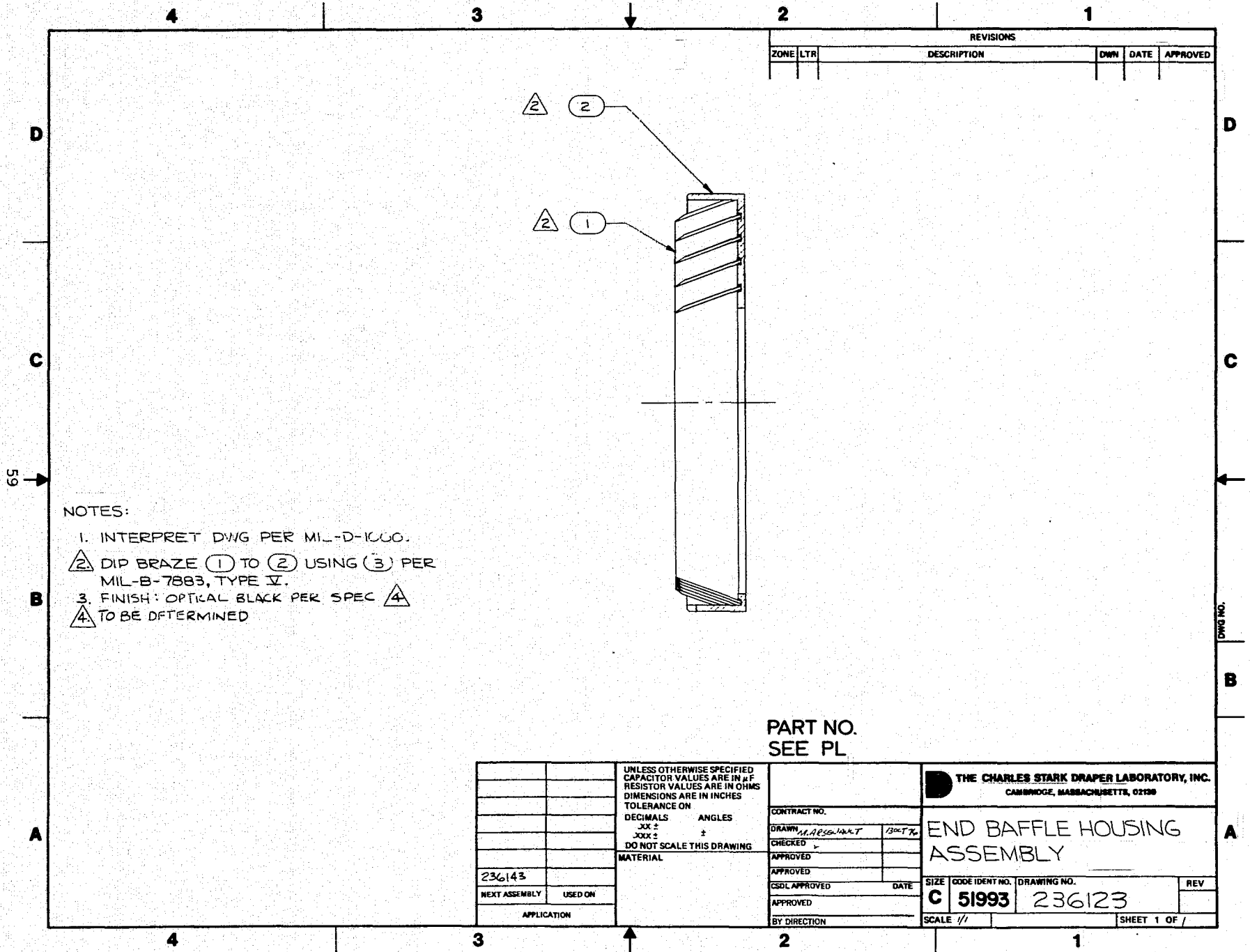
B

- B**

A

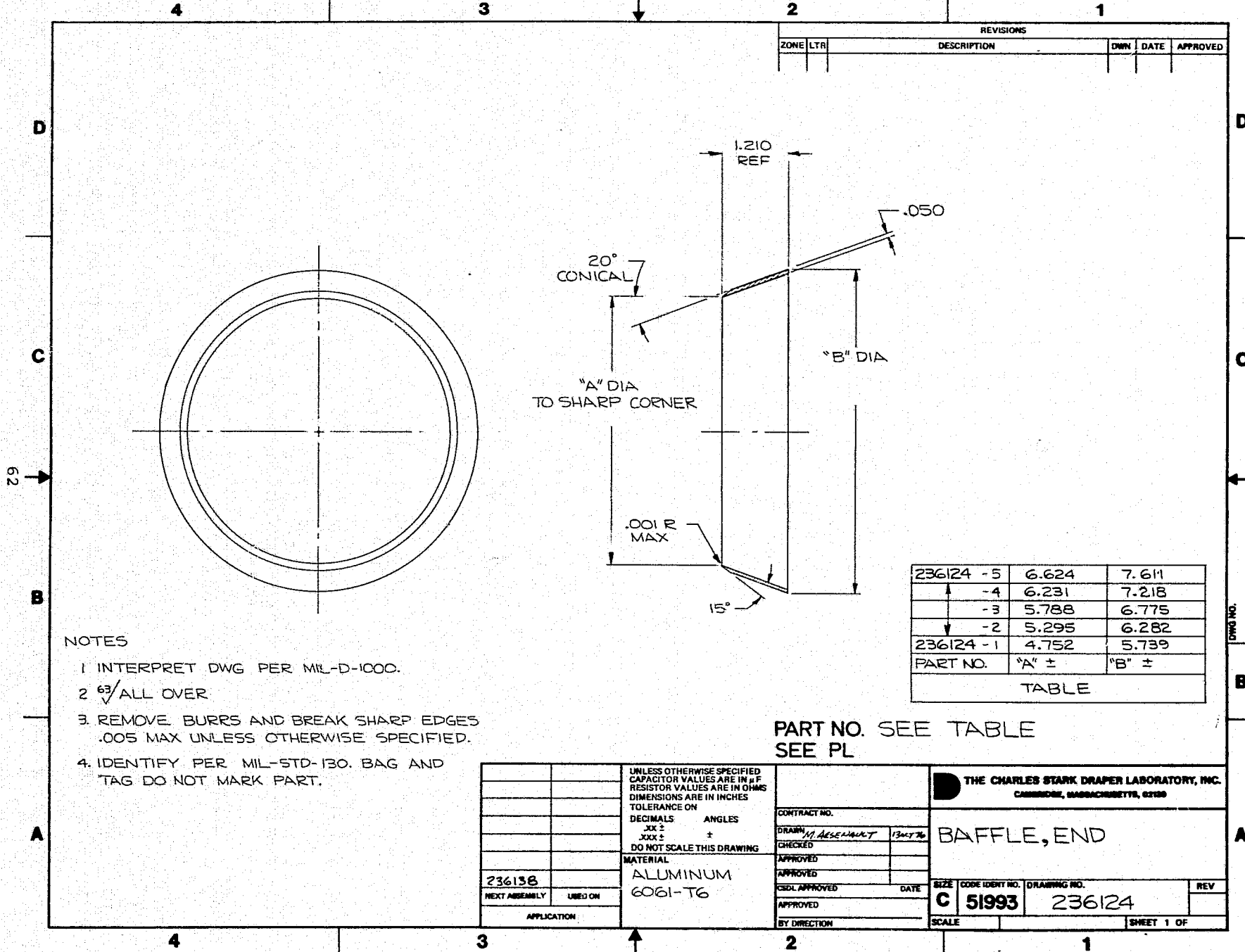
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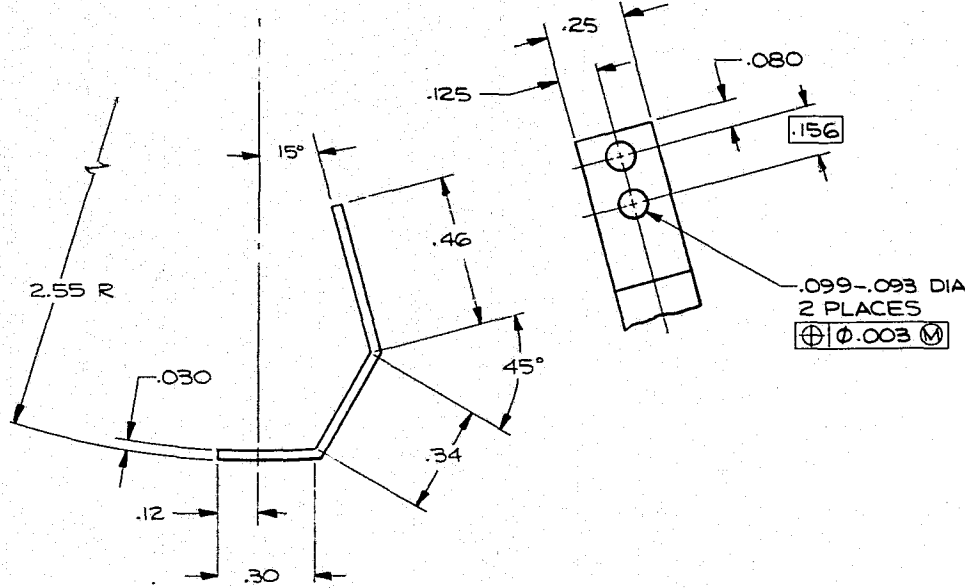


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ZONE	LTR	DESCRIPTION			DWN	DATE



NOTES:

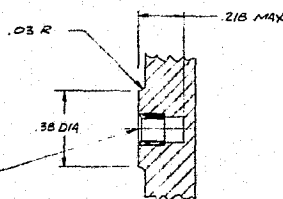
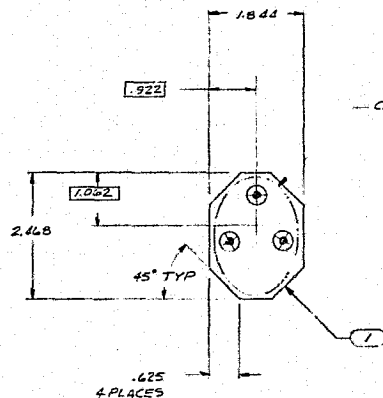
1. INTERPRET DWG PER MIL-D-1000.
2. FINISH: OPTICAL BLACK PER SPEC $\triangle$
- $\triangle$ TO BE DETERMINED

PART NO. 236125-1
SEE PL

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$.01 .XXX $\pm$.005 $\pm$ 2° DO NOT SCALE THIS DRAWING		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS 02139	
		MATERIAL		CONTRACT NO.	
236115 APPS		ALUMINUM		DRAWN <i>M. C. Cavanaugh</i> 9 Dec 76	
NEXT ASSEMBLY USED ON		6061-T6 PER QQ-A-225/8		CHECKED	
APPLICATION				APPROVED	
				APPROVED	
				CSOL APPROVED DATE	
				APPROVED	
				BY DIRECTION	
				SIZE CODE IDENT NO. DRAWING NO. REV	
				C 51993 236125	
				SCALE 4// SHEET 1 OF 1	

NOTES:

1. MATERIAL: ONE OF THE FOLLOWING MAY BE USED:
 - A. BERYLLIUM OPTICAL GRADE IT04 - BRUSH WELLMAN, INC., FAIRFIELD, NJ.
 - B. BERYLLIUM GRADE HP-B1-KANECCI BERYLCO INDUSTRIES, HARTFORD, PA.
2. ORDER OF OPERATIONS:
 - A. MACHINE AS REQ'D, CRITICAL DIMENSIONS TO .010/.020 OF FINISHED PART
 - B. STRESS RELIEVE AT $1450^{\circ}\text{F} \pm 25^{\circ}\text{F}$ FOR 1 HOUR ± 5 MIN IN VACUUM OR OTHER PROTECTIVE ATMOSPHERE. COOL TO 700°F AT A RATE NOT TO EXCEED 100°F PER HOUR; COOL IN STILL AIR FROM 700°F TO ROOM TEMP. (VACUUM OR OTHER PROTECTIVE ATMOSPHERE NOT NEEDED BELOW 700°F)
 - C. FINISH MACHINE
 - D. STABILIZE AT $100^{\circ}\text{F} \pm 10^{\circ}\text{F}$ FOR 10 MIN. ± 1 MIN. COOL TO ROOM TEMP AND HOLD FOR 10 MIN ± 1 MIN; COOL TO $-100^{\circ}\text{F} \pm 10^{\circ}\text{F}$ AND HOLD FOR 10 MIN ± 1 MIN. REPEAT STABILIZING PROCEDURE FOR A TOTAL OF 5 CYCLES.
 - E. SURFACES -A, -B- TO BE ELECTROLESS NICKEL COATED PER MIL-C-26074 CLASS 2, .004/.006 THICK. ALL OTHER SURFACES OPTIONAL
 - F. ORDER OF OPERATIONS OF THIS NOTE OPTIONAL
 1. INSTALL HELICAL COIL INSERTS
 2. PERFORM FINISH OPERATIONS TO SURFACES -A, -B- AS REQ'D PER NOTES 4 THRU 6
 3. NICKEL COATING SHALL NOT BE REDUCED TO LESS THAN .001 IN. THICK
 4. REPEAT STABILIZATION CYCLES PER NOTE 2 D FOLLOWING EACH FINISHING OPERATION OR SEQUENCE UNTIL DIMENSIONAL STABILITY IS ACHIEVED
3. SURFACE -A- TO BE ALUMINIZED PER MIL-M-13508; PROTECTIVE COATING SHALL BE $100\text{nm} \pm 25\text{nm}$ THICK OVER CLEAR APERTURE.
4. SURFACE -A- TO BE FLAT TO $\frac{1}{4} \lambda$ AT 633nm OVER THE CLEAR APERTURE.
5. SURFACE IRREGULARITY OF SURFACE -A- SHALL BE $\leq \frac{1}{4} \lambda$ AT 633nm OVER THE CLEAR APERTURE.
6. SURFACE QUALITY OF SURFACE -A- TO BE $40/20$ PER MIL-D-13830 OVER THE CLEAR APERTURE.
7. SPECULAR REFLECTANCE OF SURFACE -A- AT 15° ANGLE OF INCIDENCE SHALL BE NO LESS THAN 88% FROM 300 TO 1000nm WAVE LENGTH CLEAR APERTURE OF SURFACE -A- IS ELLIPTICAL WITH MAJOR AXIS $\cdot 2312$ IN. & MINOR AXIS $\cdot 1625$ IN.
8. ALL DIMENSIONS APPLY AFTER COATING
9. INTERPRET PER MIL-D-1000



2
120 DIA FLAT BOTTOM
TAP DRILL TO DEPTH
SHOWN 3 PLCS EQ SP.
ON A
1.250 DIA
1.005 DIA

DETAIL Z
SCALE 4/1
TYP 3 PLACES

CLEAR APERTURE

SEE DETAIL Z

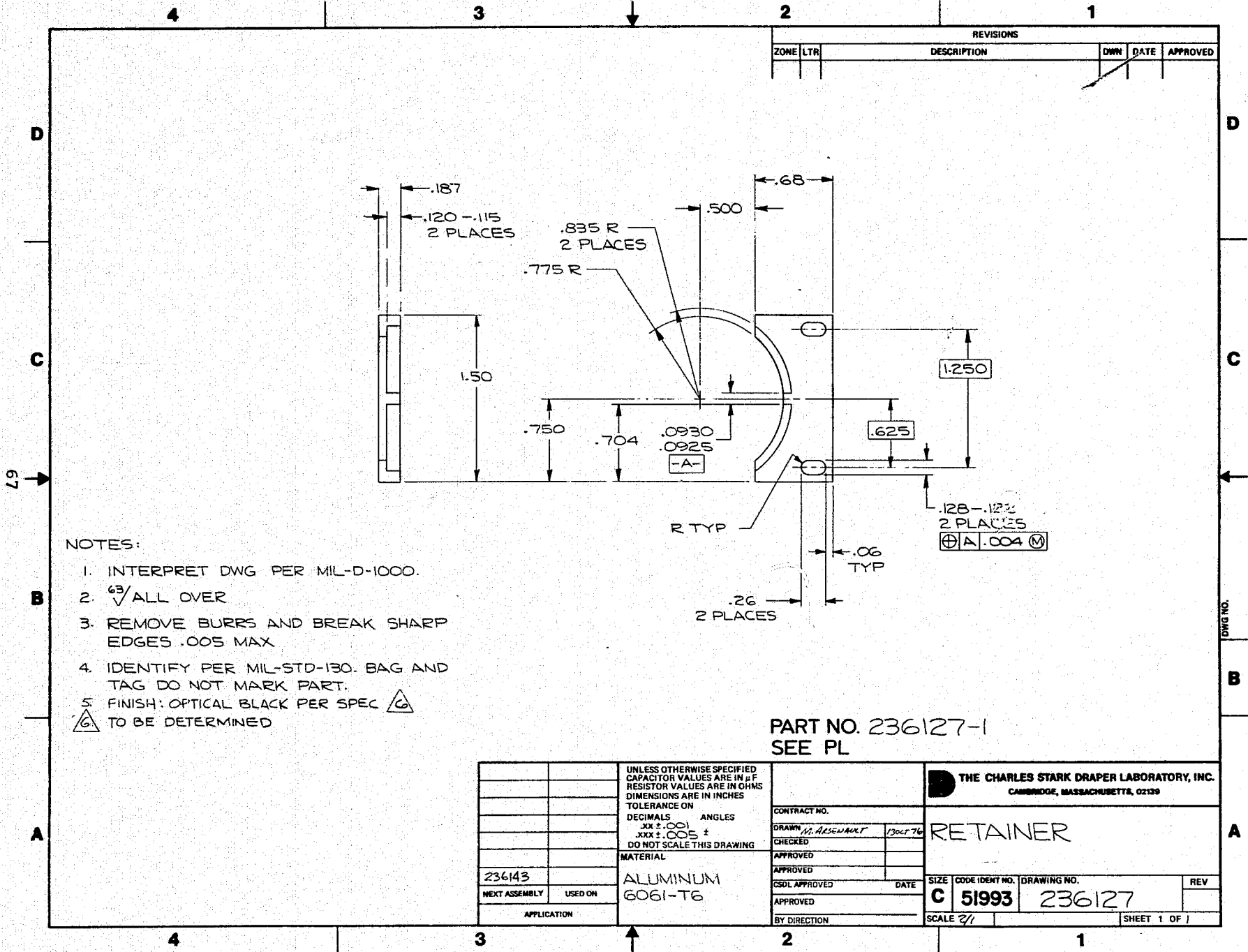
1.00005
B
11 B .001
A

PART NO. 236126-1
SEE PL 236126

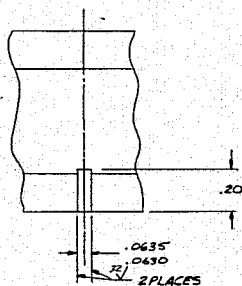
UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN P.F. RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON		CONTRACT NO.	
DECIMALS	ANGLES	DRAWING APPROVED	
$\pm .01$	$\pm 2^{\circ}$	CHECKED	
DO NOT SCALE THIS DRAWING		APPROVED	
MATERIAL		DATE	
236114		APPROVED	
NEXT ASSEMBLY		BY	
APPLICATION		SCALE 1/1	
		SHEET 1 OF 1	

REV	SHEET	REVISION STATUS
THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138		
MIRROR, RELAY		
SIZE	CODE IDENT NO	DRAWING NO.
D	51993	236126

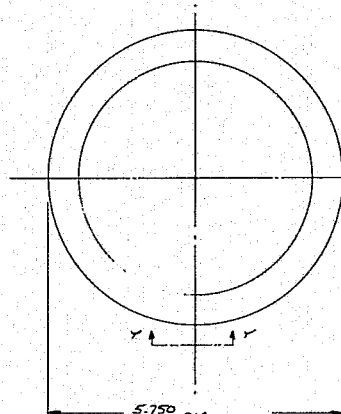
[illegible]



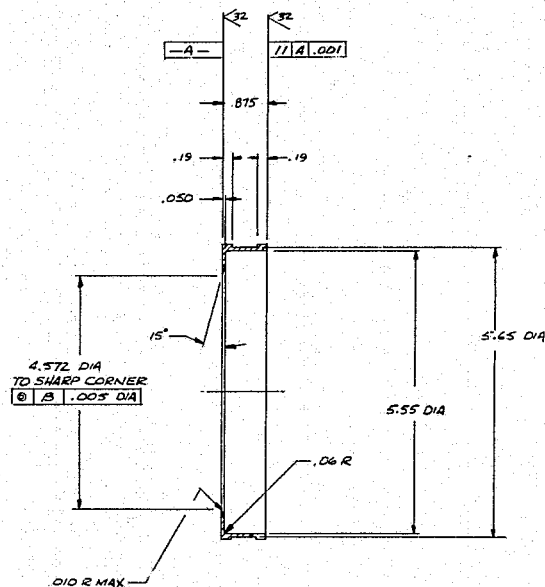
1. INTERPRET DWG PER MIL-D-1000.
2. ¹³✓ ALLOWER UNLESS OTHERWISE SPECIFIED
3. REMOVE BURRS & BREAK SHARP EDGES
.005 MAX UNLESS OTHERWISE SPECIFIED
4. FINISH OPTICAL BLACK PER SPEC 5
5. TO BE DETERMINED



PARTIAL VIEW Y-Y
SCALE 4/1

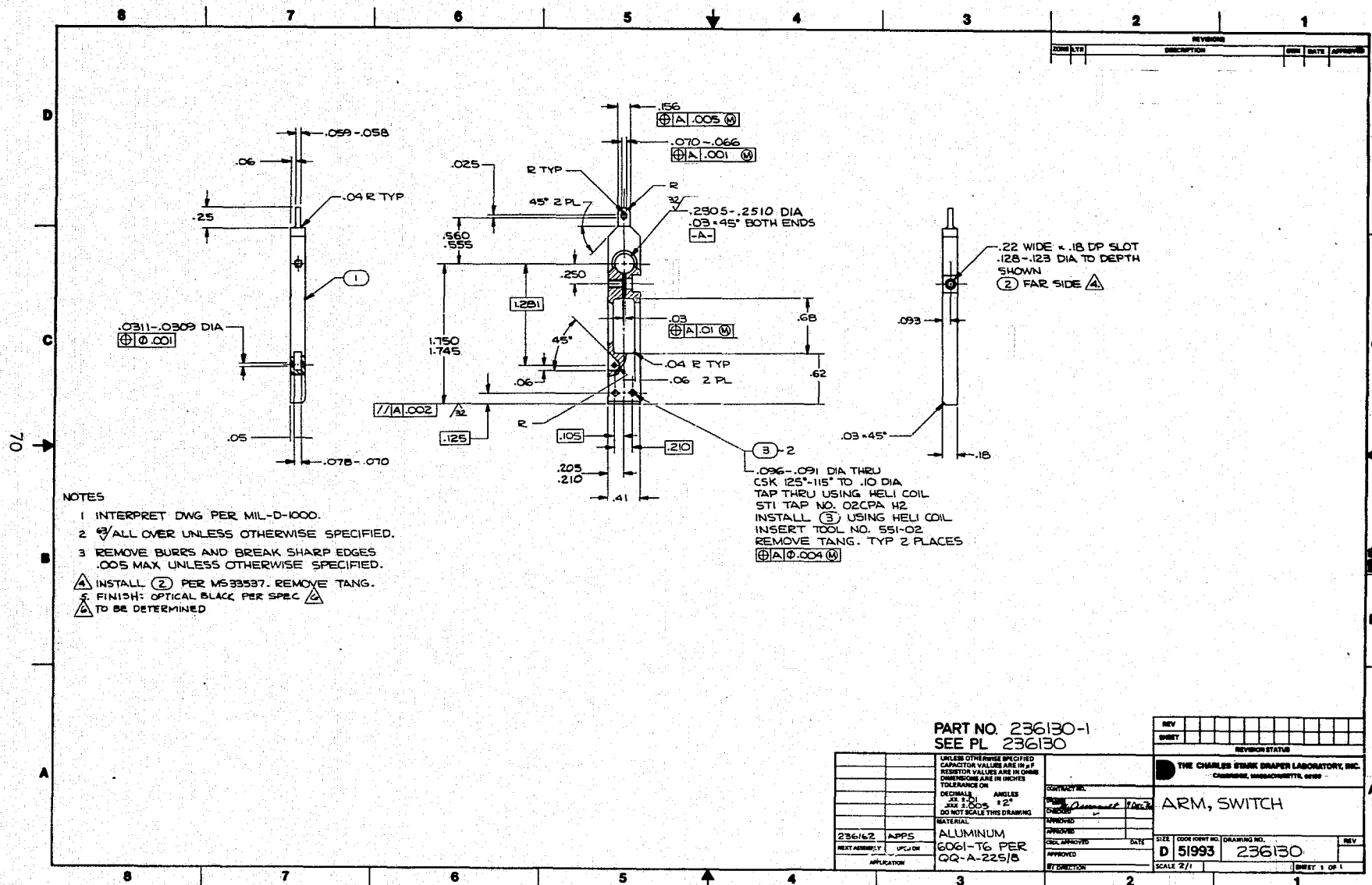


L	A	.001
— B —		



PART NO.
SEE PL

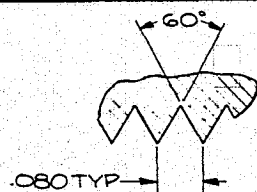
	UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN P.F. RESISTOR VALUES ARE IN OHMS TOLERANCE IN INCHES DECIMALS ANGLES 1/16" 0.015" 1/32" 0.015" DO NOT SCALE THIS DRAWING DATE: 11-1-68	CONTRACT NO. DRAWING NO. 236128 CHECKED APPROVED	WILSON STATION
236143 NEXT ASSEMBLY	USED ON ALUMINUM 6061-T6	APPROVED CROOK APPROVED DATE	THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, U.S.A.
APPLICATION		SIZE D QUOTE SHEET NO. 236128 SCALE 1/16" = 1"	DRAWING NO. 236128 SHEET 1 OF 1



[illegible]

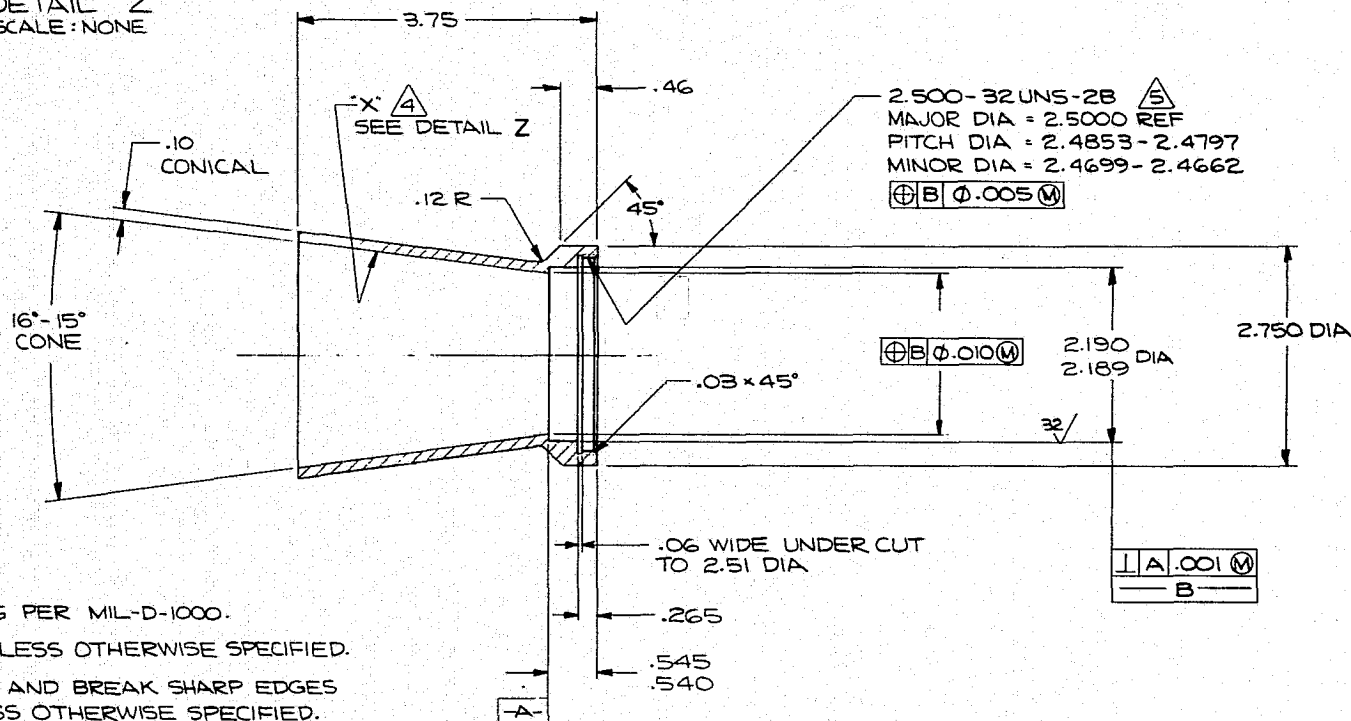
[illegible]

4 3 2 1



DETAIL Z
SCALE: NONE

REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE

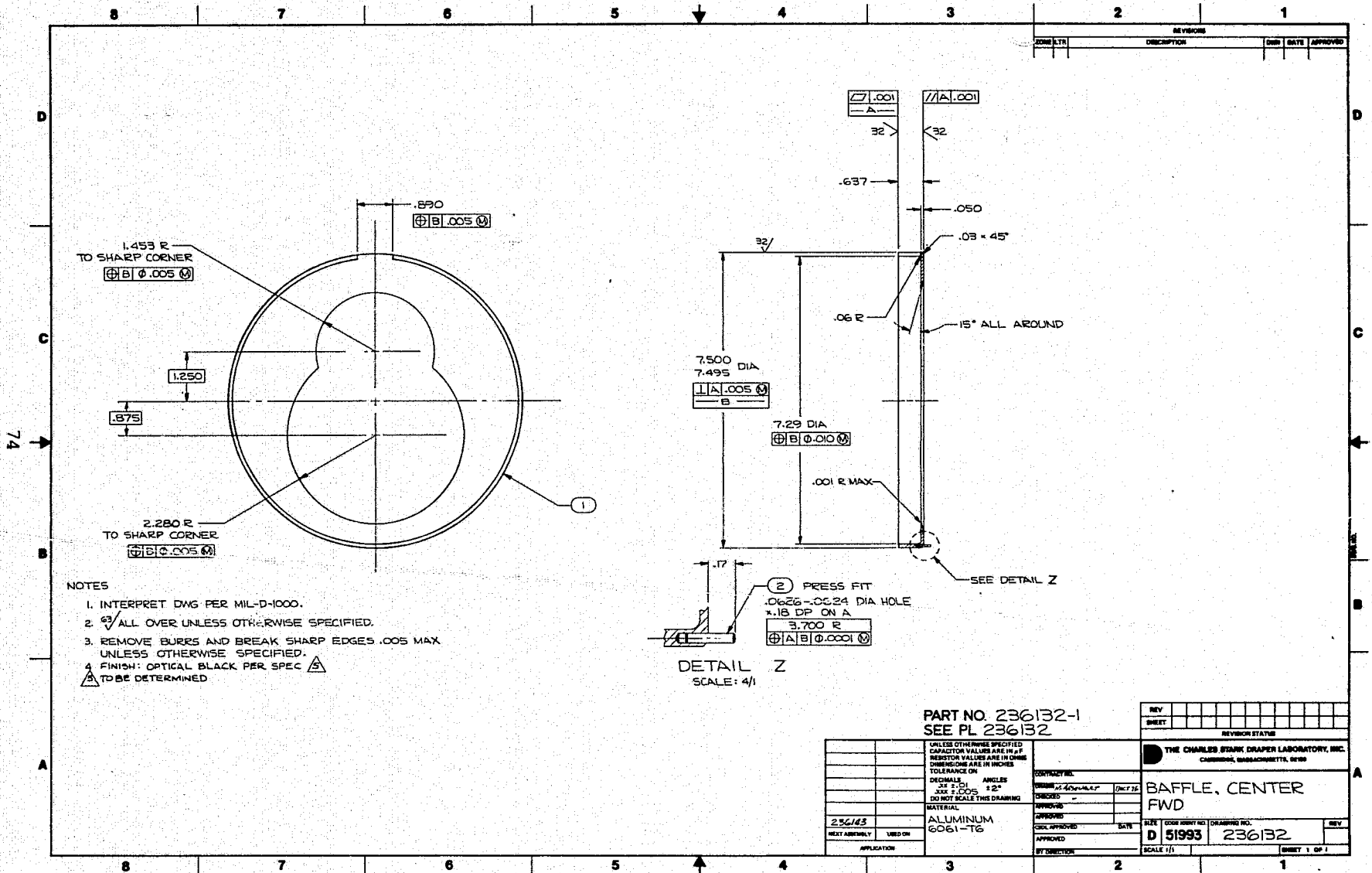


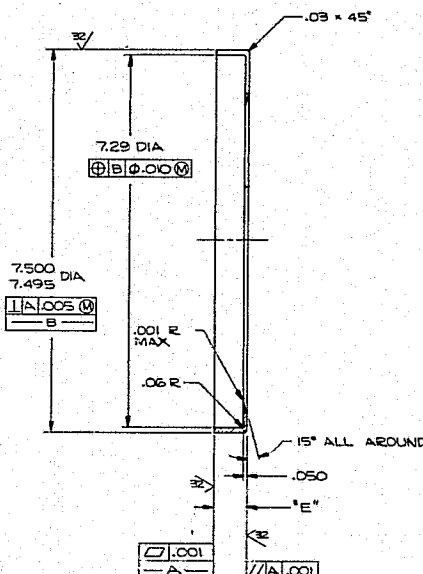
NOTES:

1. INTERPRET DWG PER MIL-D-1000.
2. $\frac{63}{\sqrt{}}$ ALL OVER UNLESS OTHERWISE SPECIFIED.
3. REMOVE BURRS AND BREAK SHARP EDGES .005 MAX UNLESS OTHERWISE SPECIFIED.
4. SURFACE MARKED "X" SHALL BE SERRATED AS SHOWN IN DETAIL Z (SEE ZONE D-4).
5. THREAD DIMENSIONS AND DESIGNATIONS SHALL BE INTERPRETED PER HANDBOOK H2B AND MIL-STD-9, RESPECTIVELY.
6. FINISH: OPTICAL BLACK PER SPEC $\frac{7}{\Delta}$ TO BE DETERMINED

PART NO. 236131-1
SEE PL

236114		NEXT ASSEMBLY		USED ON		APPLICATION		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES XX $\pm$.01 XXX $\pm$.005 $\pm$ 2° DO NOT SCALE THIS DRAWING		MATERIAL ALUMINUM 6061-T6		CONTRACT NO.		DRAWN M. ACSEN/AVLT 13 OCT 76		CHECKED		APPROVED		CSDL APPROVED		DATE		BY DIRECTION		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138		SHROUD,		SIZE C		CODE IDENT NO. 51993		DRAWING NO. 236131		REV		SCALE 1/1		SHEET 1 OF 1	
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1. INTERPRET DWG PER MIL-D-1000.
2. ☒ ALL OVER UNLESS OTHERWISE SPECIFIED.
3. REMOVE BURRS AND BREAK SHARP EDGES .005 MAX UNLESS OTHERWISE SPECIFIED.
4. FINISH: OPTICAL BLACK PER SPEC  TO BE DETERMINED

236133-3	.875	2.279	1.813	.858	.576
236133-2	.875	2.278	1.593	.955	.576
236133-1	.875	2.276	1.375	1.265	.637
PART NO.	"A" BASIC	"B" =	"C" BASIC	"D" =	"E" =

TABLE

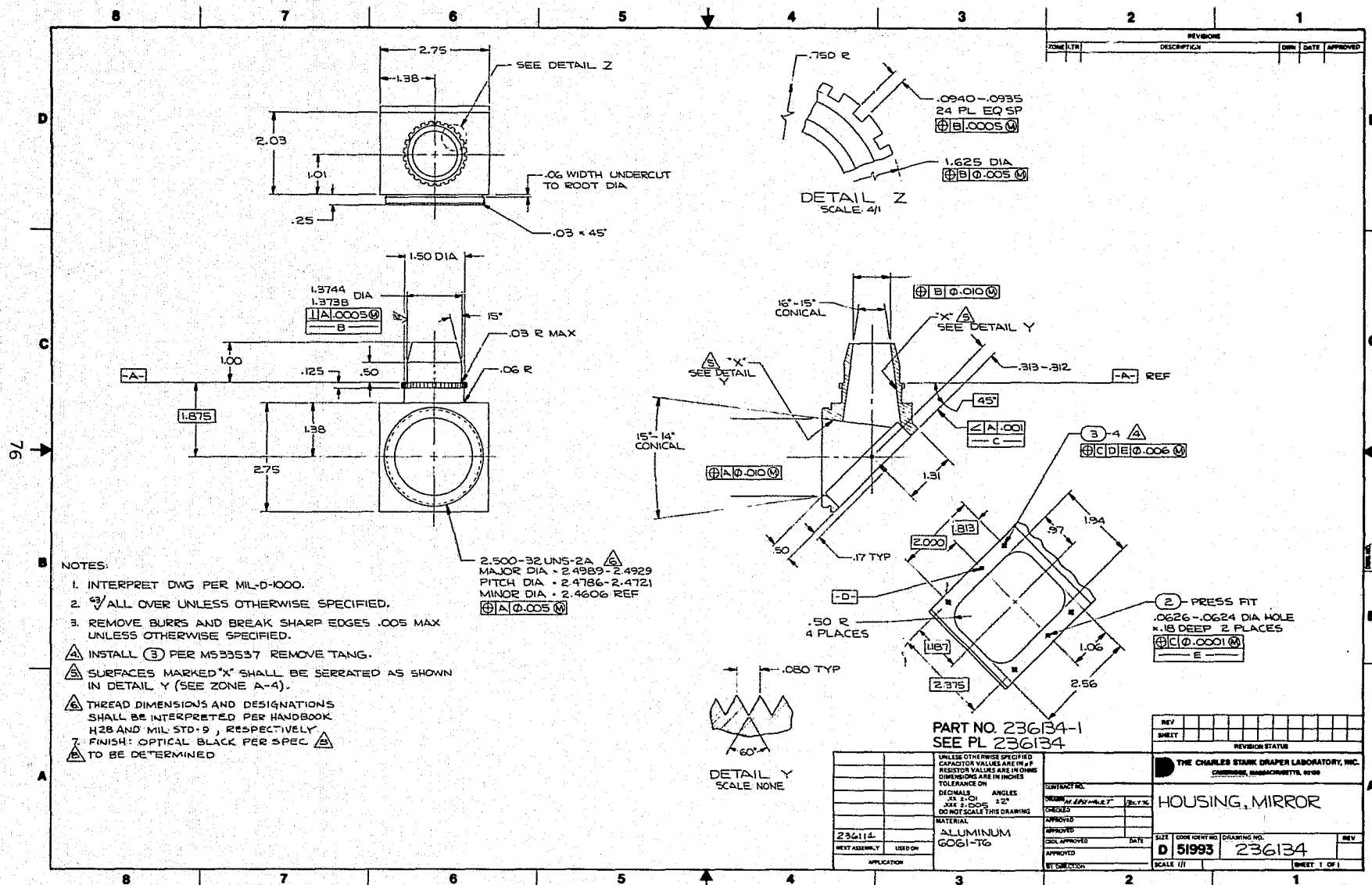
PART NO. SEE TABLE.
SEE PL

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS .010 FRACTIONS $\frac{1}{16}$ " $\pm$ 1/32" DO NOT SCALE THIS DRAWING		THE CHARL. F. TARK DRAPER LABORATORY, INC. DALLAS, TEXAS 75243, 0100	
		MATERIAL ALUMINUM 6061-T6		CONTRACT NO. WORK IN PROGRESS CHECKED DATE APPROVED DATE	
236143		NEXT FORMERLY USED ON		SIZE D 51993	
APPLICATION				DRAWING NO. 236133	
				SCALE 1/8" = 1"	

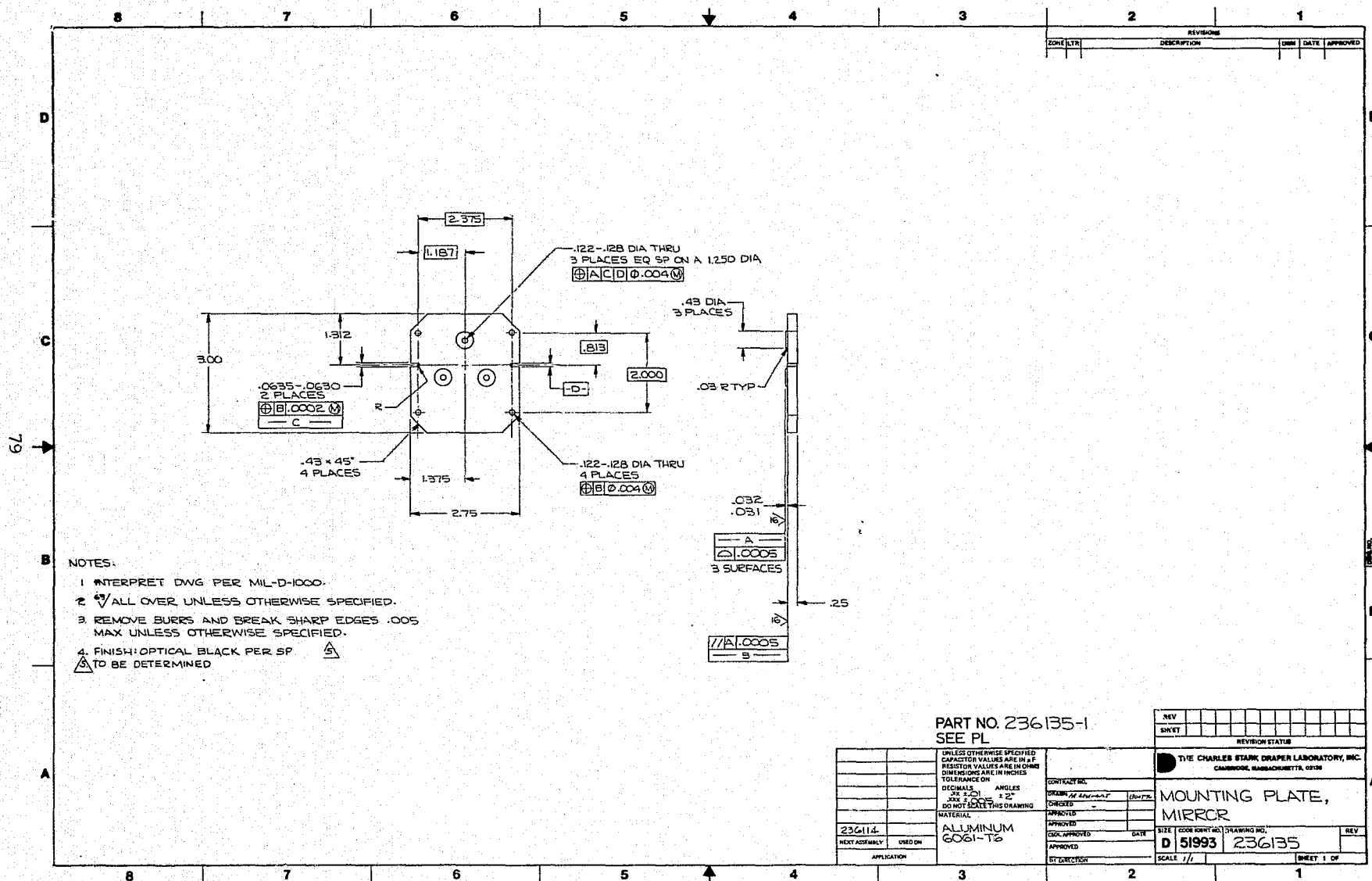
THE CHARLES STARK DRAPER LABORATORY, INC
CAMBRIDGE, MASSACHUSETTS 02139

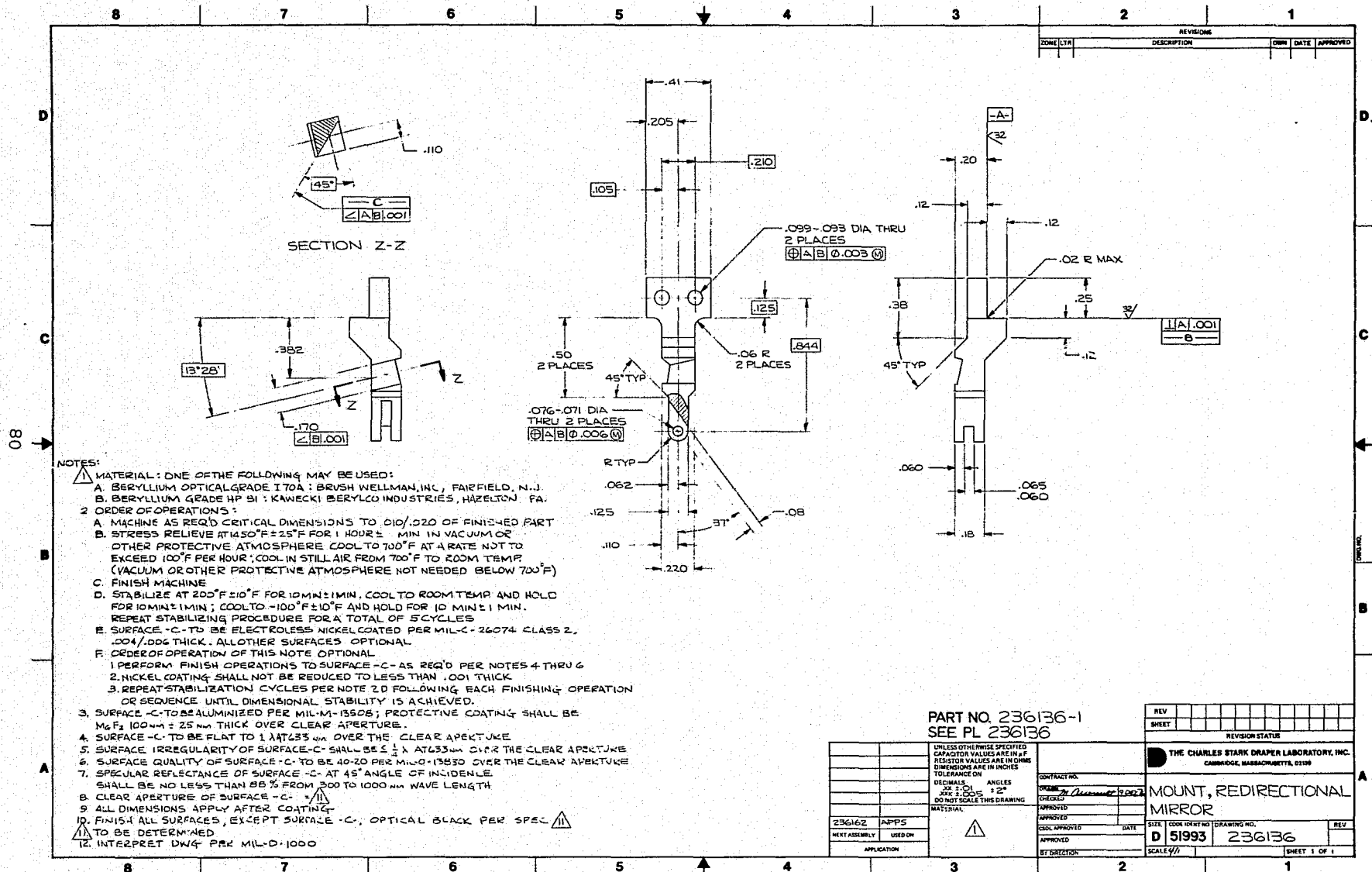
1736	BAFFLE, CENTER REAR
------	------------------------

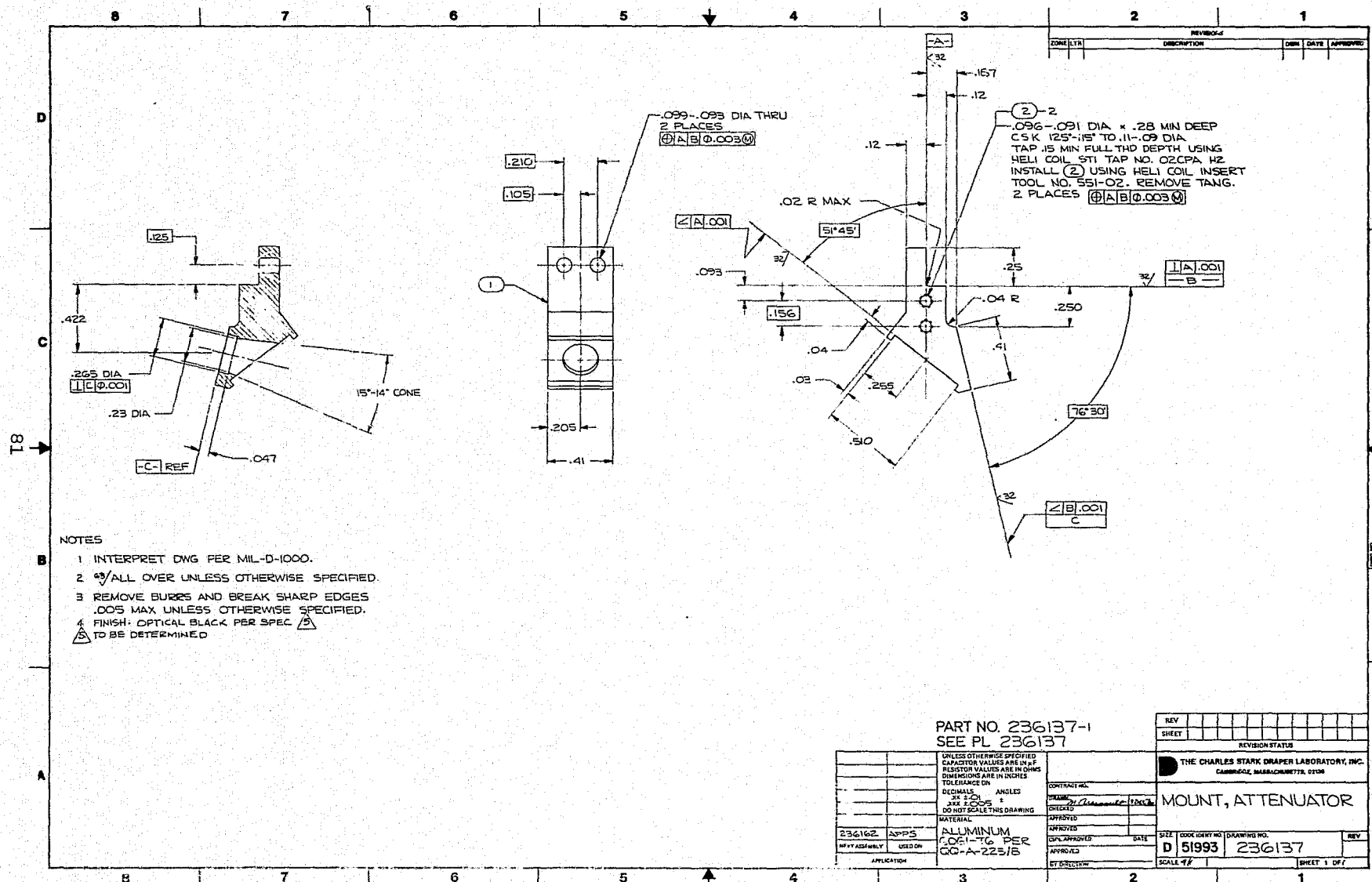
SIZE	CODE (PRINT NO.)	DRAWING NO.	REV
D	51993	236133	
SCALE (1/8"=1')	SHEET 1 OF		



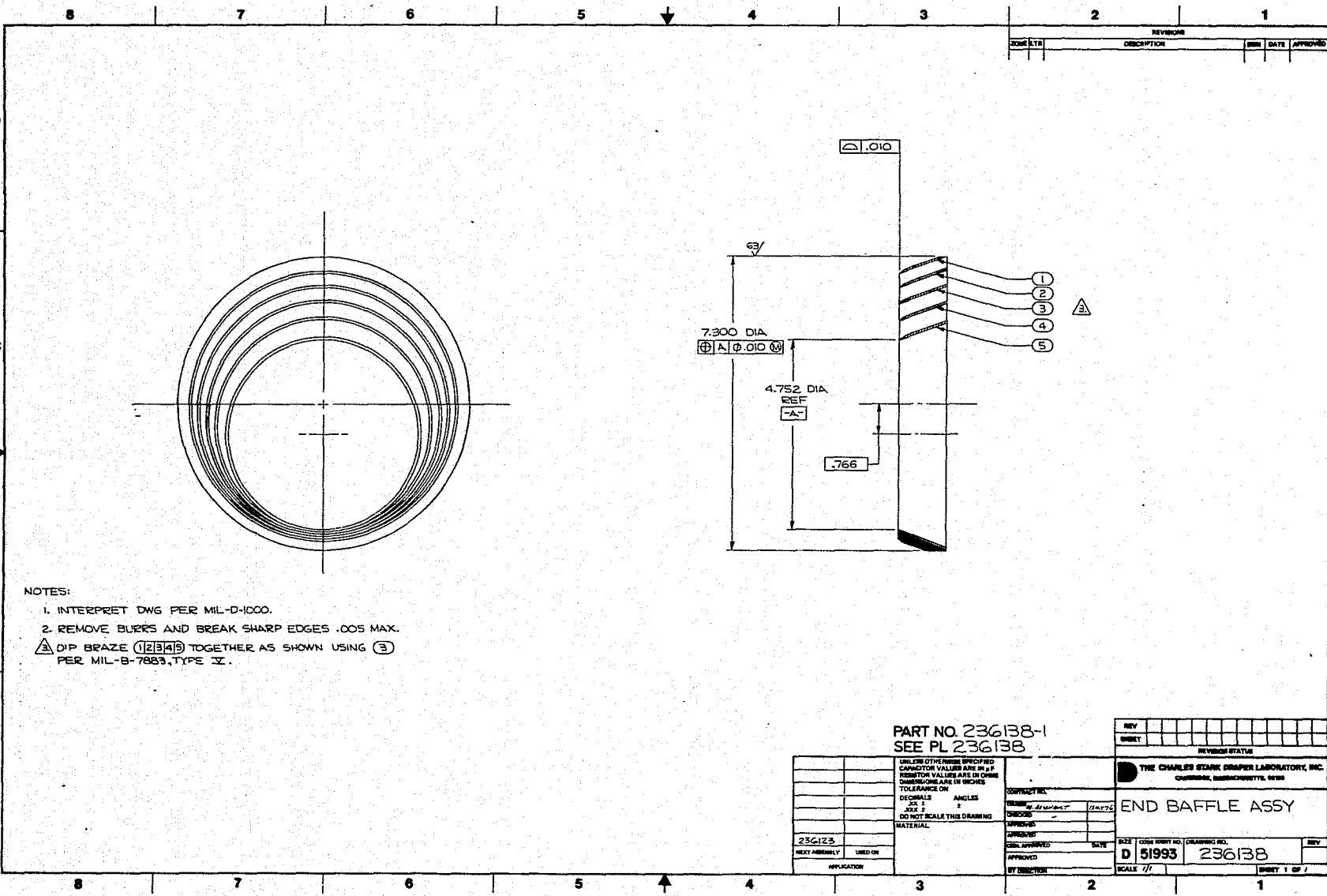
100







[illegible]



NOTES:

1. INTERPRET DWG PER MIL-D-1000.
 2. REMOVE BURRS AND BREAK SHARP EDGES .005 MAX.
- △ DIP BRAZE (1)(2)(3)(4)(5) TOGETHER AS SHOWN USING (3)
PER MIL-B-7883, TYPE X.

PART NO. 236138-1
SEE PL 236138

UNLESS OTHERWISE SPECIFIED DIMENSIONAL VALUES ARE IN INCHES DIMENSIONAL VALUES ARE IN INCHES TOLERANCE ON	
DECIMALS	ANGLES
.005	°
.005	°
DO NOT SCALE THIS DRAWING	
MATERIAL	
236123	
NEXT ASSEMBLY	USED ON
APPLICATION	

CORRECTED NO.	
DESIGNED BY	DATE
DESIGNED BY	DATE
DESIGNED BY	DATE
DESIGNED BY	DATE
DESIGNED BY	DATE
DESIGNED BY	DATE
DESIGNED BY	DATE
DESIGNED BY	DATE
DESIGNED BY	DATE
DESIGNED BY	DATE

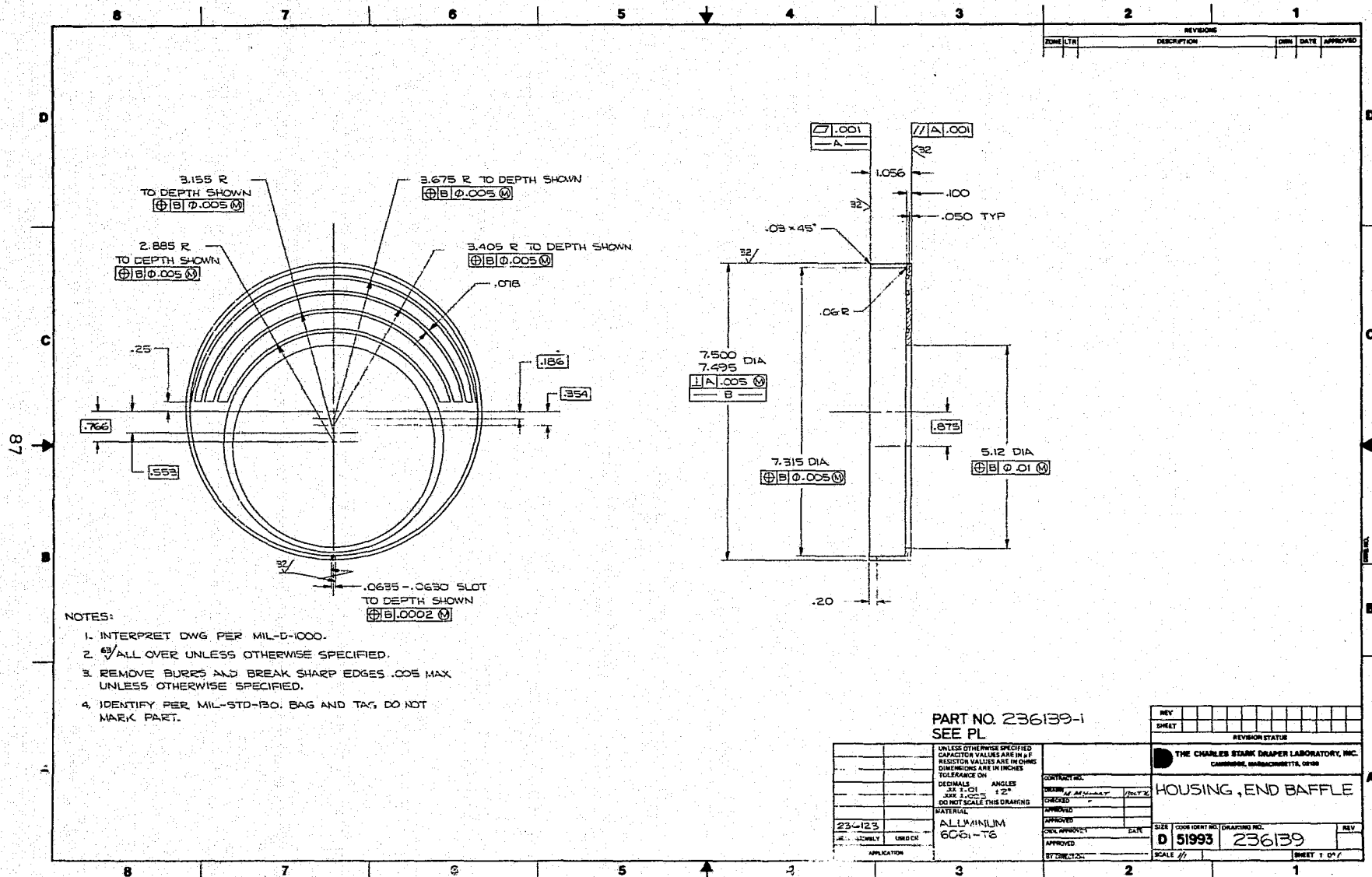
REV	DESCRIPTION	DATE	APPROVED
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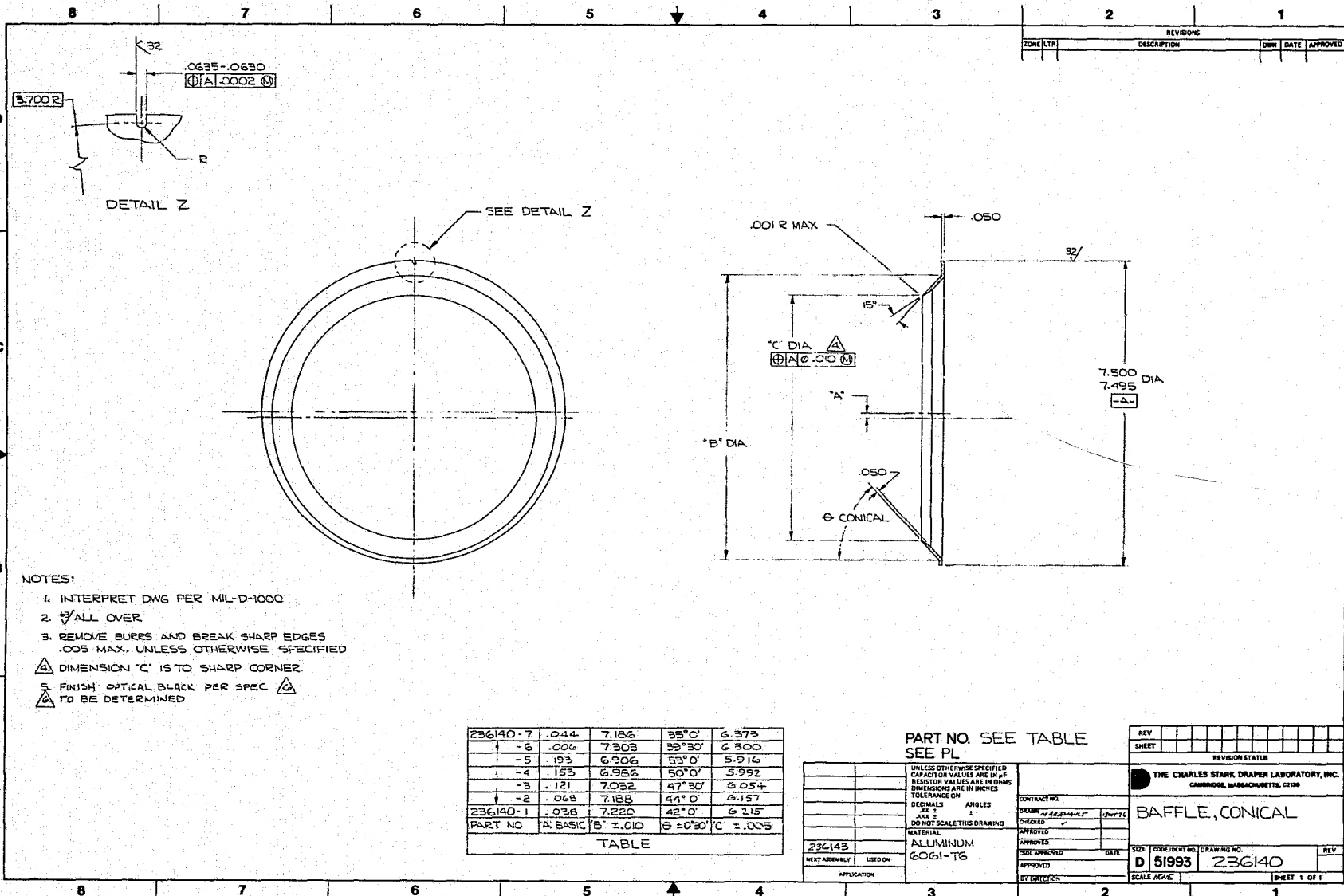
THE CHARLES STANK DRAPER LABORATORY, INC.
CHANDLER, MASSACHUSETTS, 01915

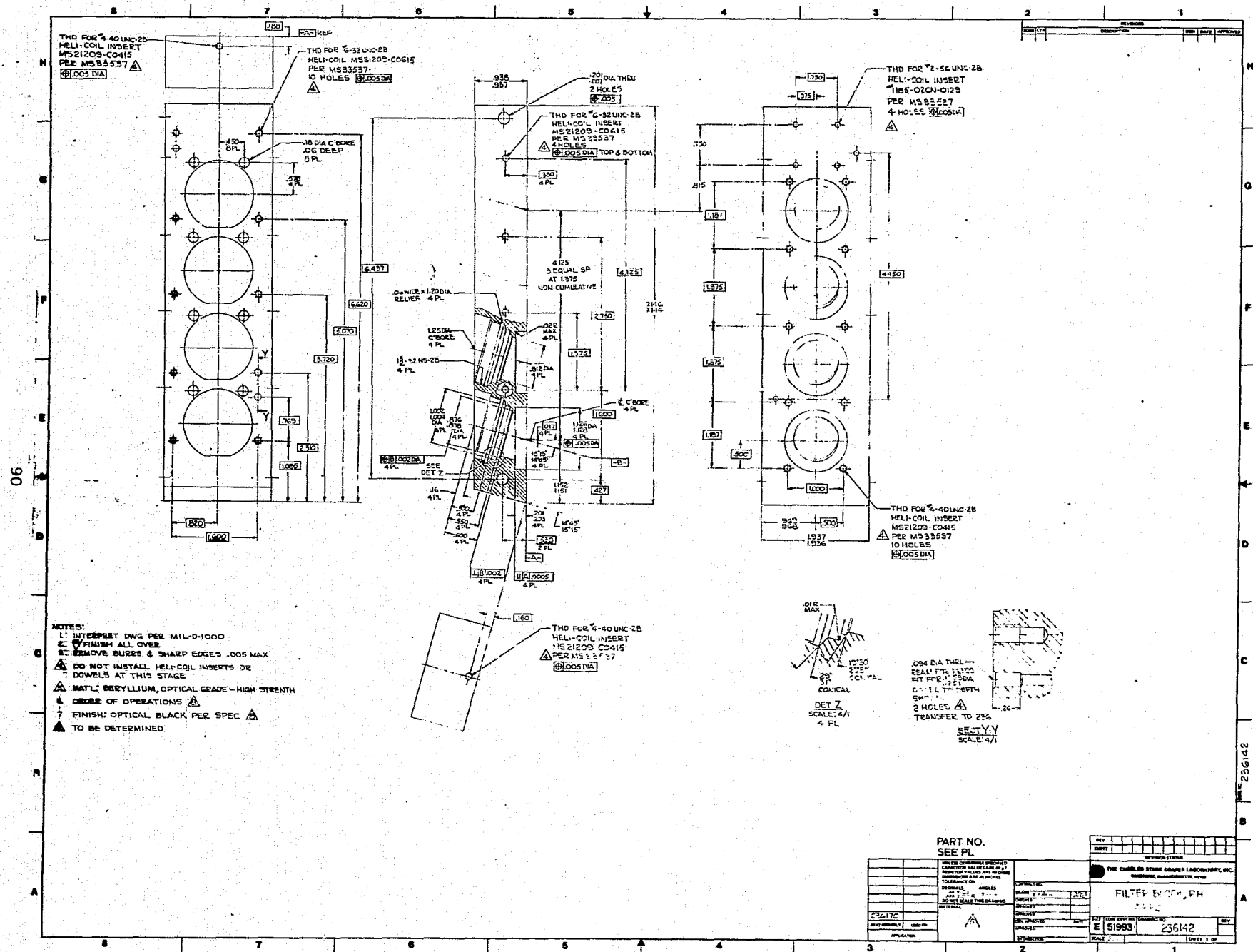
END BAFFLE ASSY

SIZE CODE PRINT NO. DRAWING NO.
D 51993 236138

SCALE 1/1 SHEET 1 OF 1

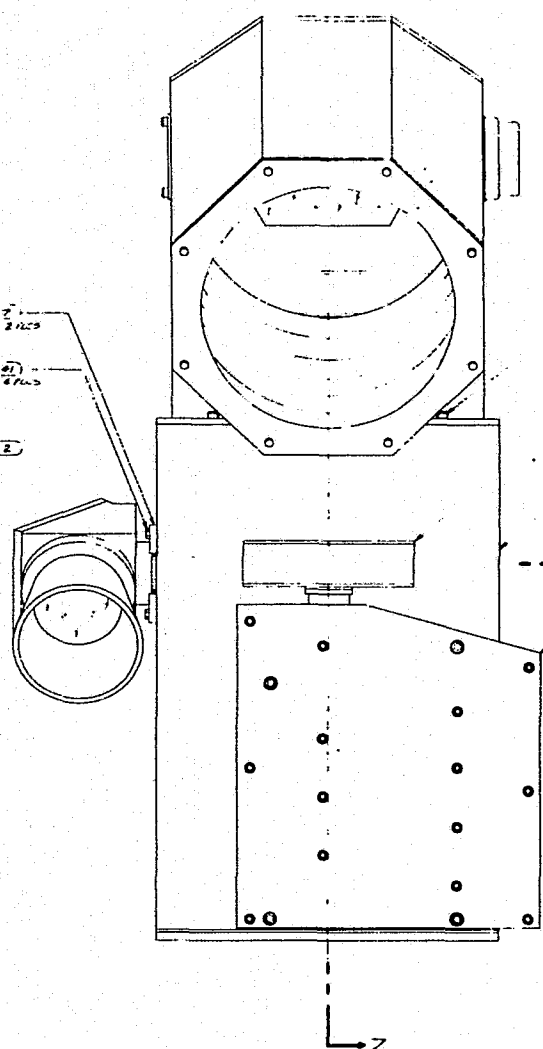
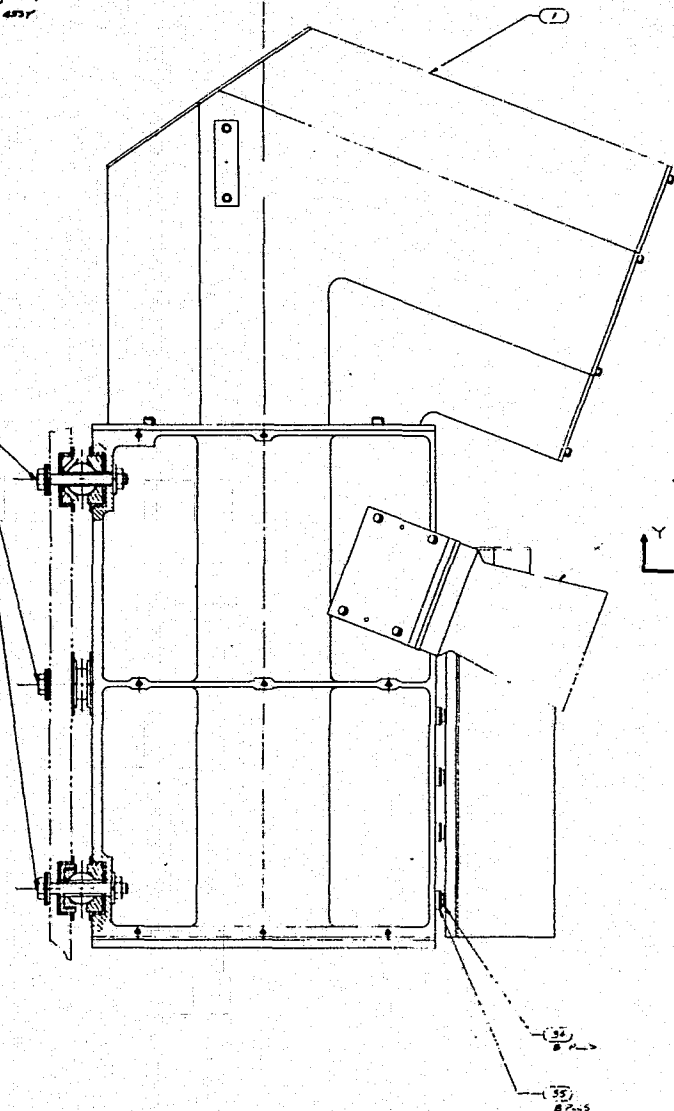






NOTES
 INTERPRET DIM. PER MIL-D-145
 TO BE DETERMINED
 TO BE MACHINED ON ASSY

MOUNTING DETAILS SHOWN
 FOR REFERENCE ONLY
 SEE DIM. 40



39 4 Pcs

3

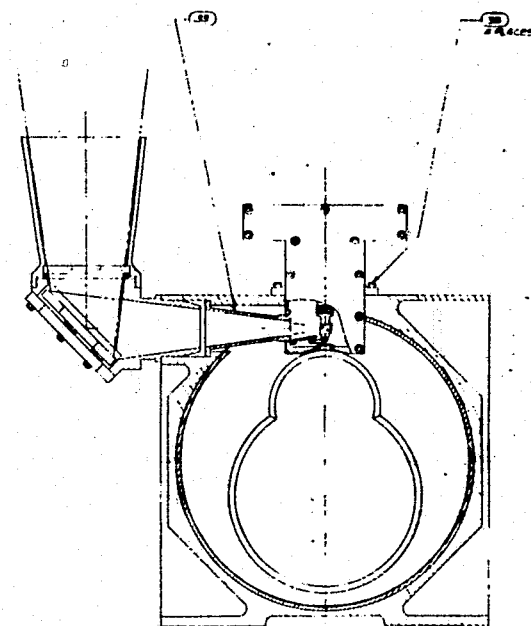
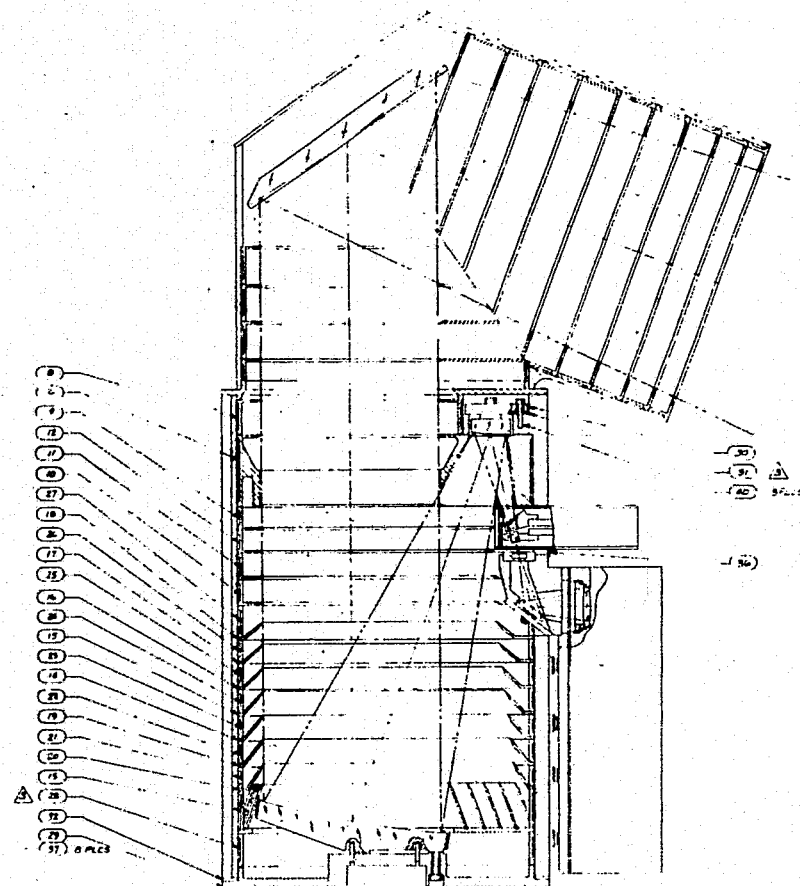
8

9

SHEET 1 OF 2

PART NO.
 SEE PL

THE CHARLES W. BAKER LABORATORY, INC. CHARLES, MASSACHUSETTS 01930	
INSTRUMENT ASSY, APPS	E 51993 236143
SCALE 1:1	SHEET 1 OF 2



SHEET 2 OF 2

PART NO
SEE PL

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

TEMPERATURE
MATERIAL
FINISH
TOLERANCE
SURFACE
TREATMENT
OTHER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

THE CHALCO STEEL RESEARCH LABORATORY, INC.
CHALCO, ILLINOIS 60424
INSTRUMENT ASS-
APPS
E 51993

PARTS LIST		 THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASS. 02139		CONTRACT NO.	CODE IDENT	PARTS LIST NO.	REV	SHEET NO.	
					51993	PL 236143		2	
FIND NO.	ZONE	DASH NO.			CODE IDENT	PART OR IDENT NO.	SYM	NOMENCLATURE/DESCRIPTION	REMARKS
		QUANTITY							
1						236211		SCANNING MIRROR ASSY	P/L 236211
2						236114		CALIBRATION DIFFUSER ASSY	P/L 236114
3						236115		SWITCH ASSY, CALIB.	P/L 236115
4						236170		FILTER ASSY	P/L 236170
5						236117		HOUSING	P/L 236117
6						256120		BAFFLE, SECONDARY MIRROR	
7		2				236127		RETAINER	
8						236128		BAFFLE ENTRANCE	
9						236132		BAFFLE, CENTER, FWID	
10	94					236133 -1		BAFFLE, CENTER, REAR	
11						236133 -2		" " "	
12						236133 -3		" " "	
13						236123		END BAFFLE HOUSING ASSY	P/L 236123
14						236140 -1		BAFFLE, CONICAL	
15						236140 -2		" "	
16						236140 -3		" "	
17						236140 -4		" "	
18						236140 -5		" "	
19						236140 -6		" "	
20						236140 -7		" "	
21						236141 -1		SPACER, BAFFLE	

PARTS LIST		 THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASS. 02139		CONTRACT NO.	CODE IDENT	PARTS LIST NO.	REV	SHEET NO.
FIND NO.	ZONE	DASH NO.		CODE IDENT	PART OR IDENT NO.	SYM	NOMENCLATURE/DESCRIPTION	REMARKS
		QUANTITY						
22					236141 -2		SPACER, Baffle	
23					236141 -3		" "	
24					236141 -4		" "	
25					236141 -5		" "	
26					236141 -6		" "	
27					236141 -7		" "	
28					236141 -8		" "	
29					236148		MIRROR ASSY, PRIMARY	P/L 236148
30					236149		" " , SECONDARY	
31	95				236150		SHIM, MIRROR SUP'T, SECONDARY	P/L 236150
32					236219		" " " PRIMARY	
33					236218		INNER SHROUD, DIFFUSER	
34	8				2		PLATE, THERMO ELECTRIC	
35	8				2		SPACER, PLATE	
36					2		SHIELD, LIGHT	
37	8						SCR, SC.HD.CAP 8-32x.50LG	
38	4						SCR, SC.HD.CAP 6-32x.38LG	
39	4						SCR, SC.HD.CAP 8-32x.38LG	
40	3						SCR, SC.HD.CAP 4-40x.50LG	
41	4						SCR, HX HD, 4-40x.38LG.	
					2			TO BE DETERMINED

NOTES:

1. MATERIAL: BERYLLIUM, INSTRUMENT - HIGH STRENGTH
2. UNLESS OTHERWISE SPECIFIED:
3. FINISH:
 - A. REMOVE BURRS & BREAK SHARP EDGES
 - B. ORDER OF OPERATIONS:
 - A. ROUGH MACHINE
 - B. STRESS RELIEVE PER SPEC.
 - C. FINISH MACHINE
 - D. STABILIZE PER SPEC.
 - E. FINISH OPTICAL BLACK PER SPEC.
 - F. FINISH: OPTICAL BLACK PER SPEC.
 - G. TO BE DETERMINED

.119 DIA THRU
.123
3 HOLES EQUALLY SPACED ON $\sqrt{.500}$ DIA
[A] [B] .001 DIA

.146 DIA THRU
.150
[A] [B] .001 DIA

.03-.45° CHAMFER
2 PLACES

-C-
[A] [B] 1 ARC MIN
[C] [D] .0001

[A] [B] .001

.0024 DIA THRU
.0029
2 HOLES
[A] [B] .001 DIA

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED
CAPACITOR VALUES ARE IN μ F
RESISTOR VALUES ARE IN OHMS
DIMENSIONS ARE IN INCHES
TOLERANCE ON
DECIMALS ANGLES
 $\pm .01$
 $\pm .005$
DO NOT SCALE THIS DRAWING
MATERIAL

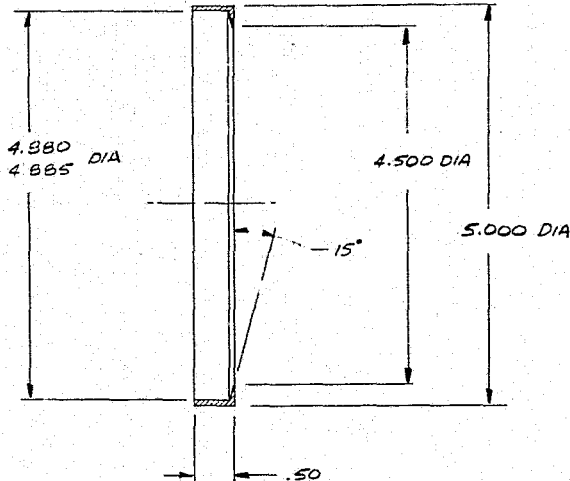
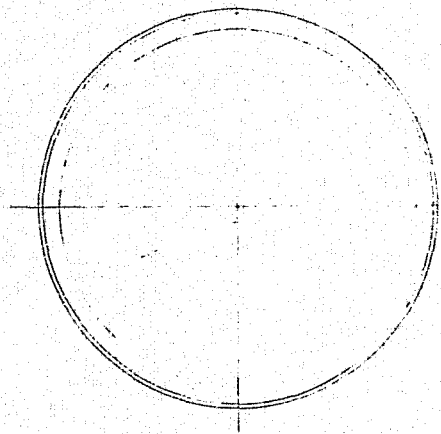
SEE NOTE

REV	DATE	DESCRIPTION	OWN	DATE	APPROVED
REVISION STATUS					
THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138					
SUPPORT, SECONDARY MIRROR - APPS					
SIZE	51993	DRAWING NO.	236146	REV	
SCALE	2x	SHEET 1 OF			

NOTES:

1. MATERIAL: 6061-T6 AL ALLOY
2. UNLESS OTHERWISE SPECIFIED:
 $\sqrt{}$ FINISH
 REMOVE BURRS & BREAK SHARP EDGES
3. FINISH: OPTICAL BLACK PER SPEC $\triangle$
4. TO BE DETERMINED $\triangle$

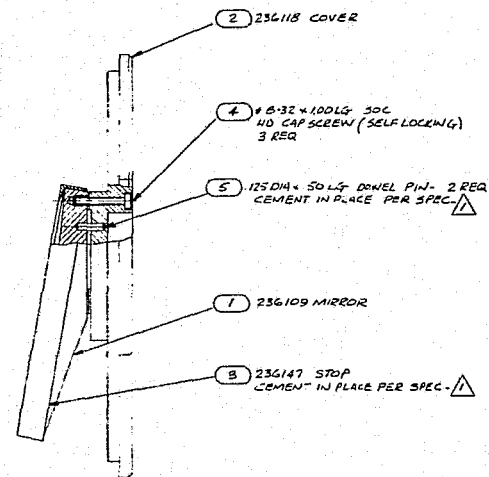
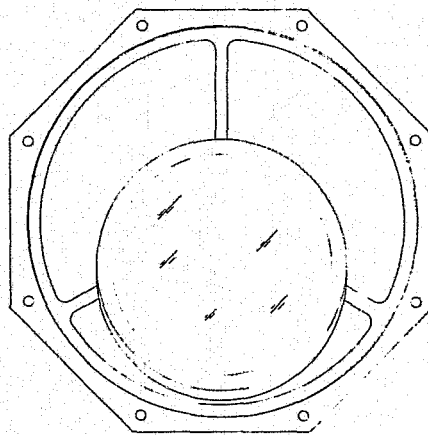
REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE



PART NO.
SEE PL

236148 NEXT ASSEMBLY USED ON APPLICATION		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$.01 $\pm$ 1° .XXX $\pm$.005 $\pm$ 1° DO NOT SCALE THIS DRAWING MATERIAL SEE NOTE 1	CONTRACT NO. DRAWN TANDERSON 10/27/76 CHECKED APPROVED CSOL APPROVED DATE APPROVED BY DIRECTION		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139 STOP, OPERATURE - APPS SIZE CODE IDENT NO. DRAWING NO. C 51993 236147 SCALE FULL SHEET 1 OF	
			REV			
			REV			
			REV			

NOTES:
1 TO BE DETERMINED



PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN P.F. RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DIMENSIONS ± .005 DO NOT SCALE THIS DRAWING MATERIAL		CONTACT NO. DRAWN <i>T. ANDERSON</i> <i>10/27/76</i> CHECKED APPROVED DATE BY <i>EDUCATION</i>
236143	NEXT ASSEMBLY USED ON	APPLICATION

REV	SHEET	REVISION STATUS
THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS 02138		
MIRROR ASSY, PRIMARY - APPS		
SIZE	CODE IDENT NO.	DRAWING NO.
D	51993	236148
SCALE	FULL	SHEET 1 OF 1

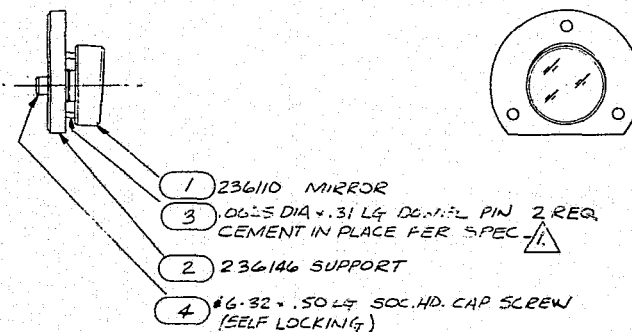
[illegible]

NOTES:



TO BE DETERMINED

REVISIONS					
ZONE	LTR	DESCRIPTION		DWN	DATE



- 1 236110 MIRROR
- 3 .0625 DIA $\pm$.01 LG DOWEL PIN 2 REQ
CEMENT IN PLACE PER SPEC $\triangle$
- 2 236146 SUPPORT
- 4 #6-32 $\times$.50 LG SOC. HD. CAP SCREW
(SELF LOCKING)

PART NO.
SEE PL

236143 NEXT ASSEMBLY USED ON APPLICATION		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$ $\pm$.XXX $\pm$ $\pm$ DO NOT SCALE THIS DRAWING MATERIAL		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
		CONTRACT NO. DRAWN T.-I. ANDERSON 28 OCT 76 CHECKED APPROVED APPROVED CSOL APPROVED DATE APPROVED BY DIRECTION		MIRROR ASSY, SECONDARY APPS	
		SIZE CODE IDENT NO. DRAWING NO. REV C 51993 236149		SCALE 1/1 SHEET 1 OF	

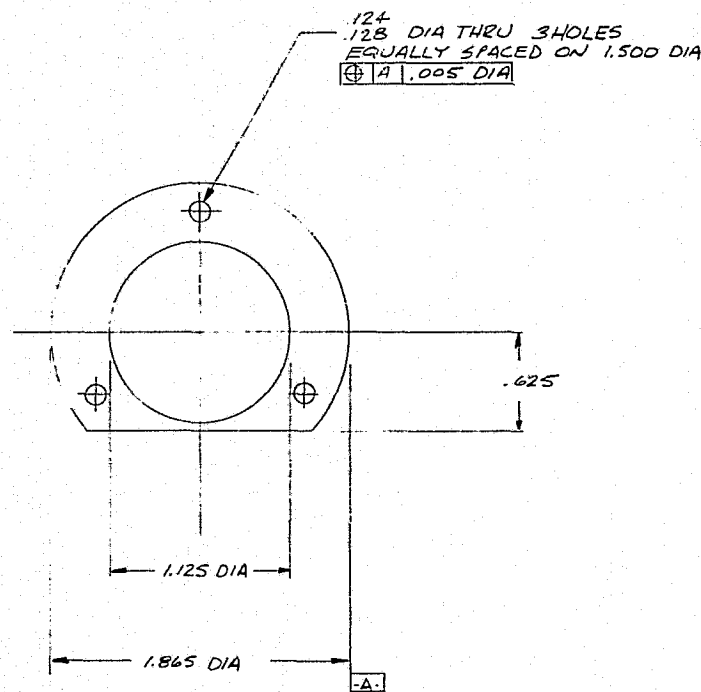
NOTES:

1. MATERIAL: 6061-T6 AL ALLOY
2. UNLESS OTHERWISE NOTED:
 Δ FINISH
 REMOVE BURRS & BREAK SHARP EDGES
3. FINISH: OPTICAL BLACK PER SPEC Δ
4. Δ TO BE DETERMINED

REVISIONS					
ZONE	LTR	DESCRIPTION	DWN	DATE	APPROVED

104

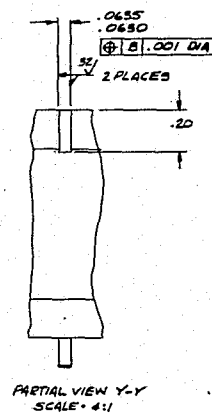
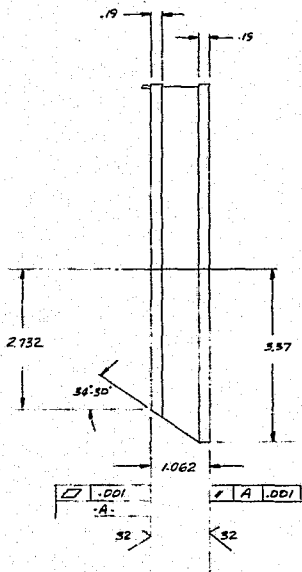
.062



PART NO.
 SEE PL

236143 NEXT ASSEMBLY USED ON APPLICATION		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$.01 .XXX $\pm$.005 $\pm$ — DO NOT SCALE THIS DRAWING MATERIAL SEE NOTE 1	CONTRACT NO. DRAWN J. ANDERSON 10/28/74 CHECKED APPROVED APPROVED CSOL APPROVED DATE APPROVED BY DIRECTION		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS 02139 SHIM, MIRROR SUPPORT-SECONDARY APPS SIZE C CODE IDENT NO. 51993 DRAWING NO. 236150 SCALE 2x SHEET 1 OF	
			REV			
			REV			
			REV			

106



DETAIL "X"
SCALE - 4/1

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN P.F. RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES XXX ± .01 XXX ± .005 ± .0° 30'		CONTRACT NO. DRAWN <u>ANDERSON</u> DATE CHECKED _____ APPROVED _____		REVISION STATUS THE CHARLES STERN DRAFTER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02140 DRAFTED, FWD SCANNING MIRROR ASSY - APPS	
MATERIAL		COPD. APPROVED _____ DATE _____		SIZE CODE IDENT NO. DRAWING NO.	
236211		APPROVED _____		D 51993 236152	
NEXT ASSEMBLY USED ON _____		BY SIGNATURE _____		SCALE 1" = 1" SHEET 1 OF	
APPLICATION _____					

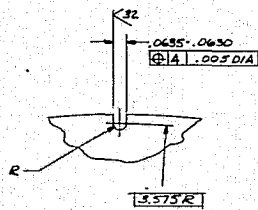
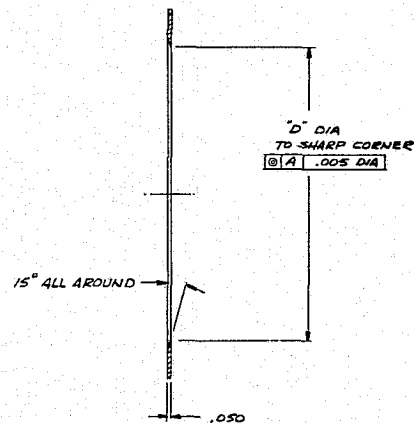
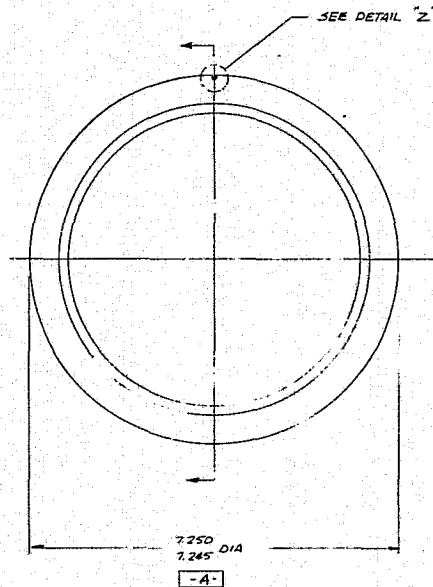
8 7

ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE

NOTES:

1. MATERIAL: 6061-T6 ALUMINUM ALLOY
2. UNLESS OTHERWISE NOTED:
3. FINISH
- REMOVE BURS & BREAK SHARP EDGES
4. FINISH OPTICAL BLACK PER SPEC. - A
5. TO BE DETERMINED



DETAIL Z
SCALE - 4/1

236154 - 4	5.944
236154 - 3	5.846
236154 - 2	5.724
236154 - 1	5.602
PART NO	"D" DIA

TABLE

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN P.P. RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON	CONTRACT NO.
DECIMALS ANGLES ± .01 ± 1° ± .005 ± 1° DO NOT SCALE THIS DRAWING	DRAWN - A. J. J. H. M.
MATERIAL	CHECKED
236211	DATE
BY ASSEMBLY	APPROVED
APPLICATION	BY ORIENTATION

SEE NOTE 1

REV	REVISION STATUS
SHEET	
THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS 02139	
BAFFLE, FLAT-FWD SCAN MIRROR ASSY - APPS	
SIZE	DATE (REV. NO.) DRAWING NO.
D 51993	236154
SCALE	SHEET 1 OF

NOTES:

1. MATERIAL: 6061-T6 ALUMINUM ALLOY
2. UNLESS OTHERWISE SPECIFIED
3. FINISH
REMOVE BURRS & BREAK SHARP EDGES
4. FINISH OPTICAL BLACK PER SPEC. - Δ
5. TO BE DETERMINED

TABLE

PART NO.	"L" DIM
234155-3	.650
234155-2	.800
234155-1	.650

DETAIL "X"
SCALE: 4/1

PARTIAL VIEW Y-Y
SCALE: 4/1

PART NO. SEE PL

THE CHARLES STARK DRAPER LABORATORY, INC.
CAMBRIDGE, MASSACHUSETTS, 02139

SPACER BAFFLE - SCANNING MIRROR ASSY - APPS

SIZE D 51993

DATE 2/24/71

BY 234271

APPROVED

REVISION STATUS

REVISIONS

REV	DATE	DESCRIPTION
1		

NOTES

1. MATERIAL: 6061-T6 ALUMINUM ALLOY
2. UNLESS OTHERWISE SPECIFIED:
 A. FINISH
 B. REMOVE BURRS & BREAK SHARP EDGES
 C. FINISH OPTICAL BLACK PER SPEC - D
3. SURFACE - C- TO BE REMACHINED AT NEXT ASSY.
4. INSTALL ITEM 2 AFTER ABOVE OPERATION
5. TO BE DETERMINED

.151 DIA THRU
.155
5 HOLES EQUALLY SPACED ON
7.625 DIA
⊕ B D .005 DIA

7.04 DIA

⊙	B	.005 DIA
---	---	----------

6.042 DIA		
③	B	.001 DIA

15° ALL AROUND -

.050

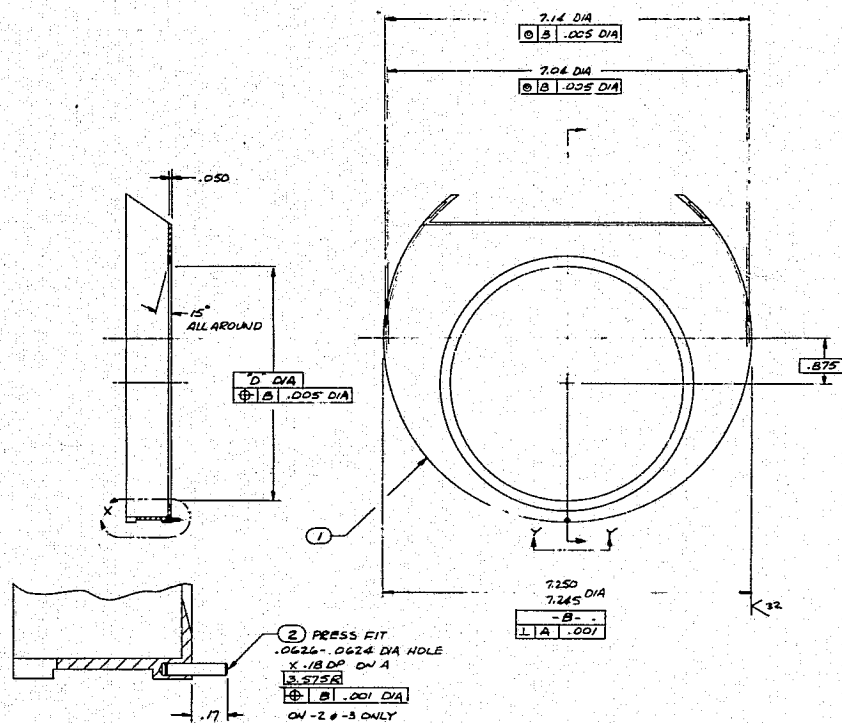
2 PRESS FIT
 .0626-.0624 DIA HOLE
 .0626-.0624 DIA SHAFT
 3.575 R
 .001 DIA
 SEE NOTE 1

DETAIL "X"
SCALE = 4/1

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μF RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES JOG 1:105 10°-30° DO NOT SCALE THIS DRAWING MATERIAL	CONTRACT NO. DRAWN BY J. ANDERSON 10-24-76 CHECKED APPROVED DATE APPROVED	THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS 02139 BAFFLE, FWD - SCANNING- MIRROR ASSY - APPS
234211 NEXT ASSEMBLY USED ON APPLICATION	SEE NOTE 1	SHEET CODE DRT NO. 1 DRAWING NO. D 51993 236156 SCALE: AS SHOWN (SHEET 1 OF 1)

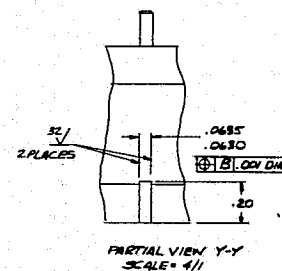
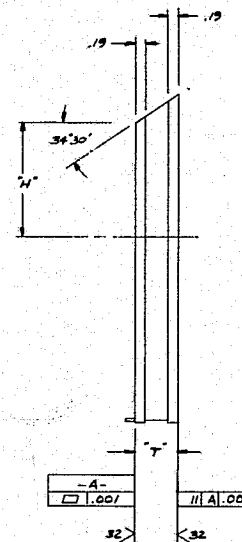
1. MATERIAL: 6061-T6 ALUMINUM ALLOY
2. UNLESS OTHERWISE NOTED:
63/ FINISH
REMOVE BURS & BREAK SHARP EDGES
3. FINISH: OPTICAL BLACK PER SPEC - 
4. TO BE DETERMINED



DETAIL "X"
SCALE = 4/1

236157 -3	4.580	978	2.844
236157 -2	4.583	.875	2.242
236157 -1	4.587	1.000	1.555
PART NO	"D"	"T"	"H"

TABLE



PART NO.
SEE PL

[illegible]

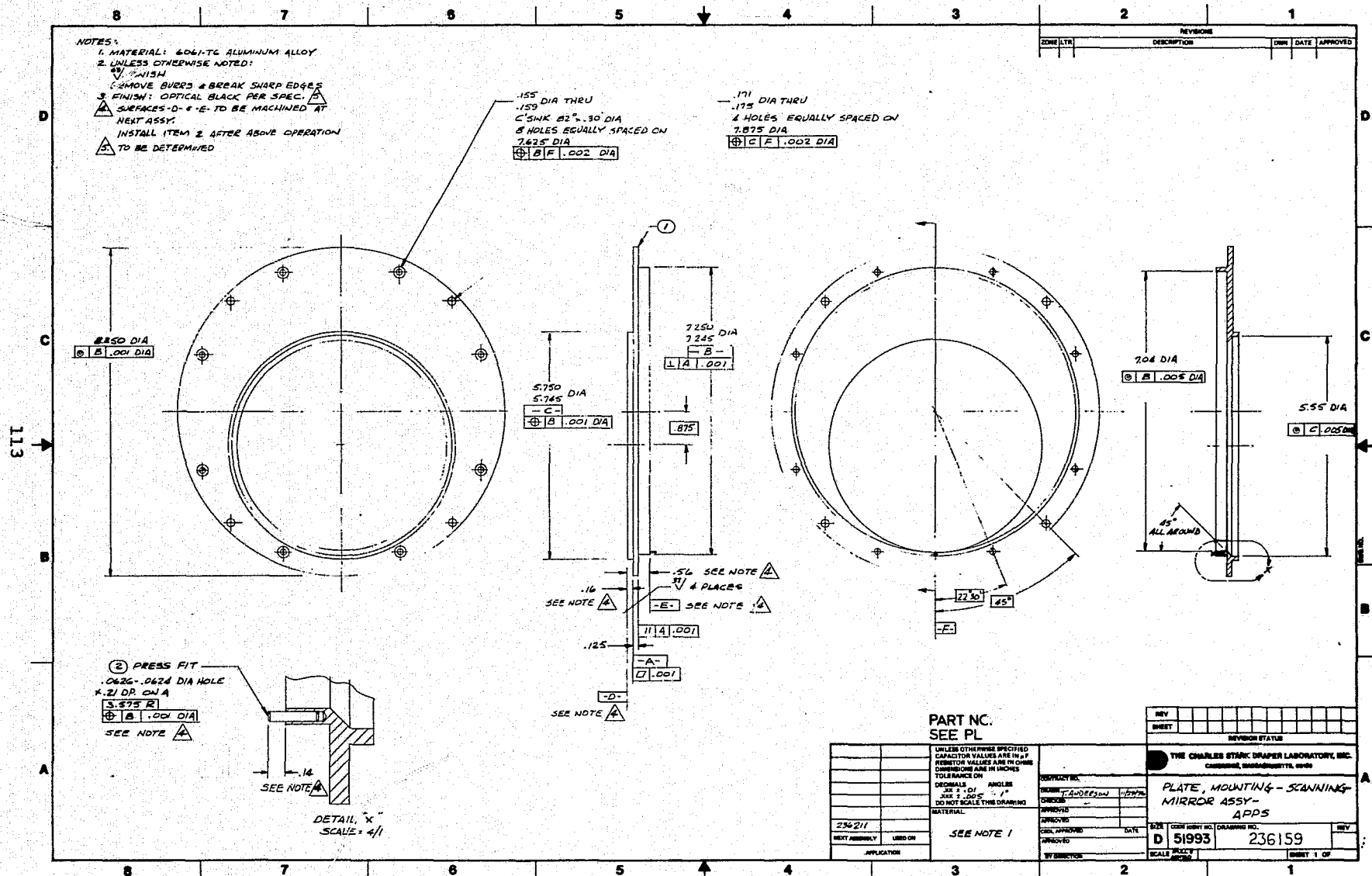
REMOVE BURRS & BREAK SHARP EDGES
3. FINISH: OPTICAL BLACK PER SPEC-4
4. TO BE DETERMINED

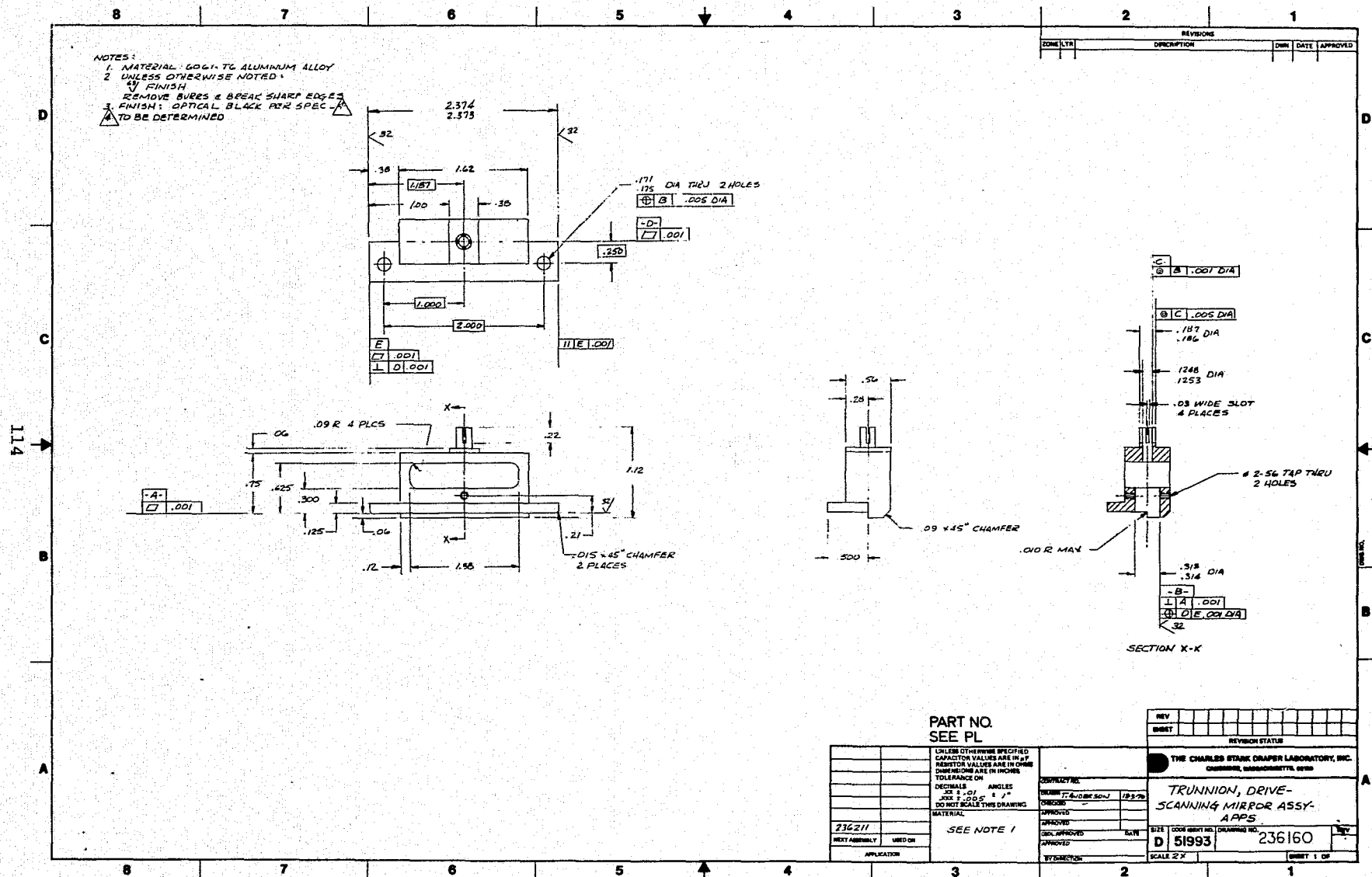


3.575R
-⊕ B .001 DIA

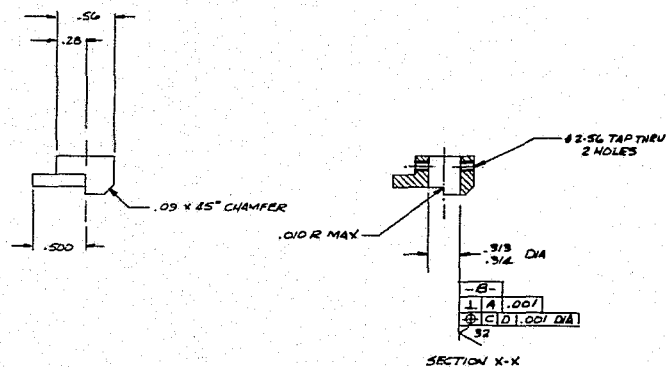
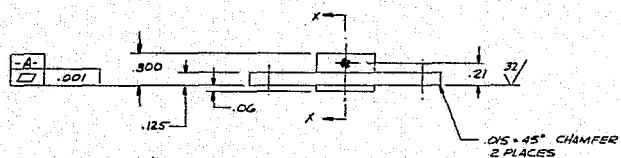
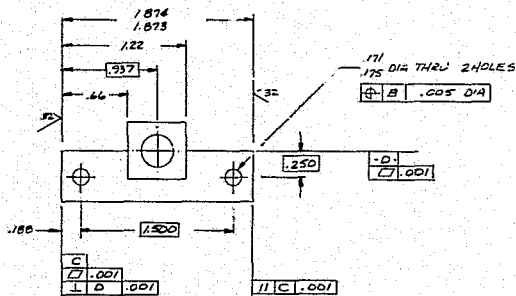
UNLESS OTHERWISE NOTED

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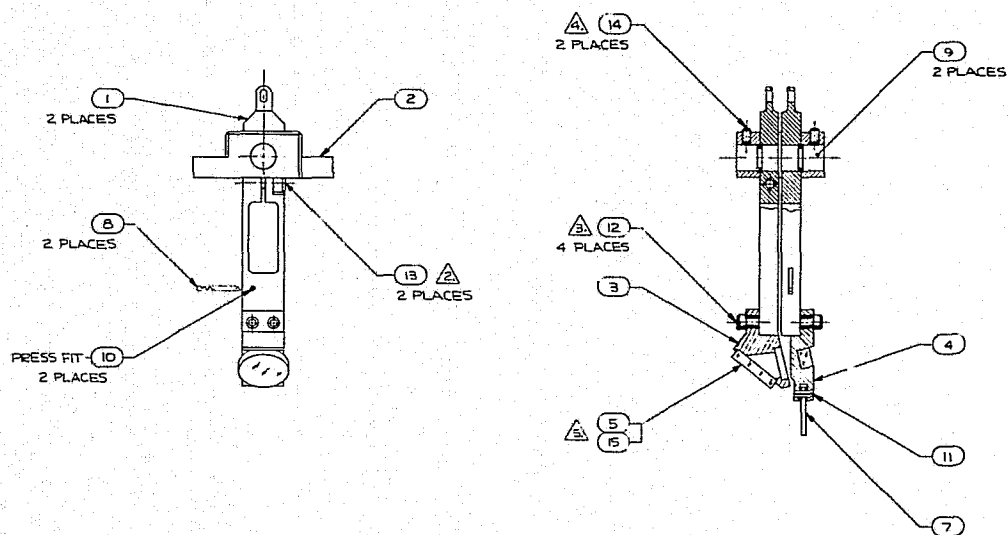
- NOTES:
 1. MATERIAL: 6061-T6 ALUMINUM ALLOY
 2. UNLESS OTHERWISE NOTED:
 FINISH
 REMOVE BURRS & BREAK SHARP EDGES
 3. FINISH: OPTICAL BLACK PER SPEC. A
 TO BE DETERMINED



PART NO.
SEE PL

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCES ON
		DECIMALS ANGLES
		XXX .001 2 $^{\circ}$
		XXX .005 1 $^{\circ}$
		DO NOT SCALE THIS DRAWING MATERIAL
23211		SEE NOTE 1
NEXT ASSEMBLY	USED ON	
APPLICATION		

116



NOTES:

1. INTERPRET DWG PER MIL-D-1000.

- △ TORQUE TO △
- △ TORQUE TO △
- △ TORQUE TO △
- △ BOND IN PLACE USING (15).
- △ TO BE DETERMINED

PART NO. 236162-1
SEE PL 236162

236115		APPS		236115		APPS	
NEXT ASSEMBLY		USED ON		236115		APPS	
APPLICATION				236115		APPS	

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN µF RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES ± .005 ± DO NOT SCALE THIS DRAWING		CONTRACT NO. DRAWN BY <i>Blumenthal</i> 12/20/53 CHECKED APPROVED DATE BY DIRECTOR	
---	--	---	--

THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
SWITCH ARM ASSY	
SIZE D	CONTRACT NO. 51993
DRAWING NO. 236162	REV 1
SCALE 2/1	

SHEET 1 OF 1

PARTS LIST		 THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASS. 02139		CONTRACT NO.	CODE IDENT	PARTS LIST NO.	REV	SHEET NO.
FIND NO.	ZONE	DASH NO.	QUANTITY	CODE IDENT	PART OR IDENT NO.	SYM	NOMENCLATURE/DESCRIPTION	REMARKS
		-1						
1		2			236130-1		ARM, SWITCH	PL 236130
2		1			236129-1		PIVOT, SWITCH ARM	
3		1			236131-1		MOUNT, ATTENUATOR	PL 236131
4		1			236136-1		MOUNT, REDIRECTIONAL MIRROR	
5		1			236119-1		ATTENUATOR	
7		1			236122-1		LINK, DIFFUSER DOOR	
8	118	2			E1008A-75		SPRING	LEE SPRING CO.
9		2			5008-800		FLEX PIVOT	BENDIX CO.
10		2			D2-187		PIN, DOWEL .032 DIA x .18 LG	PIC
11		1			236163 -2		PIN, ROLL .062 x .25 LG	
12		4					SCR, SCHDCAP, 2-56 x .31 LG	
13		2					SCR, SCHDCAP, 4-40 x .31 LG	
14		2			CS-8		SCR, SET, SCHD, 2-56 x .15 LG	PIC
15	AR						ADHESIVE	
							TO BE DETERMINED	

5

4

↓ 3

2

1

D

D

C

C

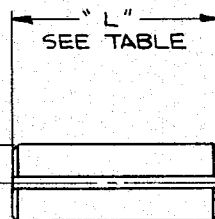
119

B

B

A

A

.18 DIA EXPANDED
REF"L"
SEE TABLE.015 MAX x 45°
THIS END ONLY

NOTES:

1. INTERPRET DWG PER MIL-D-1000.
2. PURCHASE PART FROM PIC AND ALTER AS SHOWN.
3. IDENTIFY PER MIL-STD-130. BAG AND TAG. DO NOT MARK PART.

236163 -2	.18
236163 -1	.40
PART NO.	"L"
TABLE	

ALTERED ITEM DRAWING
PART NO. SEE TABLE

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$.01 $\pm$ 2° XXX $\pm$.01 DO NOT SCALE THIS DRAWING		CONTRACT NO.		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
236115		MATERIAL	MAKE FROM PIC PN C3-2	APPROVED		PIN, ROLL	
236162	APPS	APPLICATION		CSOL APPROVED	DATE	SIZE	CODE IDENT NO. DRAWING NO.
NEXT ASSEMBLY	USED ON			APPROVED		B 51993	236163
				BY DIRECTION		SCALE	SHEET 1 OF 1

5

4

↑ 3

2

1

5

4

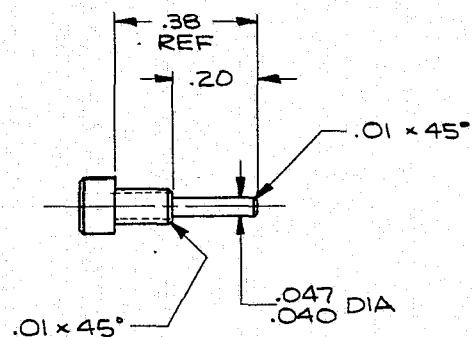
3

2

1

REVISIONS

ZONE	LTR	DESCRIPTION	DWN	DATE	APPROVED



NOTES

- 1 INTERPRET DWG PER MIL-D-1000.
- 2 REMOVE BURRS AND BREAK SHARP EDGES .005 MAX UNLESS OTHERWISE SPECIFIED.
- 3 $\sqrt{63}$ AS REQUIRED.
- 4 IDENTIFY PER MIL-STD-130. BAG AND TAG. DO NOT MARK PART.

ALTERED ITEM DRAWING

PART NO. 236164-1

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON		CONTRACT NO.		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
		DECIMALS ANGLES XX $\pm .01$ $\pm 2^\circ$ XXX $\pm$ DO NOT SCALE THIS DRAWING		DRAWN CHECKED		MTG SCREW, SPRING	
		MATERIAL		APPROVED		SIZE CODE IDENT NO. DRAWING NO.	
236115 APPS		MAKE FROM SCHD CAP SCR 2-56UNC x .38LG		APPROVED		B 51993 236164	
NEXT ASSEMBLY USED ON				DATE		REV	
APPLICATION				BY DIRECTION		SCALE 4/1 SHEET 1 OF 1	

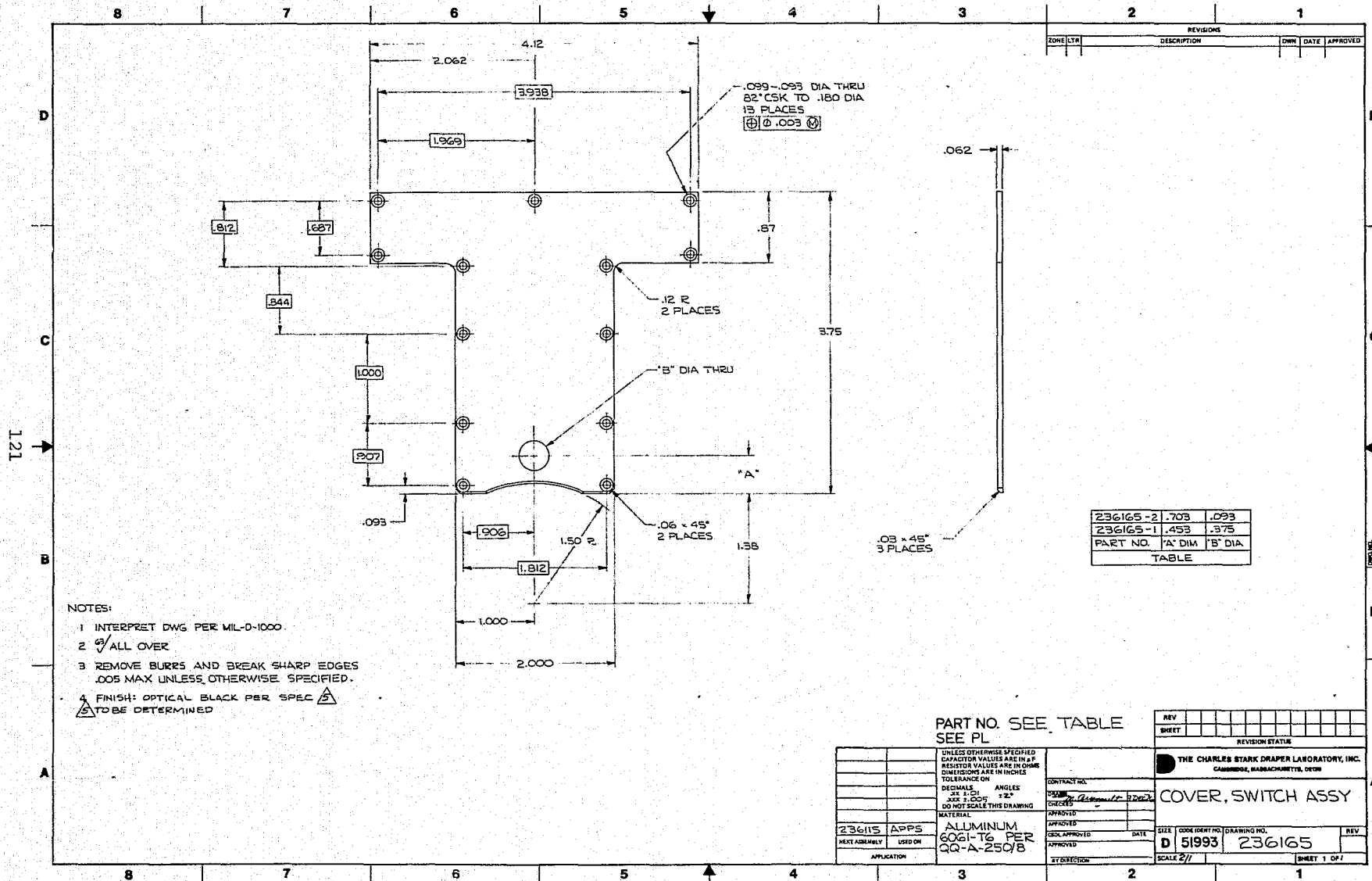
5

4

3

2

1



4

3

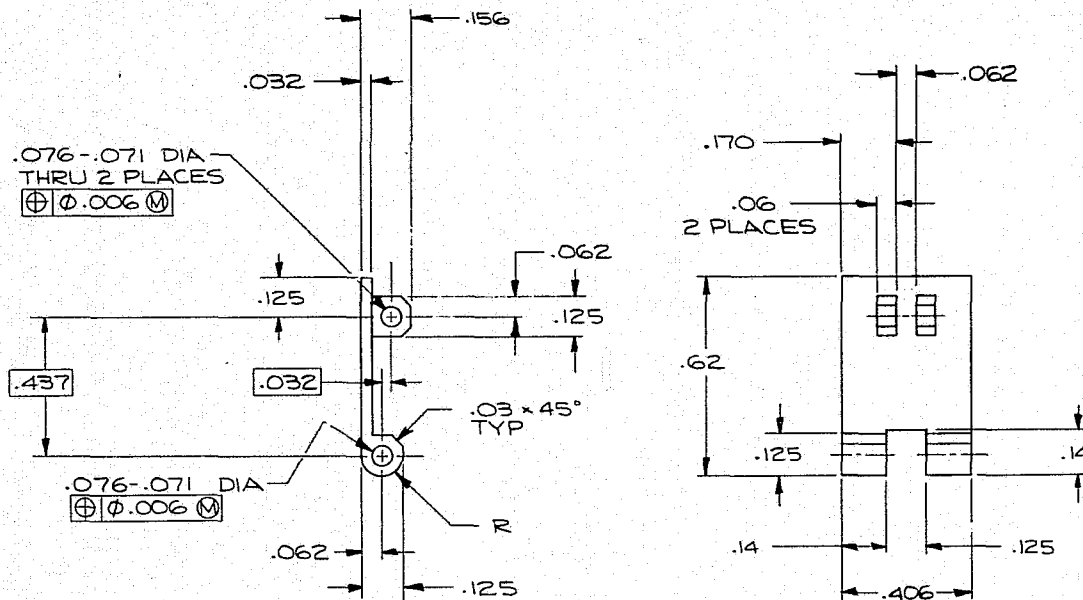
2

1

REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE

D

D



C

C

1.22

B

NOTES:

1. INTERPRET DWG PER MIL-D-1000.
2. $\sqrt[63]{}$ ALL OVER.
3. REMOVE BURRS AND BREAK SHARP EDGES .005 MAX UNLESS OTHERWISE SPECIFIED.
4. FINISH: OPTICAL BLACK PER SPEC $\triangle$ TO BE DETERMINED

PART NO. 236166-1
SEE PL

A

DWG NO.

B

A

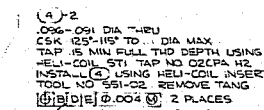
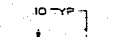
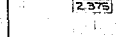
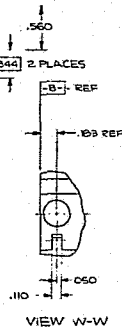
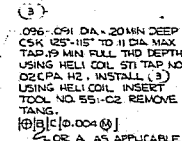
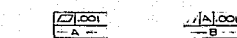
		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES XX $\pm$.01 $\pm$ 5° XXX $\pm$.005 $\pm$ 5° DO NOT SCALE THIS DRAWING		CONTRACT NO.		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138	
				DRAWN CHECKED		DOOR, DIFFUSER	
				APPROVED			
				CSDL APPROVED		DATE	
				APPROVED			
				BY DIRECTION			
236115 APPS		MATERIAL ALUMINUM 6061-T6 PER QQ-A-250/8		SIZE		CODE IDENT NO. DRAWING NO.	
NEXT ASSEMBLY USED ON				C 51993		236166	
APPLICATION				SCALE 4/1		SHEET 1 OF 1	

4

3

2

1

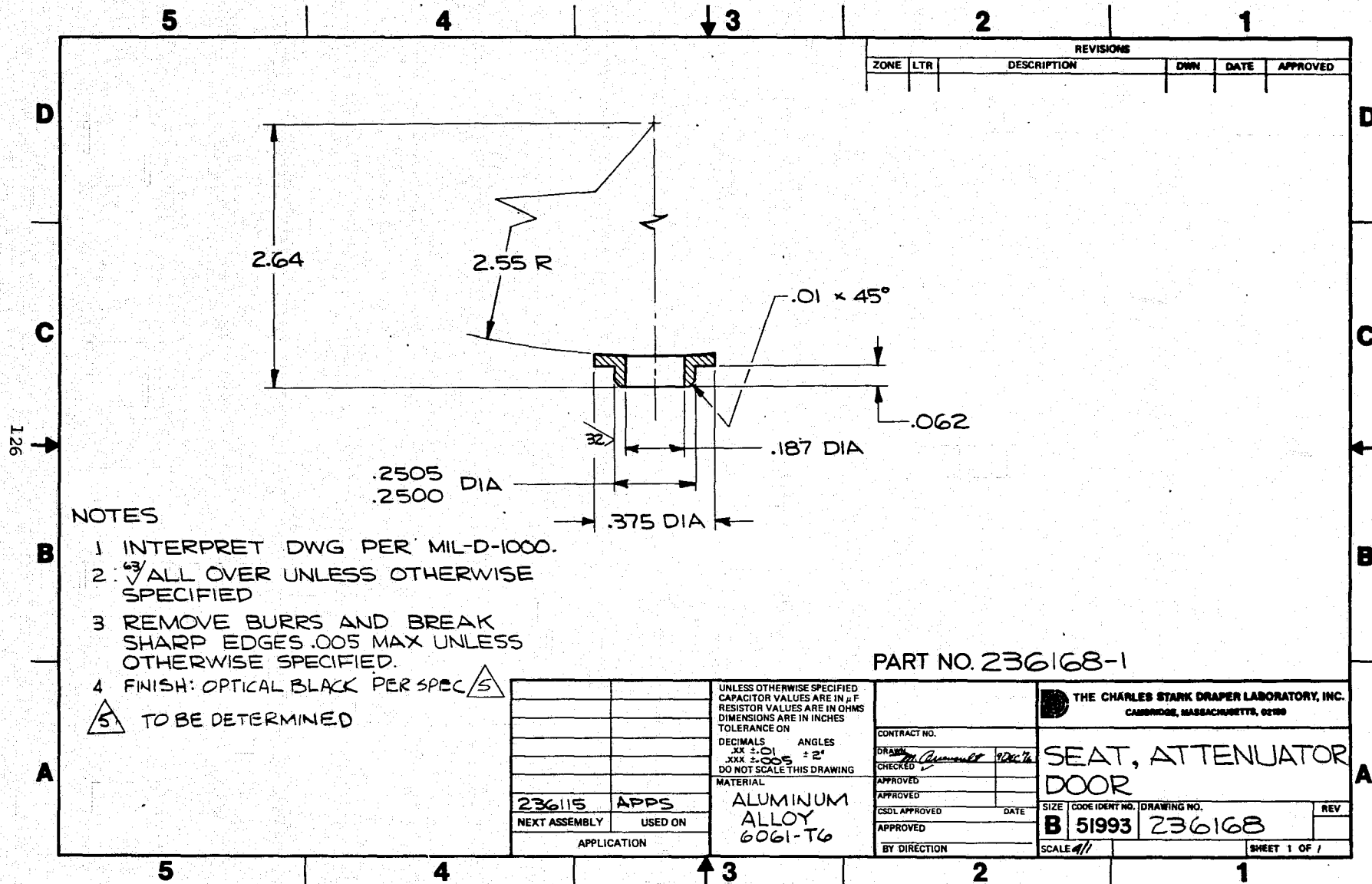


1. INTERPRET DWG PER MIL-D-1000.
2. ✓ ALL OVER UNLESS OTHERWISE SPECIFIED.
3. REMOVE BURRS AND BREAK SHARP EDGES .005 MAX UNLESS OTHERWISE SPECIFIED.
4. △ INSTALL (2) PER MS33537. REMOVE TANG.
5. FINISH: OPTICAL BLACK PER SPEC △
TO BE DETERMINED

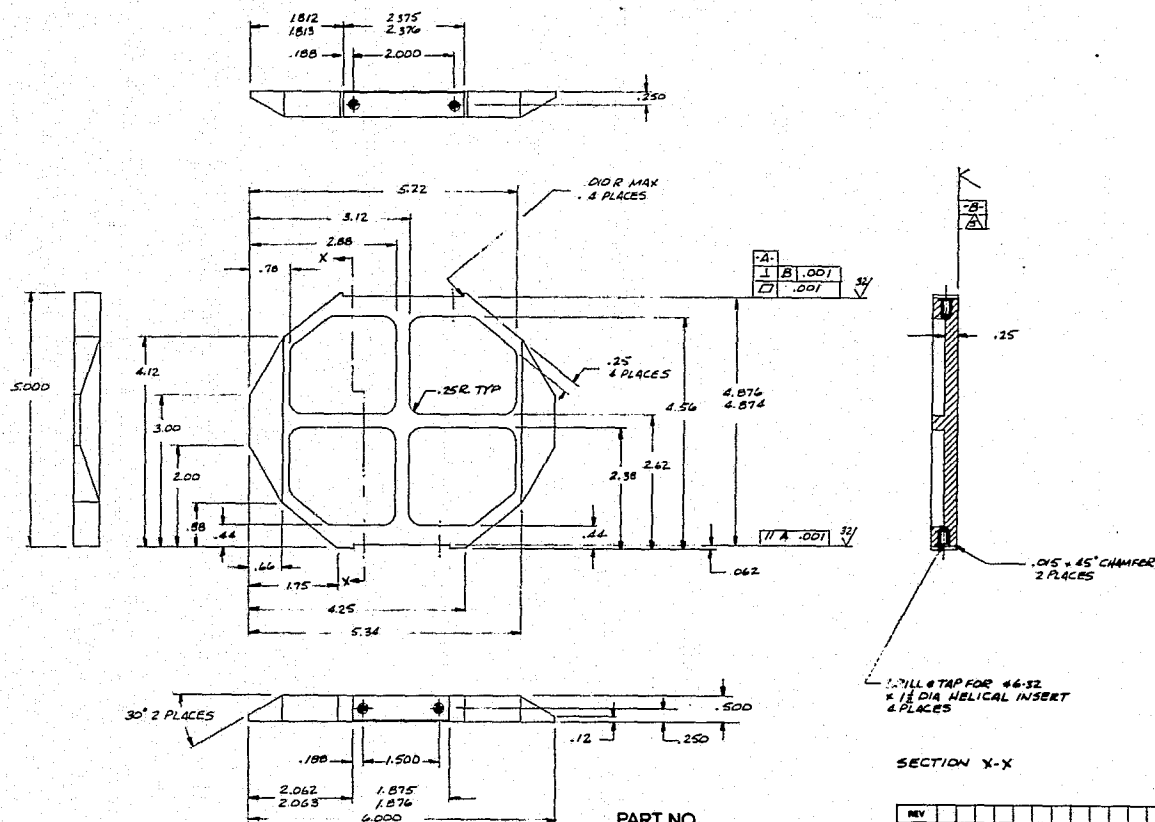
UNLESS OTHERWISE SPECIFIED
CAPACITOR VALUES ARE IN μ F
RESISTOR VALUES ARE IN OHMS.

[illegible]

[illegible]



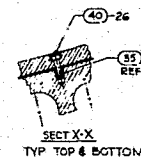
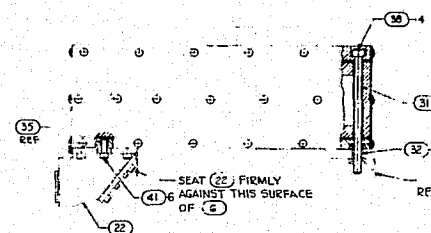
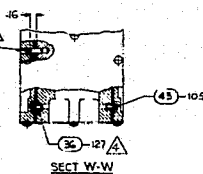
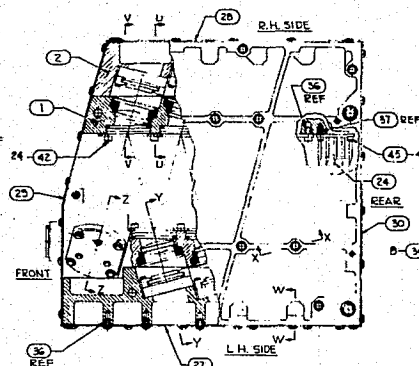
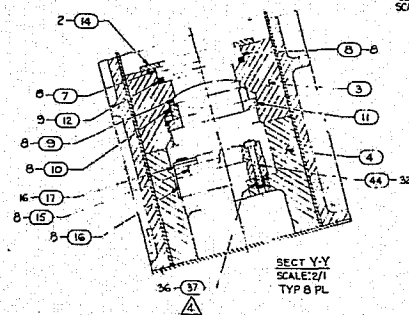
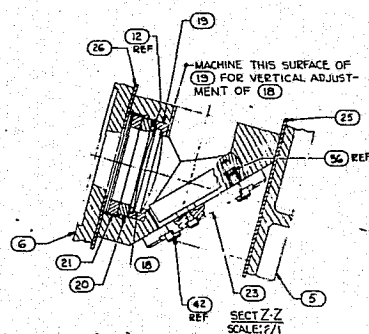
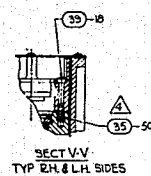
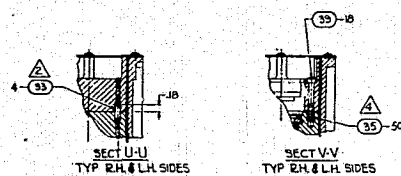
1. MATERIAL: ONE OF THE FOLLOWING MAY BE USED:
 - A. BERYLLIUM OPTICAL GRADE I-TO-A MANUFACTURED BY DUBUSH WELLMAN INC., FAIRFIELD, N.J.
 - B. BERYLLIUM GRADE HP-811 MANUFACTURED BY HAWKES BERYLLIUM INDUSTRIES INC., HARTLTON, PA.
2. ORDER OF OPERATIONS:
 - A. MACHINE AS REQ'D, CRITICAL DIMENSIONS MACHINED TO .010/.020 OF FINISHED PART
 - B. STRESS RELIEVE AT 1150° F $\pm 25^{\circ}$ F FOR 1 HOUR ± 5 MIN IN VACUUM OR OTHER PROTECTIVE ATMOSPHERE COOL TO 700° F. HOLD TO EXCEED 100° F PER HOUR, COOL IN STILL AIR FROM 700° F TO ROOM TEMPERATURE. (VACUUM OR OTHER PROTECTIVE ATMOSPHERE NOT NEEDED BELOW 700° F.
 - C. FINISH MACHINING
 - D. STABILIZE AT 200° F $\pm 10^{\circ}$ F FOR 10 MINUTES ± 1 MIN. COOL TO ROOM TEMPERATURE AND HOLD FOR 10 MINUTES ± 1 MIN. COOL TO -100° F $\pm 10^{\circ}$ F AND HOLD FOR 10 MINUTES ± 1 MIN. REPEAT STABILIZING PROCEDURE A TOTAL OF 5 CYCLES
 - E. SURFACE-B TO BE RELIED TO BE NICKEL COATED PER MIL-C-36074 CLASS 2, .004/.006 THICK.
 - ALL OTHER SURFACES OPTIONAL
 - F. ORDER OF OPERATIONS OF THIS NOTE OPTIONAL
 - 1. INSTALL SURFACES
 - 2. PERFORM FINISH OPERATIONS TO SURFACE-B.
 - 4.5 REQ'D PER NOTES 5 & 6
 - 3. NICKEL COATING SHALL NOT BE REDUCED TO LESS THAN .001 THICK
 - 4. REPEAT STABILIZATION CYCLES PER NOTE 2 D FOLLOWING EACH FINISHING OPERATION OR SEQUENCE UNTIL DIMENSIONAL STABILITY IS ACHIEVED.
3. SURFACE-B TO BE ALUMINIZED PER MIL-M-13508. PROTECTIVE COATING SHALL BE MIL-P 100-125 IN THICK OVER THE EFFECTIVE SURFACE
4. EFFECTIVE SURFACE SHALL LIE WITHIN .06 INCHES OF ALL EDGES OF SURFACE -B
5. SURFACE-B TO BE 8- TO 10-
 - S & A AT 635 MM OVER THE EFFECTIVE SURFACE
6. SURFACE QUALITY OF SURFACE -B TO BE 40/20 PER MIL-O-13830 OVER THE EFFECTIVE SURFACE
7. UNLESS OTHERWISE NOTED:
 - NO SURFACES & BREAK SHARP EDGES
 - FINISH



SECTION X-X

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS .015 ANGLES XXX $\pm$.015 3" $\pm$ DO NOT SCALE THIS DRAWING MATERIAL		REVISION STATUS	
		THE CHARLES STANT DRAFTER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02142	
		CONTRACT NO.	
		DRAWING TITLE <i>D-10052</i>	DATE <i>11/7/76</i>
CHECKED		APPROVED	
APPROVED		APPROVED	
DATE		DATE	
APPROVED		APPROVED	
IN CHARGE		SCALE <i>1/4" = 1"</i>	
APPLICATION		SIZE <i>D</i> QUOTED IN CHARGE NO. <i>51993</i> DRAWING NO. <i>236169</i> REV	
USED ON		SHEET 1 OF	



- NOTES:
1. INTERPRET DWG PER MIL-D-1000
A PRESS FIT (35) INTO (1) & (5), FOUR PLACES.
SEE SECT U-U
A AFTER ALIGNING SYSTEM OPTICALLY, DRILL & REAM
FOR (36), FOUR PLACES TOP & BOTTOM. PRESS FIT
IN (1) & (5). LOCATE FROM EXISTING .03 DIA BLIND HOLES.
SEE SECT W-W
A INSTALL (35), (36) & (37) PER WS33537. REMOVE TANGS

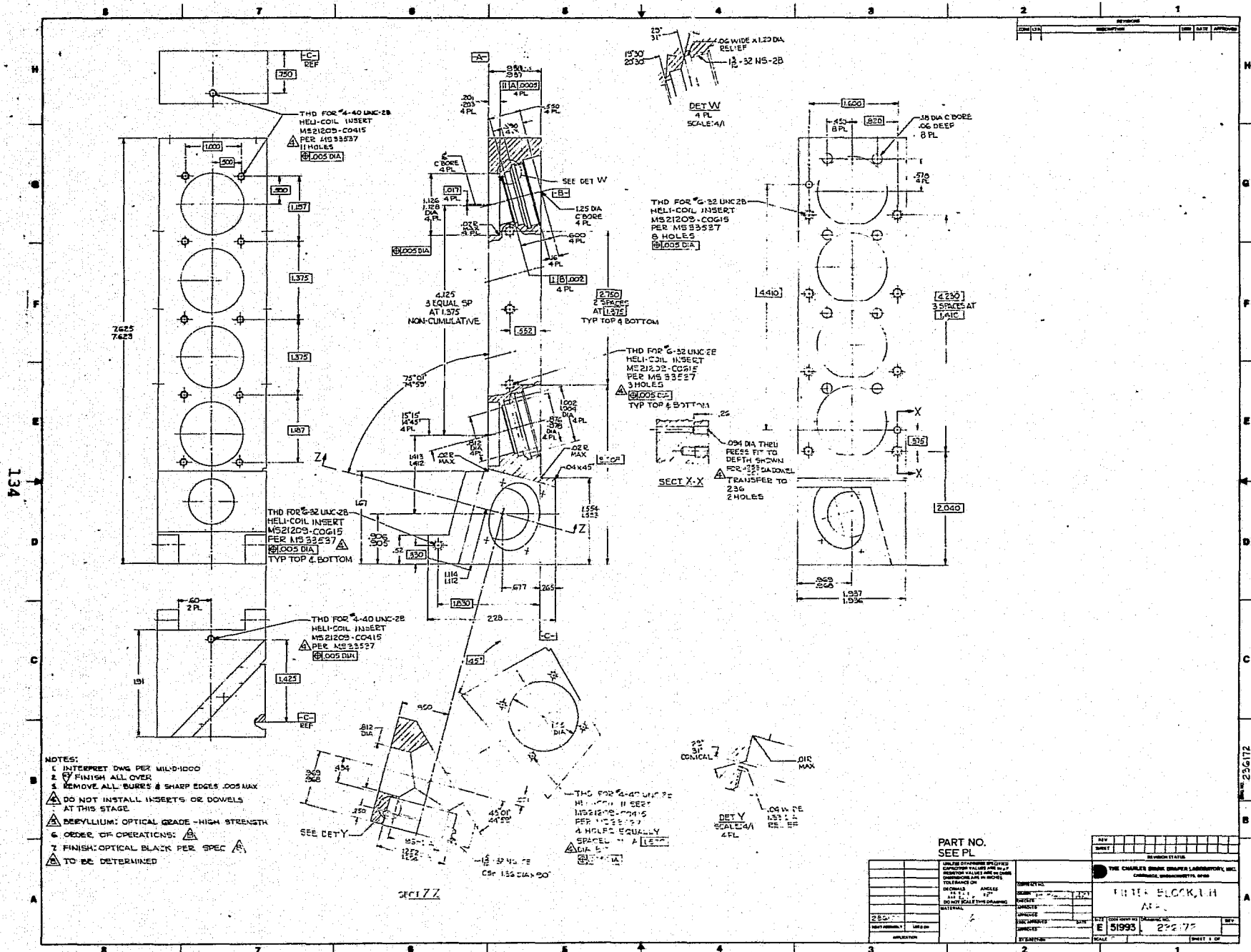
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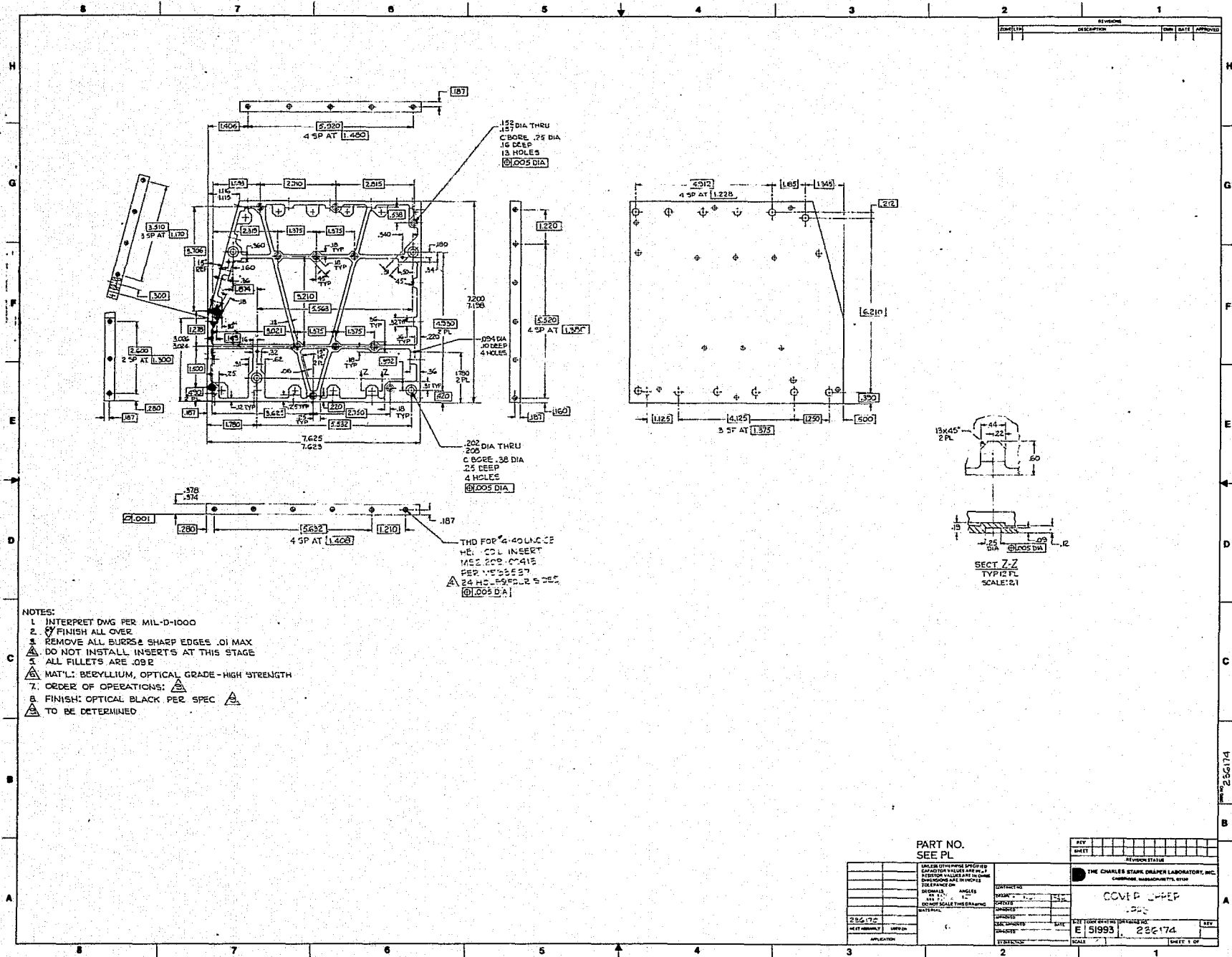
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PARTS LIST		 THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASS. 02139			CONTRACT NO.	CODE IDENT	PARTS LIST NO.	REV	SHEET NO.
						51993	PL 236170		2
FIND NO.	ZONE	DASH NO.		CODE IDENT	PART OR IDENT NO.	SYM	NOMENCLATURE/DESCRIPTION	REMARKS	
		QUANTITY							
		-1							
1		1			236142		FILTER BLOCK, R.H.		
2		1			236171		DETECTOR BLOCK, R.H.		
3		1			236172		FILTER BLOCK, L.H.		
4		1			236173		DETECTOR BLOCK, L.H.		
5		1			236174		COVER, UPPER		
6		1			236175		COVER, LOWER		
7		8			236176-001		FILTER, OUTER		
8		8			236176-002		FILTER, INNER		
9		8			236177		LENS, FILTER		
10	130	8			236178		RETAINER, FILTER LENS		
11		8			236179		RING, LOCKING, " "		
12		9			236180		O-RING	1.00 I.D. x .070	
13									
14		2			236181		RETAINER, FILTER		
15		8			236182		DETECTOR	E.G. #G	
16		8			236183		PLATE, CONNECTOR		
17		16			236184		RETAINER, DETECTOR		
18		1			236185		LENS, TRANSFER		
19		1			236186		ADAPTER, TRANS. LENS		
20		1			236187		RETAINER, TRANS. LENS		
21		1			236188		RING, LOCKING, " "		

PARTS LIST		 THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASS. 02139			CONTRACT NO.	CODE IDENT	PARTS LIST NO.	REV	SHEET NO.
FIND NO.	ZONE	DASH NO.		CODE IDENT	PART OR IDENT NO.	SYM	NOMENCLATURE/DESCRIPTION		REMARKS
		QUANTITY							
		-1							
22		1			236189		FOCAL PLANE ASS'Y		P/L 236189
23		1			236199		MIRROR ASS'Y, 2ND REDIE.		P/L 236199
24		1			236202		BAFFLE, LIGHT		
25		1			236203		SHIELD, UPPER		
26		1			236204		SHIELD, LOWER		
27		1			236205		SHIELD, L.H.		
28		1			236206		SHIELD, R.H.		
29		1			236207		SHIELD, FOR WARD		
30	131	1			236208		SHIELD, REAR		
31		1			236209		SLEEVE, HOLD-DOWN SCR		
32		4			236210		STAND-OFF, THERMAL		
33		4					DOWEL		.1253 DIA X.38 LG (CRES)
34		8					DOWEL		.1253 DIA X.31 LG (CRES)
35		50			MS21209-00615		INSERT, HELICAL COIL		*6-32 X 1 1/2 DIA LG (CRES)
36		127			MS21209-00415		INSERT, HELICAL COIL		*4-40 X 1 1/2 DIA LG (CRES)
37		36		HELI-COIL	1185-02CM-0129		INSERT, HELICAL COIL		*2-56 X 1 1/2 DIA LG (CRES)
38		4					SCREW, HEX SOC HD CAP		#10-32 X 3.00 LG (CRES)
39		18					SCREW, HEX SOC HD CAP		*6-32 X 1.00 LG (CRES)
40		26					SCREW, HEX SOC HD CAP		*6-32 X .50 LG (CRES)
41		6					SCREW, HEX SOC HD CAP		*6-32 X .38 LG (CRES)
42		24					SCREW, HEX SOC HD CAP		*4-40 X .25 LG (CRES)

[illegible]





SAMPLE OF SPECIES SPECIFIED CAPTIONED VALLEY AND PLANT LESTER VALLEY AND PLANT LESTER VALLEY AND PLANT LESTER VALLEY AND PLANT LESTER VALLEY AND PLANT		THE CHARLES STARK DRAPER LABORATORY, INC. CHEMISTS, MANASSAS, VIRGINIA	
MATERIAL ANALYSIS ANALYST: J. L. H. H. DATE: 10/1/67 (DO NOT SCALE THIS DRAWING)		COVER SHEET 10/1/67	
256172	DATE	DATE	DATE
NO. 1	NO. 2	NO. 3	NO. 4
NO. 5	NO. 6	NO. 7	NO. 8
NO. 9	NO. 10	NO. 11	NO. 12
NO. 13	NO. 14	NO. 15	NO. 16
NO. 17	NO. 18	NO. 19	NO. 20
NO. 21	NO. 22	NO. 23	NO. 24
NO. 25	NO. 26	NO. 27	NO. 28
NO. 29	NO. 30	NO. 31	NO. 32
NO. 33	NO. 34	NO. 35	NO. 36
NO. 37	NO. 38	NO. 39	NO. 40
NO. 41	NO. 42	NO. 43	NO. 44
NO. 45	NO. 46	NO. 47	NO. 48
NO. 49	NO. 50	NO. 51	NO. 52
NO. 53	NO. 54	NO. 55	NO. 56
NO. 57	NO. 58	NO. 59	NO. 60
NO. 61	NO. 62	NO. 63	NO. 64
NO. 65	NO. 66	NO. 67	NO. 68
NO. 69	NO. 70	NO. 71	NO. 72
NO. 73	NO. 74	NO. 75	NO. 76
NO. 77	NO. 78	NO. 79	NO. 80
NO. 81	NO. 82	NO. 83	NO. 84
NO. 85	NO. 86	NO. 87	NO. 88
NO. 89	NO. 90	NO. 91	NO. 92
NO. 93	NO. 94	NO. 95	NO. 96
NO. 97	NO. 98	NO. 99	NO. 100

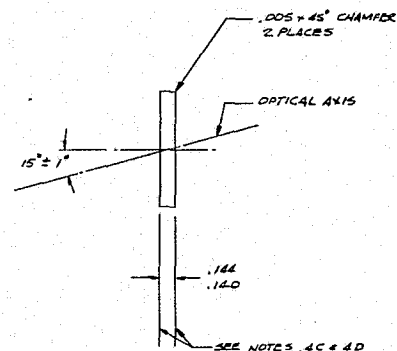
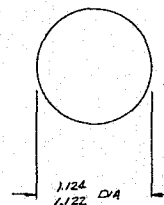
1. INTERFER DNG PER MIL-D-10327
2. SUPPLIER SHALL CONFORM TO QUALITY ASSURANCE PROVISIONS PER ND 1015406, CLASS 2
3. EDGES TO BE FINE GRIND
4. OPTICAL REQUIREMENTS PER MIL-D-13630
 - A. SURFACE QUALITY 40-20
 - B. CLEAR APERTURE, 1.000" DIA
 - C. BOTH SIDES POLISHED FLAT WITHIN $\frac{1}{4}$ " AT 5461 Å
 - D. BOTH SIDES PARALLEL WITHIN 0'-03"
 - E. TRANSMISSION PROPERTIES FOR PARALLEL

1. LIGHT ALONG OPTICAL AXIS
 2. CENTER WAVE LENGTH : SEE TABLE
 3. EFFECTIVE BAND WIDTH $100 \text{ \AA} \pm 1\%$
 4. PEAK TRANSMISSION : GREATER THAN 40%
 5. BAND PASS WALL SLOPE :
 - 10% TRANS. PT. : .98 TO 1.02
 - 50% TRANS. PT. : .98 TO 1.02
 6. TRANSMISSION AT ANY WAVE LENGTH OUTSIDE BAND PASS (FROM $3000 \text{ \AA}$ TO $10,000 \text{ \AA}$) LESS THAN 1%
 7. POLARIZATION OF TRANSMITTED BEAM SHALL NOT EXCEED 6%
45. DEFINED BY $\left(\frac{T_{\lambda} - T_{\lambda}}{T_{\lambda} + T_{\lambda}} \right) \times 100$

- ## 5. DESIGN REQUIREMENTS

- A. NO DIMMING OF MATERIALS SHALL BE EXPERIENCED AFTER EXPOSURE TO 100% RELATIVE HUMIDITY AT 20°C FOR 50 HOURS
- B. NO PHYSICAL OR OPTICAL DEGRADATION SHALL BE EXPERIENCED AFTER EXPOSURE TO A VACUUM OF 10^{-4} MM HG FOR 50 HOURS
- C. $\leq 5\%$ DEGRADATION IN EFF. BW & PEAK TRANSMISSION SHALL BE EXPERIENCED AFTER EXPOSURE TO A(n) INTEGRATED DOSE OF 10^4 RADS IONIZING RADIATION
- D. $\leq 5\%$ DEGRADATION IN EFF. BW & PEAK TRANSMISSION SHALL BE EXPERIENCED AFTER EXPOSURE TO SOLAR RADIATION OF ONE SUN FOR 30 HOURS
- E. OPERATING TEMPERATURE : 0°F TO 150°F TO BE DETERMINED

△



23676 - 8		△
↑ -7		△
-6		△
↑ -5	6000 ± 50	
-4	5000	↑
↑ -3	4000	
↓ -2	3500	↓
237176 - 1	3000 ± 50	
CENTER WAVELENGTH (Å)		

TABLE

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE 10% P RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES JAN 2 1 JUL 2 1 DO NOT SCALE THIS DRAWING MATERIAL		REVISION STATUS THE CHARLES STANLEY DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138	
CONTRACT NO.		DRAWN T. J. Dwyer, Jr. 11 Jan 77	
CHECKED		APPROVED	
APPROVED		APPROVED	
CRO. APPROVED		DATE	
APPROVED		DATE	
236170		SIZE D 51993 236170	
NEXT ASSEMBLY		SCALE 2/1	
APPLICATION		SHEET 1 OF 1	

THE CHARLES STARK DRAPER LABORATORY, INC.
CAMBRIDGE, MASSACHUSETTS, 02139

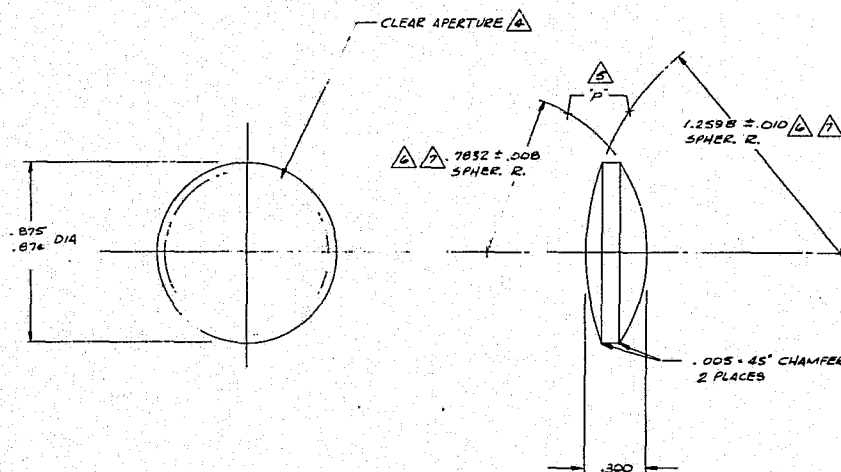
FILTER, LIGHT -
APPS

SIZE	CODE IDENT NO.	DRAWING NO.
D	51993	236176

SCALE 2/1

NOTES:

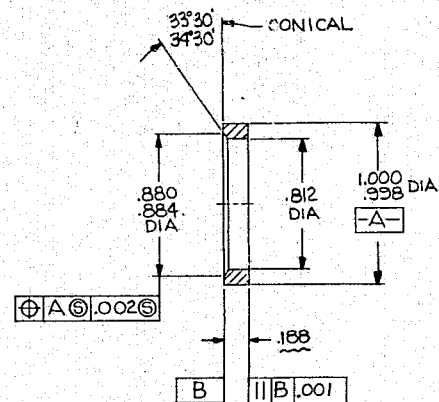
1. INTERPRET DWG PER MIL-D-1000 & MIL-D-70327
2. ELEMENT IN ACCORDANCE WITH MIL-D-13830 A
3. MATERIAL: UV GRADE FUSED SILICA
SOURCE: AMERIL, INC. - SUPRASIL GRADES.
DYNASTYL CORP. - UV NO. 1000
4. CLEAR APERTURE - 0.500" DIA
SURFACE QUALITY 40-20 OVER CLEAR APERTURE
CENTERING ERROR + 3 MIN, MAX
5. ALL SURFACES MARKED "P" POLISHED;
OTHERS FINE GROUND
6. IRREGULARITY OF POLISHED SURFACES TO BE
NO MORE THAN 1 WAVE AT 433 NM WAVE LENGTH
OVER THE CLEAR APERTURE
7. COAT POLISHED SURFACES WITH 1000 Å
OF MgF₂ PER MIL-C-675 A.



PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN P.P. RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCES ON		DECIMALS ANGLES DIA ± DO NOT SCALE THIS DRAWING	
MATERIAL		CONTACT NO. DRAWN BY CHECKED APPROVED DATE	
236/70 NEXT ASSEMBLY USED ON APPLICATION		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS 02139 LENS, FILTER- APPS SIZE CODE IDENT NO. DRAWING NO. D 51993 236/77 SCALE 4/11 SHEET 1 OF 1	

REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE



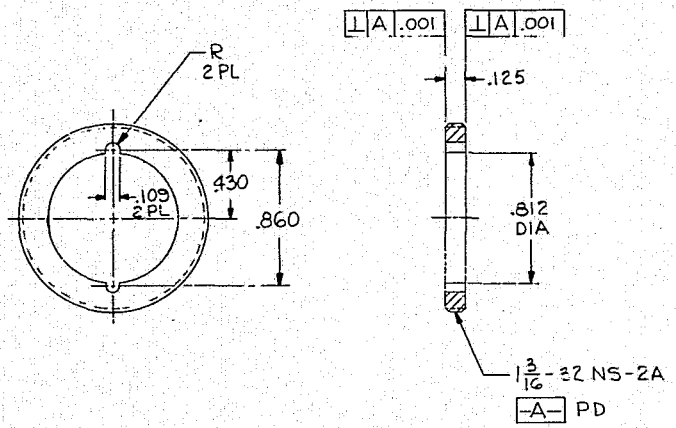
NOTES:

1. INTERPRET DWG PER MIL-D-1000
2. ~~3~~ FINISH ALL OVER
3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
4. FINISH: OPTICAL BLACK PER SPEC Δ
5. Δ TO BE DETERMINED

PART NO.
SEE PL

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON		CONTRACT NO.		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138	
		DECIMALS ANGLES XX ± .005 ±		DRAWN <i>Shannon</i> 5/10/76		RETAINER, FILTER LENS	
		DO NOT SCALE THIS DRAWING		CHECKED <i>Shannon</i>		APPS	
		MATERIAL		APPROVED		SIZE CODE IDENT NO. DRAWING NO. REV	
236170		AL 2024-T4 PER QQ-A-351		CSD APPROVED DATE		C 51993 236178	
NEXT ASSEMBLY USED ON		APPLICATION		APPROVED BY DIRECTION		SCALE 2/1 SHEET 1 OF 1	

REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE



NOTES:

1. INTERPRET DWG PER MIL-D-1000
2. $\sqrt{63}$ FINISH
3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
4. FINISH: OPTICAL BLACK PER SPEC $\triangle$ TO BE DETERMINED

PART NO.
SEE PL

236170 NEXT ASSEMBLY USED ON APPLICATION		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS .001 ANGLES .005 XXX $\pm$.005 $\pm$ — DO NOT SCALE THIS DRAWING MATERIAL CRES TYPE 303 PER QQ-5-763 COND A	CONTRACT NO. DRAWN <i>John</i> 10/25/76 CHECKED <i>✓</i> APPROVED CSDL APPROVED DATE APPROVED BY DIRECTION		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139 RING, LOCKING, FILTER LENS APPS	
			SIZE C CODE IDENT NO. 51993 SCALE 2/1	DRAWING NO. 236179 REV SHEET 1 OF		

DWG NO. 236179

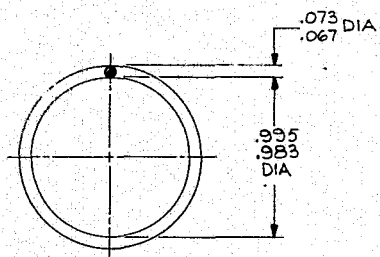
142

D

C

B

A



NOTES:

1. INTERPRET DWG PER MIL-D-100C
2. SOURCE: PARKER SEAL CO.
CULVER CITY, CALIF.
PART NO. 2-022 N-525-60

PART NO.
SEE PL

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES XXX ± ± DO NOT SCALE THIS DRAWING		CONTRACT NO.	
		MATERIAL		DRAWN <i>TD Mean</i> 10 NOV 1976	
				CHECKED	
				APPROVED	
				CSOL APPROVED DATE	
				APPROVED	
				BY DIRECTION	
236170				SIZE CODE IDENT NO. DRAWING NO. REV	
NEXT ASSEMBLY USED ON				C 51993 236180	
APPLICATION				SCALE 2/1 SHEET 1 OF 1	

THE CHARLES STANK DRAPER LABORATORY, INC.
CAMBRIDGE, MASSACHUSETTS, 02139O-RING
APPS

1 180

D

C

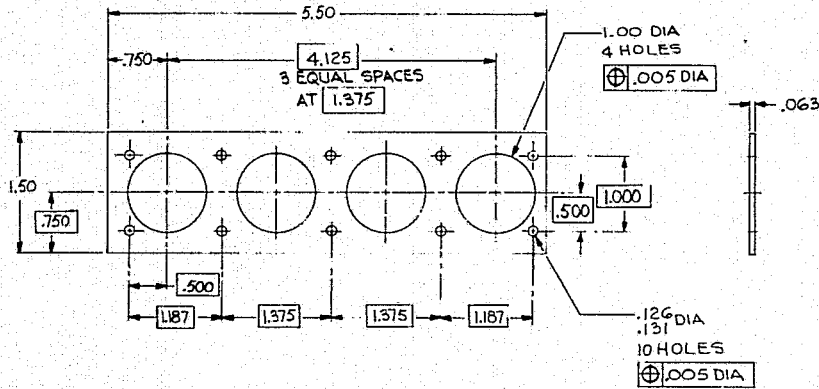
236180

B

A

4 3 2 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE



NOTES:

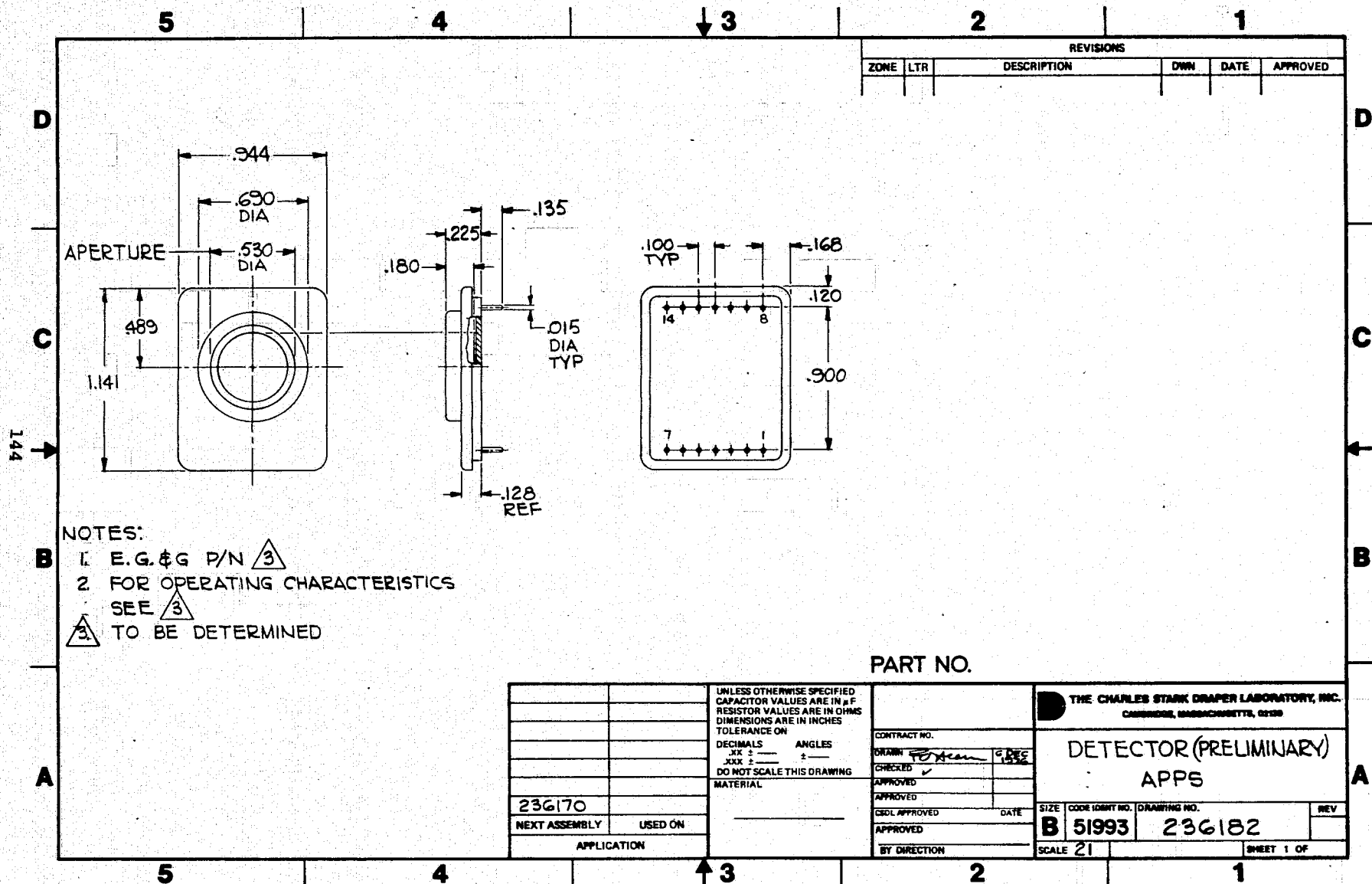
1. INTERPRET DWG PER MIL-D-1000
2. $\sqrt{\text{V}}$ FINISH
3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
4. FINISH: OPTICAL BLACK PER SPEC $\triangle$
5. $\triangle$ TO BE DETERMINED

PART NO.
SEE PL

236170 NEXT ASSEMBLY USED ON APPLICATION		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$.01 .XXX $\pm$.005 $\pm$ DO NOT SCALE THIS DRAWING MATERIAL AL 2024-T3 PER QQ-A-355	CONTRACT NO.		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
			DRAWN <i>F. H. H.</i> 28 OCT 1976		RETAINER, FILTER APPS	
			CHECKED ☒		SIZE CODE IDENT NO. DRAWING NO. REV	
			APPROVED ☐		C 51993 236181	
APPROVED ☐		DATE		SCALE 1/1 SHEET 1 OF		
APPROVED ☐		BY DIRECTION				

4 3 2 1

DWG NO. 236181





B

- # A

236170	
NEXT ASSEMBLY	USED ON
APPLICATION	

AL 2024-T351
PER QQ-A-250/4

THE CHARLES STARK DRAPER LABORATORY, INC.
CAMBRIDGE, MASSACHUSETTS, 02139

SIZE C	CODE IDENT NO. 51993	DRAWING NO. 236184	REV
SCALE 2/1			SHEET 1 OF

1. INTERPRET DWG. PER MIL-D-1000 & MIL-D-70327
2. ELEMENT IN ACCORDANCE WITH MIL-D-1383DA
3. MATERIAL: UV GRADE FUSED SILICA
SOURCE: AMERSIL, INC. - SUPRASIL GRADES.
DYNASYL CORP. - UV NO. 1000

4. CLEAR APERTURE - 0.850" DIA
SURFACE QUALITY 40-20 OVER CLEAR APERTURE
CENTERING ERROR - 3 MIN. MAX.

△ 5. SURFACES MARKED "P" TO BE POLISHED,
OTHERS FINE GROUND

△ IRREGULARITY OF POLISHED SURFACES TO BE NO MORE THAN 1 WAVE AT 633 NM WAVE LENGTH

7. OVER THE CLEAR APERTURE
COAT POLISHED SURFACES WITH 1000 Å

OF M₄F₂ PER MIL-C-675A
ASPHALTIC SURFACE IS DEFINED BY THE FORMULA:

$$E = \frac{C\rho^2}{(1 + \sqrt{1 - C^2\rho^2})} + D\rho^4 + E\rho^6 + F\rho^8 + G\rho^{10}$$

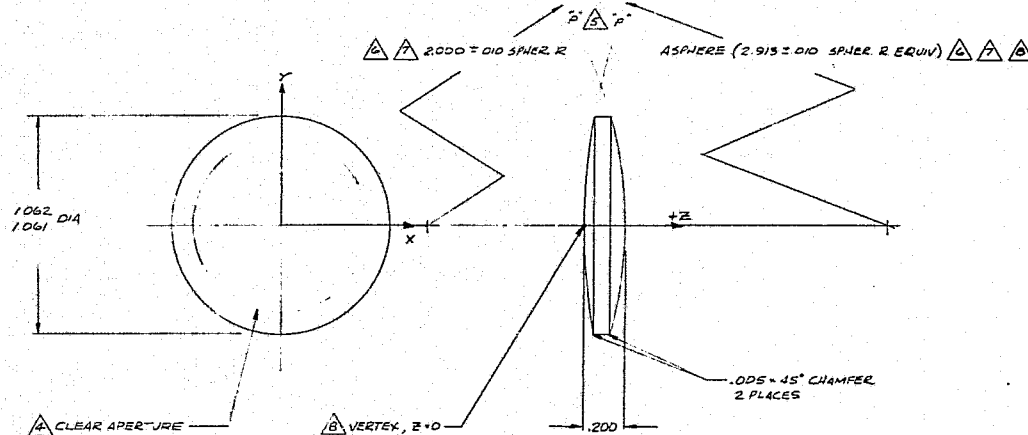
WHERE $z, \rho = 0$ AT VERTEX, $\rho^2 = x^2 + y^2$

 $C = 0.34526$

0. - 0.04747

 $\epsilon = 0.01659$
$$F = 0.17375$$
 $G = -0.10669$

COORDINATES TO BE TABULATED EVERY .005
INCHES BEFORE MANUFACTURING



PART NO.
SEE PL

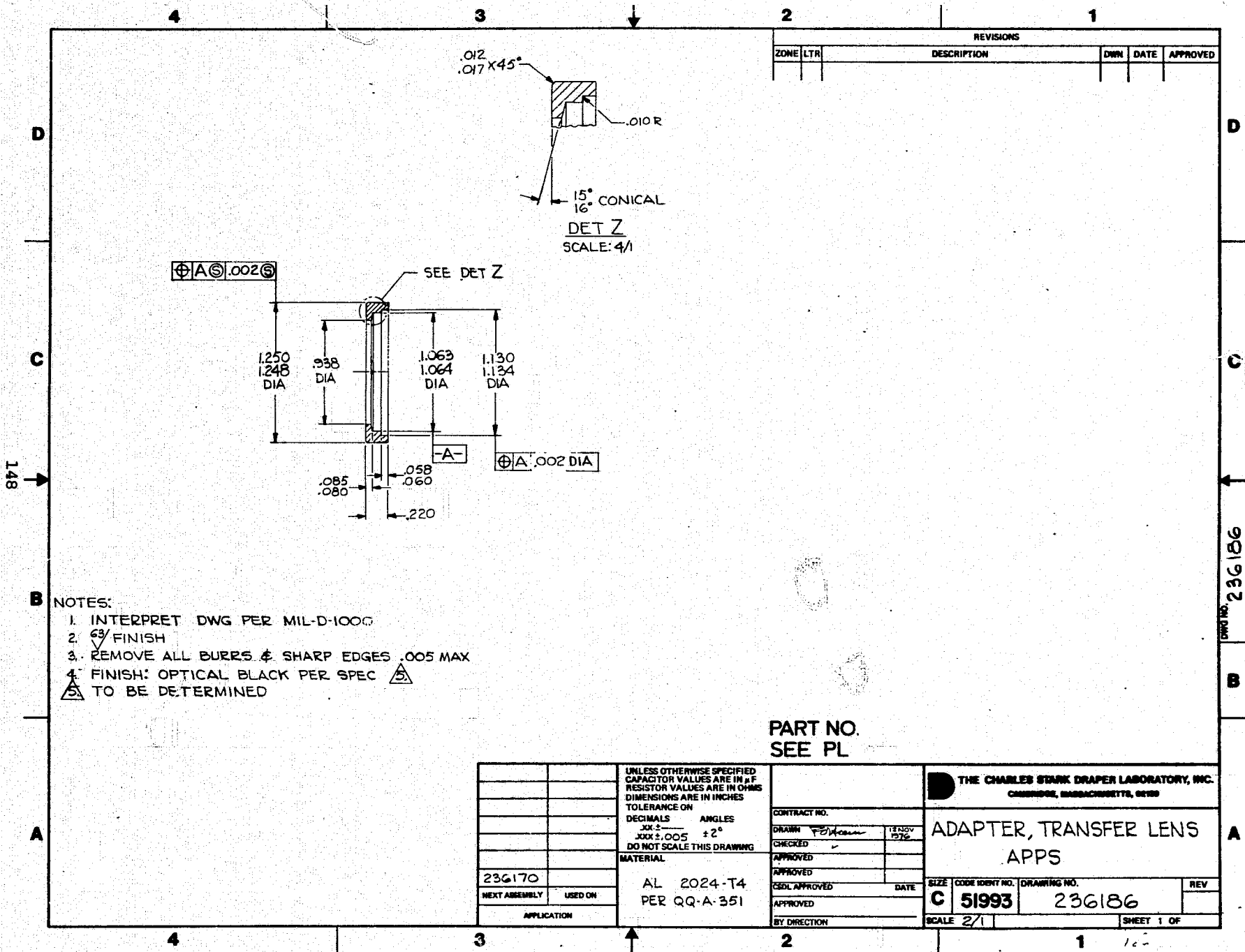
236170	
NEXT ASSEMBLY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
CAPACITOR VALUES ARE IN μ F
RESISTOR VALUES ARE IN OHMS
DIMENSIONS ARE IN INCHES
TOLERANCE ON
DECIMALS ANGLES
XX $\pm$.005 $\pm$
XXX $\pm$.005
DO NOT SCALE THIS DRAWING
MATERIAL



CONTRACT NO.	
DRAWN <i>T. ANDERSON</i>	11 JAN 1964
CHECKED	
APPROVED	
APPROVED	
CMDR APPROVED	DATE
APPROVED	
BY DIRECTOR	

REV				
SHEET				
REVISION STATUS				
D THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138 <i>LENS, TRANSFER - APPS</i>				
SIZE	Q302 IDENT NO.	DRAWING NO.	RE	
D	51993	236185		
SCALE 4/1			SHEET 1 OF	



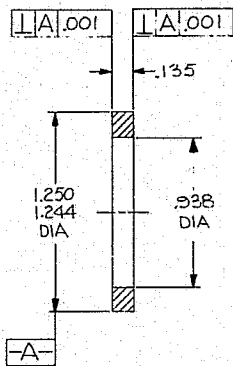
REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE

- NOTES:
1. INTERPRET DWG PER MIL-D-10000
 2. 63/ FINISH
 3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
 4. FINISH: OPTICAL BLACK PER SPEC $\triangle$ TO BE DETERMINED

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES XXX $\pm$.005 $\pm$ 2° DO NOT SCALE THIS DRAWING		THE CHARLES STANK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
MATERIAL AL 2024-T4 PER QQ-A-351		ADAPTER, TRANSFER LENS APPS	
CONTRACT NO. DRAWN <i>F. H. H. H.</i> CHECKED <i>✓</i> APPROVED <i>✓</i> CDL APPROVED <i>✓</i> APPROVED <i>✓</i> BY DIRECTION		SIZE CODE IDENT NO. DRAWING NO. REV C 51993 236186	
NEXT ASSEMBLY USED ON APPLICATION		SCALE 2/1 SHEET 1 OF 1	

REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE



NOTES:

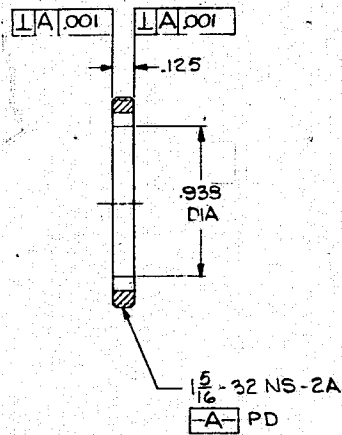
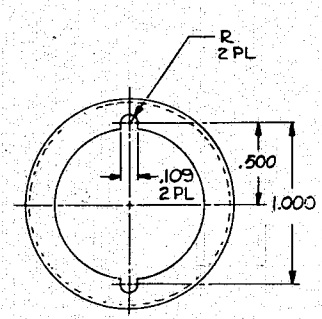
1. INTERPRET DWG PER MIL-D-1000
2. ~~63~~ FINISH
3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
4. FINISH: OPTICAL BLACK PER SPEC Δ
5. Δ TO BE DETERMINED

PART NO.
SEE PL

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$ $\pm$.XXX $\pm$ $\pm$ DO NOT SCALE THIS DRAWING		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
		MATERIAL		CONTRACT NO. DRAWN <i>W. Kern</i> 22 NOV 1976 CHECKED ☒ APPROVED ☐ CSOL APPROVED ☐ DATE ☐ APPROVED ☐ BY DIRECTION ☐	
236170		AL 2024-T4 PER QQ-A-268		RETAINER, TRANSFER LENS APPS	
NEXT ASSEMBLY USED ON		APPLICATION		SIZE CODE IDENT NO. DRAWING NO. REV C 51993 236187 SCALE 2/1 SHEET 1 OF 1	

DWG NO. 236187

REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE



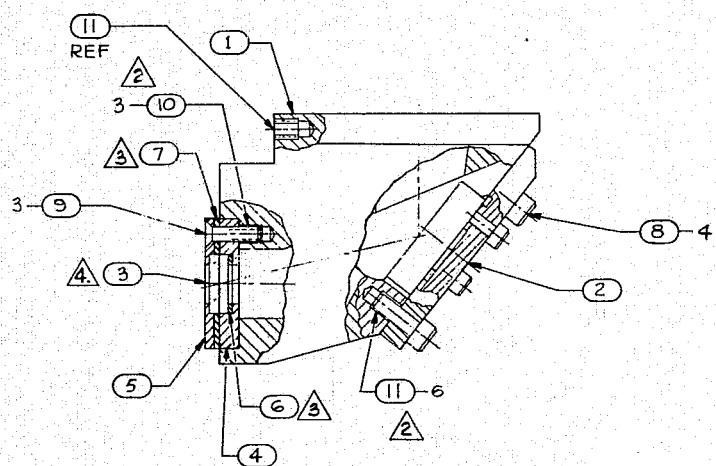
- NOTES:
- 1 INTERPRET DWG PER MIL-D-1000
 - 2 ∇ FINISH
 - 3 REMOVE ALL BURRS & SHARP EDGES .005 MAX
 - 4 FINISH: OPTICAL BLACK PER SPEC $\triangle$ 5
 - $\triangle$ 5 TO BE DETERMINED

PART NO.
SEE PL

236170 NEXT ASSEMBLY USED ON		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
		DECIMALS ANGLES .XXX $\pm$.005 $\pm$ DO NOT SCALE THIS DRAWING		CONTRACT NO. DRAWN <i>PD</i> 32 NOV 1976 CHECKED ☒ APPROVED ☐ APPROVED ☐ CSDL APPROVED ☐ DATE ☐ APPROVED ☐ BY DIRECTION ☐	
APPLICATION		MATERIAL CRES TYPE 303 PER QQ-S-763 COND A		RING, LOCKING, TRANSFER LENS APPS	
				SIZE CODE IDENTY NO. DRAWING NO. REV C 51993 236188	
				SCALE 2/1 SHEET 1 OF 1	

DWG NO. 236188

REVISIONS				
ZONE	LTR	DESCRIPTION	DWN	DATE



NOTES:

1. INTERPRET DWG PER MIL-D-1000

2 INSTALL (10) & (11) IN (1) PER MS33537. REMOVE TANGS

3 GRIND THICKNESS OF (6) & (7) TO SUIT

4 SLOT IN (3) TO BE PARALLEL TO TOP SURFACE OF (1)

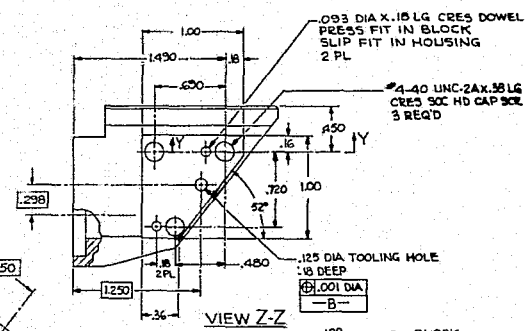
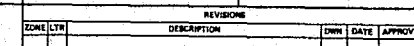
PART NO. 236189-1
SEE PL 236189

236170 NEXT ASSEMBLY USED ON APPLICATION		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$.XX $\pm$ DO NOT SCALE THIS DRAWING		CONTRACT NO. DRAWN <i>FD</i> 50 NOV 1976 CHECKED <i>FD</i> APPROVED CSOL APPROVED DATE APPROVED BY DIRECTION		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
		FOCAL PLANE ASSY APPS					
		SIZE C	CODE IDENT NO. 51993	DRAWING NO. 236189	REV		
		SCALE 2/1		SHEET 1 OF			

DWG NO. 236189

[illegible]

[illegible]



NOTES:

- 1 INTERPRET DWG PER MIL-D-1000
- 2 ~~59~~ FINISH
- 3 REMOVE ALL BURS & SHARP EDGES .005 MAX

 DO NOT INSTALL INSERTS AT THIS STAGE

 DO NOT REMOVE TOOLING HOLE UNTIL AFTER INSPECTION OF HOUSING

MAT'L: BERYLLIUM, OPTICAL GRADE-HIGH STRENGTH.

- 7 REMOVE OF OPERATIONS: 
- 8 FINISH: OPTICAL BLACK PER SPEC 

TO BE DETERMINED

[illegible]

4		3		2		1																																																	
				REVISIONS																																																			
				ZONE	LTR	DESCRIPTION	OWN	DATE	APPROVED																																														
NOTES: 1. INTERPRET DWG PER MIL-D-1000 2. INSTALL (3) IN (1) PER MS33537. REMOVE TANG																																																							
PART NO. 236191-1 SEE PL 236191																																																							
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2" style="text-align: center;">UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μF RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES</td> </tr> <tr> <td style="text-align: center;">TOLERANCE ON</td> <td style="text-align: center;">ANGLES</td> </tr> <tr> <td style="text-align: center;">.XX $\pm$</td> <td style="text-align: center;">$\pm$</td> </tr> <tr> <td style="text-align: center;">.XXX $\pm$</td> <td style="text-align: center;">$\pm$</td> </tr> <tr> <td colspan="2" style="text-align: center;">DO NOT SCALE THIS DRAWING</td> </tr> <tr> <td colspan="2" style="text-align: center;">MATERIAL</td> </tr> <tr> <td style="text-align: center;">236183</td> <td></td> </tr> <tr> <td style="text-align: center;">NEXT ASSEMBLY</td> <td style="text-align: center;">USED ON</td> </tr> <tr> <td colspan="2" style="text-align: center;">APPLICATION</td> </tr> </table>		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES		TOLERANCE ON	ANGLES	.XX $\pm$	$\pm$	.XXX $\pm$	$\pm$	DO NOT SCALE THIS DRAWING		MATERIAL		236183		NEXT ASSEMBLY	USED ON	APPLICATION		<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2" style="text-align: center;">CONTRACT NO.</td> </tr> <tr> <td style="text-align: center;">DRAWN</td> <td style="text-align: center;">DATE</td> </tr> <tr> <td style="text-align: center;">CHECKED</td> <td style="text-align: center;">DATE</td> </tr> <tr> <td style="text-align: center;">APPROVED</td> <td style="text-align: center;">DATE</td> </tr> <tr> <td style="text-align: center;">CSDL APPROVED</td> <td style="text-align: center;">DATE</td> </tr> <tr> <td colspan="2" style="text-align: center;">BY DIRECTION</td> </tr> </table>		CONTRACT NO.		DRAWN	DATE	CHECKED	DATE	APPROVED	DATE	CSDL APPROVED	DATE	BY DIRECTION		<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="4" style="text-align: center;">THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139</td> </tr> <tr> <td colspan="4" style="text-align: center;">MIRROR ASS'Y, 1ST REDIR. APPS</td> </tr> <tr> <td style="text-align: center;">SIZE</td> <td style="text-align: center;">CODE IDENT NO.</td> <td style="text-align: center;">DRAWING NO.</td> <td style="text-align: center;">REV</td> </tr> <tr> <td style="text-align: center;">C</td> <td style="text-align: center;">51993</td> <td style="text-align: center;">236191</td> <td style="text-align: center;"></td> </tr> <tr> <td colspan="2" style="text-align: center;">SCALE 2/1</td> <td colspan="2" style="text-align: center;">SHEET 1 OF</td> </tr> </table>		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139				MIRROR ASS'Y, 1ST REDIR. APPS				SIZE	CODE IDENT NO.	DRAWING NO.	REV	C	51993	236191		SCALE 2/1		SHEET 1 OF	
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SIZE	CODE IDENT NO.	DRAWING NO.	REV																																																				
C	51993	236191																																																					
SCALE 2/1		SHEET 1 OF																																																					

[illegible]

[illegible]

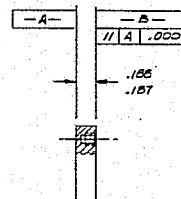


MATERIAL: ONE OF THE FOLLOWING MAY BE USED:

- A. BERYLLIUM OPTICAL GRADE I TO A - BEISH WELLMAN, INC, FARFIELD, N.J.
B. BERYLLIUM GRADE HPB1 - KAWECKI BERYLCO INDUSTRIES, HAZELTON, PA.

2 ORDER OF OPERATION:

1. MACHINE AS REQ'D CRITICAL DIMENSIONS TO .0010/0.020 OF FINISHED PART
 A. STRESS RELIEVE AT 1450°F $\pm$ 25°F FOR 1 HOUR $\pm$ 5 MIN IN VACUUM OR OTHER PROTECTIVE ATMOSPHERE. COOL TO 700°F AT A RATE NOT TO EXCEED 100°F/HR; COOL IN STILL AIR FROM 700°F TO ROOM TEMP.
 (VACUUM OR OTHER PROTECTIVE ATMOSPHERE NOT NEEDED BELOW 700°F)
 C. FINISH MACHINE
 D. STABILIZE AT 200°F $\pm$ 10°F AND HOLD FOR 10 MIN $\pm$ 1 MIN. COOL TO ROOM TEMP. AND HOLD FOR 10 MIN $\pm$ 1 MIN; COOL TO -100°F $\pm$ 10°F AND HOLD FOR 10 MIN $\pm$ 1 MIN. REPEAT STABILIZING PROCEDURE FOR ATOTAL OF 5 CYCLES.
 E. SURFACES -A & -B TO BE ELECTROLESS NICKEL COATED
 PER MIL-C-32074 CLASS 2, 100%/100 THICK. ALL OTHER SURFACES OPTIONAL.
 F. ORDER OF OPERATIONS OF THIS NOTE OPTIONAL
 1. INSTALL HELICAL COIL INSERTS
 2. PERFORM FINISH OPERATIONS TO SURFACES -A, -B-AS REQ'D PER NOTES & THROUGH
 3. NICKEL COATING SHALL NOT BE REDUCED TO LESS THAN .001 THICK
 4. REPEAT STABILIZATION CYCLES PER NOTE 2 D. FOLLOWING EACH FINISHING OPERATION OR SEQUENCE UNTIL DIMENSIONAL STABILITY IS ACHIEVED.
 REFERENCE -A TO BE ALUMINIZED PER MIL-M-13508; PROTECTIVE COATING SHALL BE MgF₂ 100nm $\pm$ 25 nm THICK OVER CLEAR APERTURE
 SURFACE -A TO BE FLAT TO $\frac{1}{4}$ λ AT 633 nm OVER THE CLEAR APERTURE
 SURFACE IRREGULARITY OF SURFACE -A- SHALL BE $\leq \frac{1}{2}$ λ AT 633 nm OVER THE CLEAR APERTURE
 SURFACE QUALITY OF SURFACE -A- TO BE 40/20 PER MIL-D-13830 OVER THE CLEAR APERTURE
 SURFACE REFLECTANCE OF SURFACE -A- AT 45° ANGLE OF INCIDENCE SHALL BE NO LESS THAN 86 % FROM 300 TO 1000 nm WAVE LENGTH
 SURFACE APERTURE OF SURFACE -A- IS CIRCULAR WITH DIA. $\pm$.025 IN. & DIMENSIONS APPLY AFTER COATING
 INTERPRET DNG PER MIL-D-1000



THD FOR #2-56 UNC-2B
HELICOIL INSERT
#1185-02CN-0086
PER MS 33537
(FLAT BOTTOM TAP DRILL-
DO NOT BREAK THEM)
3 HOLES EQUALLY SPACED
ON A .500 DIA BC

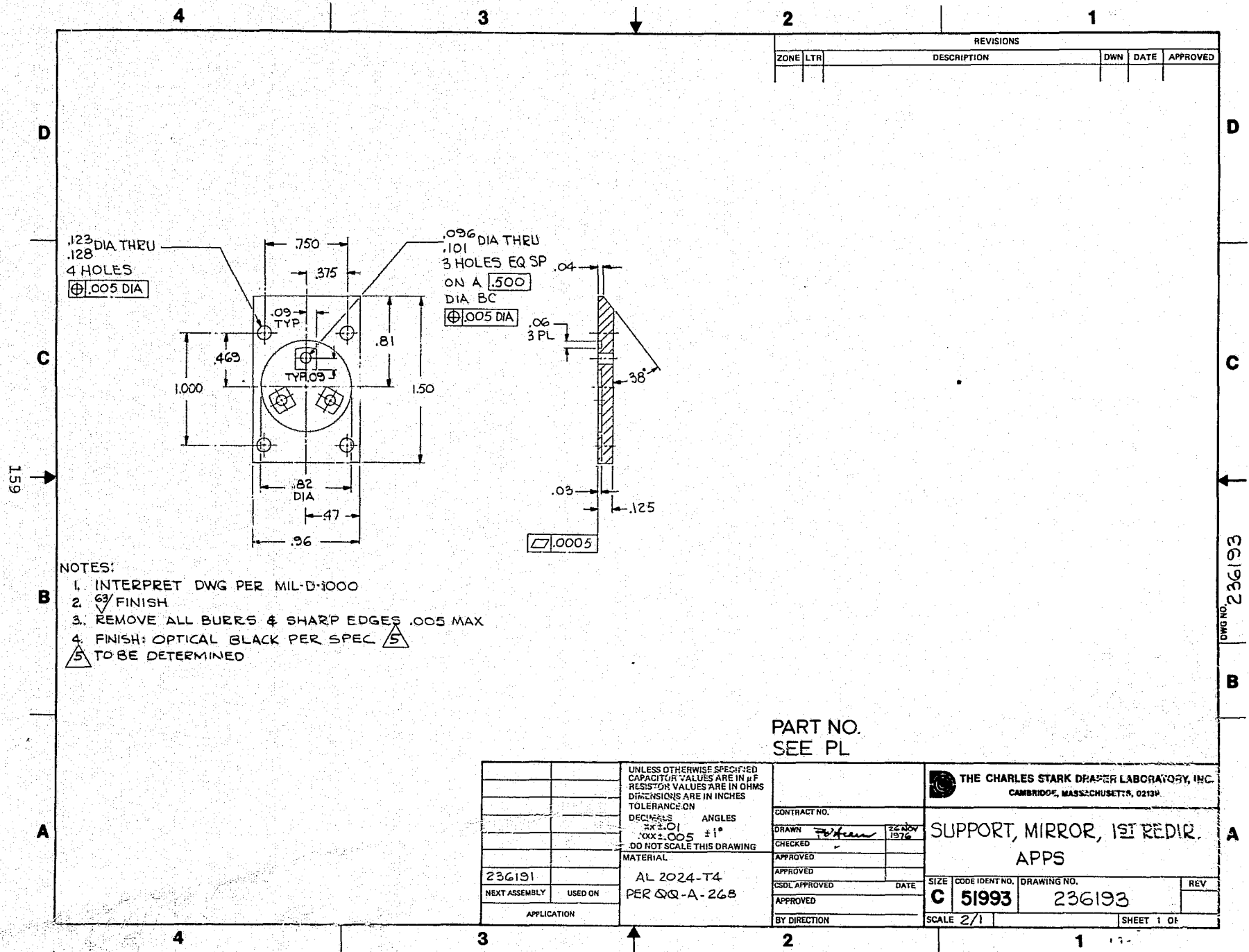
△ CLEAR APERTURE

PART NO.
SEE PL

	UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS XIN 2 — 2 — XIN 2 .005 DO NOT SCALE THIS DRAWING MATERIAL
236191	
NEXT ASSEMBLY	USED ON
APPLICATION	

CONTRACT NO.	
ORIGIN <i>T. Anderson</i>	DATE
CHECKED	
APPROVED	
APPROVED	
CSOL APPROVED	DATE
APPROVED	

REV									
SHEET									
REVISION STATUS									
THE CHARLES STARK DRAPER LABORATORY, INC.									
CAMBRIDGE, MASSACHUSETTS 02139									
MIRROR, 1 1/2 REDIR.									
APPS									
SIZE	COLOR IDENT NO.	DRAWING NO.					REV		
D	51993	236192							
SCALE 2/1				SHEET 1 OF					

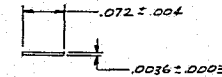


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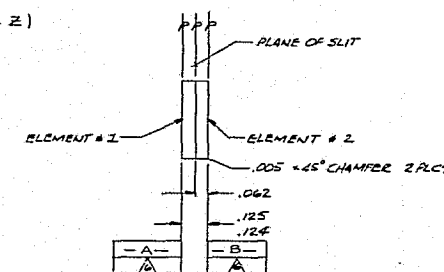
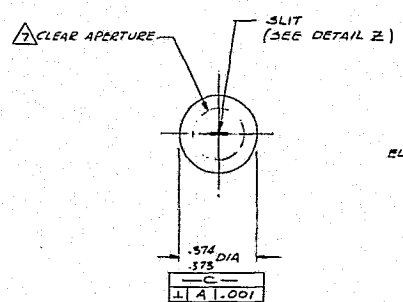
REVISIONS			
ZONE	LTN	DESCRIPTION	OWN DATE APPROVED

NOTES:

1. INTERPRET DWG PER MIL-D-1000 & MIL-D-70127
2. ELEMENT IN ACCORDANCE WITH MIL-D-15830 A
3. MATERIAL: ELEMENTS #1 & 2 UNGRADE FUSED SKKA
SOURCE: AMRESIL, INC. - SUPRASEL GRADES
DYNASIL CORP. - UN NO. 1000
COATING: CHROMIUM, NICKEL CHROMIUM,
OR ALUMINUM
4. SURFACES MARKED "P" POLISHED; ALL OTHERS
FINE GRIND, BLACK COATING OPTIONAL
5. SURFACE QUALITY OF -A- & -B- TO BE 20-40
OVER THE CLEAR APERTURE
6. SURFACES -A- & -B- TO BE PARALLEL AFTER CEMENTING
WITHIN 15 ARC MINUTES AND FLAT TO $\frac{1}{2}$ X AT 633nm WAVELENGTH
OVER THE CLEAR APERTURE
7. CLEAR APERTURE = 0.250 DIA
8. SLIT TO BE PRODUCED ON ELEMENT 1 BY REMOVAL OF
DEPOSITED METAL COATING AND FREE OF SCRATCHES
AND DIGS. BLACK OXIDE METAL COATING BEFORE
CEMENTING TO ELEMENT 2. TRANSMITTANCE OF
FINISHED PART WITHIN CLEAR APERTURE, BUT
OUTSIDE SLIT DIMENSIONS SHALL NOT EXCEED
2% OF SLIT TRANSMITTANCE
9. SURFACES -A- & -B- TO BE PROTECTIVE COATED WITH MgF_2 ,
100nm THICK; DURABILITY PER MIL-C-675A
10. FINISHED PART TO SATISFY REQ'S OF NOTE 3
WHEN OPERATED FROM 0° TO 150° F WITHOUT
SEPARATION OF SUBSTRATES



DETAIL Z
(SLIT DIMENSIONS)
SCALE 10/1



PART NO.
SEE PL

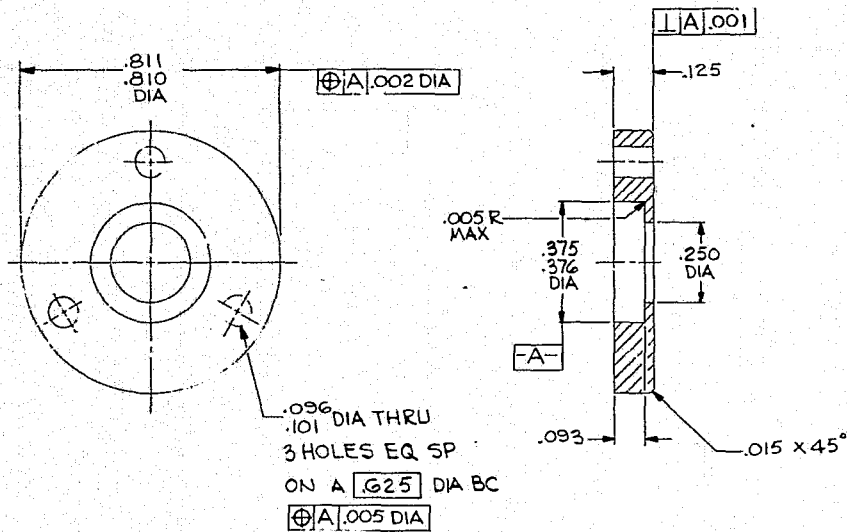
UNLESS OTHERWISE SPECIFIED: DIMENSIONAL VALUES ARE IN INCHES TOLERANCE ON DECIMALS ANGLES ±.005 ±.0005 DO NOT SCALE THIS DRAWING		CONTRACT NO. DRAWN BY CHECKED APPROVED DATE BY	
MATERIAL 236/90 HEAT TREATMENT APPLICATION		DATE	
THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138		ELEMENT, FOCAL PLANE - APPS	
SIZE D 51993		DRAWING NO. 236194	
SCALE 8/1		SHEET 1 OF 1	

160

A

8 7 6 5 4 3 2 1

REVISIONS			
ZONE	LTR	DESCRIPTION	DWN DATE APPROVED



NOTES:

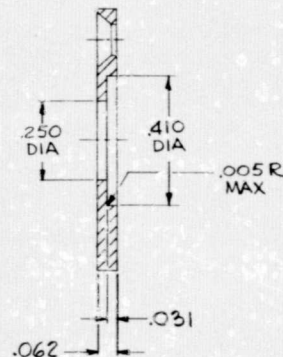
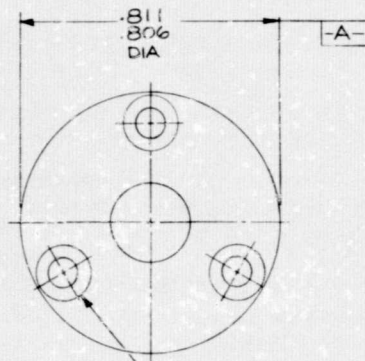
1. INTERPRET DWG PER MIL-D-1000
2. $\sqrt{63}$ FINISH
3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
4. FINISH: OPTICAL BLACK PER SPEC Δ S
5. TO BE DETERMINED

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES .XX $\pm$.005 $\pm$ 2° XXX $\pm$.005 $\pm$ 2° DO NOT SCALE THIS DRAWING		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02138	
MATERIAL AL 2024-T4 PER QQ-A-268		CONTRACT NO. DRAWN <i>Edman</i> 12/15/76 CHECKED <i>✓</i> APPROVED CSOL APPROVED APPROVED BY DIRECTION	
236189 NEXT ASSEMBLY USED ON APPLICATION		HOUSING, ELEMENT APPS SIZE CODE IDENT NO. DRAWING NO. REV C 51993 236195 SCALE 4/1 SHEET 1 OF	

DWG NO. 236195

REVISIONS			DWN	DATE	APPROVED
ZONE	LTR	DESCRIPTION			



.096 DIA THRU
.101 CSK .172 DIA 82°
.170 DIA 80°
3 HOLES EQ SP
ON A .625 DIA BC
ΦA .005 DIA

NOTES:

1. INTERPRET DWG PER MIL-D-1000
2. ~~63~~ FINISH
3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
4. FINISH: OPTICAL BLACK PER SPEC 5
5. TO BE DETERMINED

PART NO.
SEE PL

236189 NEXT ASSEMBLY USED ON APPLICATION		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES XX ± XXX ± .005 ± DO NOT SCALE THIS DRAWING MATERIAL AL 2024-T4 PER QQ-A-268		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
				CONTRACT NO.	
				DRAWN <i>[Signature]</i> 25 APR 1976 CHECKED ☒ APPROVED ☐ APPROVED ☐ CSDL APPROVED ☐ DATE APPROVED ☐ BY DIRECTION	
				RETAINER, ELEMENT APPS	
SIZE CODE IDENT NO DRAWING NO. REV C 51993 236196		SCALE 4/1 SHEET 1 OF			

DWG NO. 236196

4		3		2		1	
				REVISIONS			
ZONE	LTR	DESCRIPTION		OWN	DATE	APPROVED	

Technical drawing of a shim. Dimensions shown: .045, .040, .374 DIA, .372 DIA, .250 DIA.

NOTES:

1. INTERPRET DWG PER MIL-D-1000
2. ☒ FINISH
3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
4. FINISH: OPTICAL BLACK PER SPEC ☒ 5
5. TO BE DETERMINED

PART NO.
SEE PL

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES XX $\pm$.005 $\pm$ — DO NOT SCALE THIS DRAWING		MATERIAL	
236189		AL 2024-T4	
NEXT ASSEMBLY	USED ON	PER QQ-A-268	
APPLICATION			

THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
CONTRACT NO.	
DRAWN	22 NOV 1976
CHECKED	
APPROVED	
CSDL APPROVED	DATE
APPROVED	
BY DIRECTION	

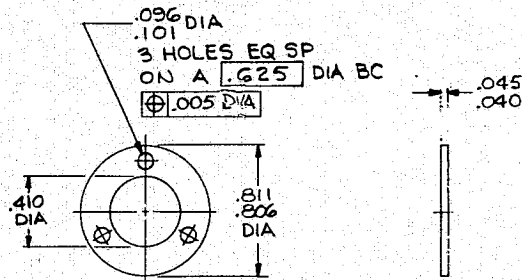
SIZE	CODE IDENT NO.	DRAWING NO.	REV
C	51993	236197	
SCALE 4/1		SHEET 1 OF 1	

DWG NO. 236197

B

A

REVISIONS							
ZONE	LTR	DESCRIPTION			DWN	DATE	APPROVED



NOTES:

1. INTERPRET DWG PER MIL-D-1000
2. $\sqrt{63}$ FINISH
3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
4. FINISH: OPTICAL BLACK PER SPEC $\triangle$
5. TO BE DETERMINED

PART NO.
SEE PL

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON		CONTRACT NO.		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS 02139	
		DECIMALS ANGLES XX $\pm$ $\pm$ XXX $\pm$ $\pm$		DRAWN <i>[Signature]</i> 25120V 1976		SHIM, OUTER APPS	
		DO NOT SCALE THIS DRAWING		CHECKED ☒		SIZE CODE IDENT NO. DRAWING NO. REV	
		MATERIAL		APPROVED		C 51993 236198	
236189		AL 2024-T4 PER QQ-A-268		APPROVED		SCALE 2/1 SHEET 1 OF	
NEXT ASSEMBLY USED ON				DATE			
APPLICATION				BY DIRECTION			

DWG NO. 236198

A

198

4		3		2		1	
				REVISIONS			
ZONE	LTR	DESCRIPTION		DWN	DATE	APPROVED	

165

NOTES:

1. INTERPRET DWG PER MIL-D-1000

2. INSTALL (3) IN (1) PER MS33537. REMOVE TANG

PART NO. 236199-1
SEE PL 236199

UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON	
DECIMALS	ANGLES
.XX ±	±
.XXX ±	±
DO NOT SCALE THIS DRAWING	
MATERIAL	
236170	
NEXT ASSEMBLY	USED ON
APPLICATION	

THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
CONTRACT NO.	
DRAWN	12 NOV 1976
CHECKED	
APPROVED	
CSOL APPROVED	DATE
APPROVED	
BY DIRECTION	

MIRROR ASS'Y, 2ND REDIR APPS	
SIZE	CODE IDENT NO.
C 51993	236199
SCALE	2/1
SHEET 1 OF 1	

[illegible]

1

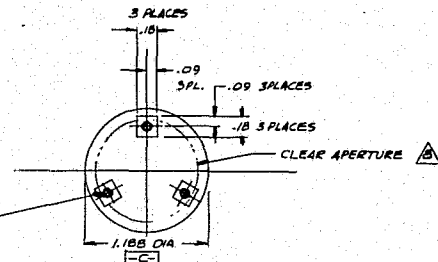
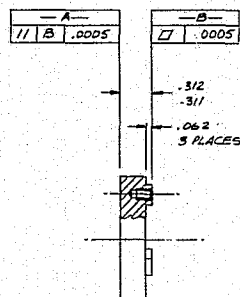
MATERIAL: ONE OF THE FOLLOWING MAY BE USED:

- A. BERYLLIUM OPTICAL GRADE ITOA - BRUSH WELLMAN INC, FAIRFIELD, N.J.
B BERYLLIUM GRADE HP 81- KANECKI BERYLCO INDUSTRIES, HAZELTON, PA.

2. ORDER OF OPERATION

- A. MACHINE AS RECD CRITICAL DIMENSIONS TO DIM. OF FINISHED PART
B. STRESS RELIEVE AT $1650^{\circ}\text{F} \pm 25^{\circ}\text{F}$ FOR 1 HOUR $\pm 5\text{MIN}$ IN VACUUM OR
OTHER PROTECTIVE ATMOSPHERE. COOL TO 700°F AT A RATE NOT TO EXCEED
 $100^{\circ}\text{F}/\text{HR}$; COOL IN STILL AIR FROM 700°F TO ROOM TEMP.
(VACUUM OR OTHER PROTECTIVE ATMOSPHERE NOT NEEDED BELOW 700°F)
C. FINISH MACHINE.
D. STABILIZE AT $200^{\circ}\text{F} \pm 10^{\circ}\text{F}$ AND HOLD FOR $10\text{MIN} \pm 1\text{MIN}$. COOL TO ROOM
TEMP AND HOLD FOR $10\text{MIN} \pm 1\text{MIN}$; COOL TO $-100^{\circ}\text{F} \pm 10^{\circ}\text{F}$ AND HOLD FOR $10\text{MIN} \pm 1\text{MIN}$.
REPEAT STABILIZING PROCEDURE FOR A TOTAL OF 5 CYCLES
E. SURFACES A-A-B TO BE ELECTROLESS NICKEL COATED
PER MK-C-24074 CLASS 2, .004/.006 THICK. ALL OTHER SURFACES OPTIONAL
F. ORDER OF OPERATIONS OF THIS NOTE OPTIONAL
1. INSTALL HELICAL COIL INSERTS
2. PERFORM FINISH OPERATIONS TO SURFACES A-A-B-A-S REQ'D PER NOTES 1 & THRU 6
3. NICKEL COATING SHALL NOT BE REDUCED TO LESS THAN .001 THICK
4. REPEAT STABILIZATION CYCLES PER NOTE 2 FOLLOWING EACH
FINISHING OPERATION OR SEQUENCE UNTIL DIMENSIONAL
STABILITY IS ACHIEVED

3. SURFACE -A- TO BE ALUMINIZED PER MIL-M-13508; PROTECTIVE COATING SHALL BE MgF_2 100 μ m $\pm$ 25% THICK OVER CLEAR APERTURE
4. SURFACE -A- TO BE FLAT TO $\frac{1}{4}$ λ AT 633 nm OVER THE CLEAR APERTURE
5. SURFACE IRREGULARITY OF SURFACE -A- SHALL BE $\frac{1}{2}$ λ AT 633 nm OVER THE CLEAR APERTURE
6. SURFACE QUALITY OF SURFACE -A- TO BE 40/20 PER MIL-D-13530 OVER THE CLEAR APERTURE
7. SPECULAR REFLECTANCE OF SURFACE -A- AT 45° ANGLE OF INCIDENCE SHALL BE NO LESS THAN 88 % FROM 300 TO 1000 nm WAVE LENGTH CLEAR APERTURE OF SURFACE -A- IS CIRCULAR WITH DIA = 1.000 IN.
8. ALL DIMENSIONS APPLY AFTER COATING
9. INTERPRET DNG PER MIL-D-1000

[illegible]

THD FOR #2-56 UNC-2B
HELICOIL INSERT
#1185-DZCN-0129
PER M3 33537 (BOTTOM TAP)
3 HOLES EQ SP
ON A .876 DIA BC
⊕ C .005 DIA

PART NO.
SEE PL

236/99	
NEXT ASSEMBLY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
CAPACITOR VALUES ARE IN pF
RESISTOR VALUES ARE IN OHMS
DIMENSIONS ARE IN INCHES
TOLERANCE ON
DECIMALS ANGLES
XX ± .01 ± —
XXX ± .005
DO NOT SCALE THIS DRAWING
MATERIAL



CONTRACT NO.	
DRAWN <i>TANDERSON</i>	7. ANT
CHECKED	
APPROVED	

APPROVED	
CDL APPROVED	DATE
APPROVED	

BY ORIGINATOR

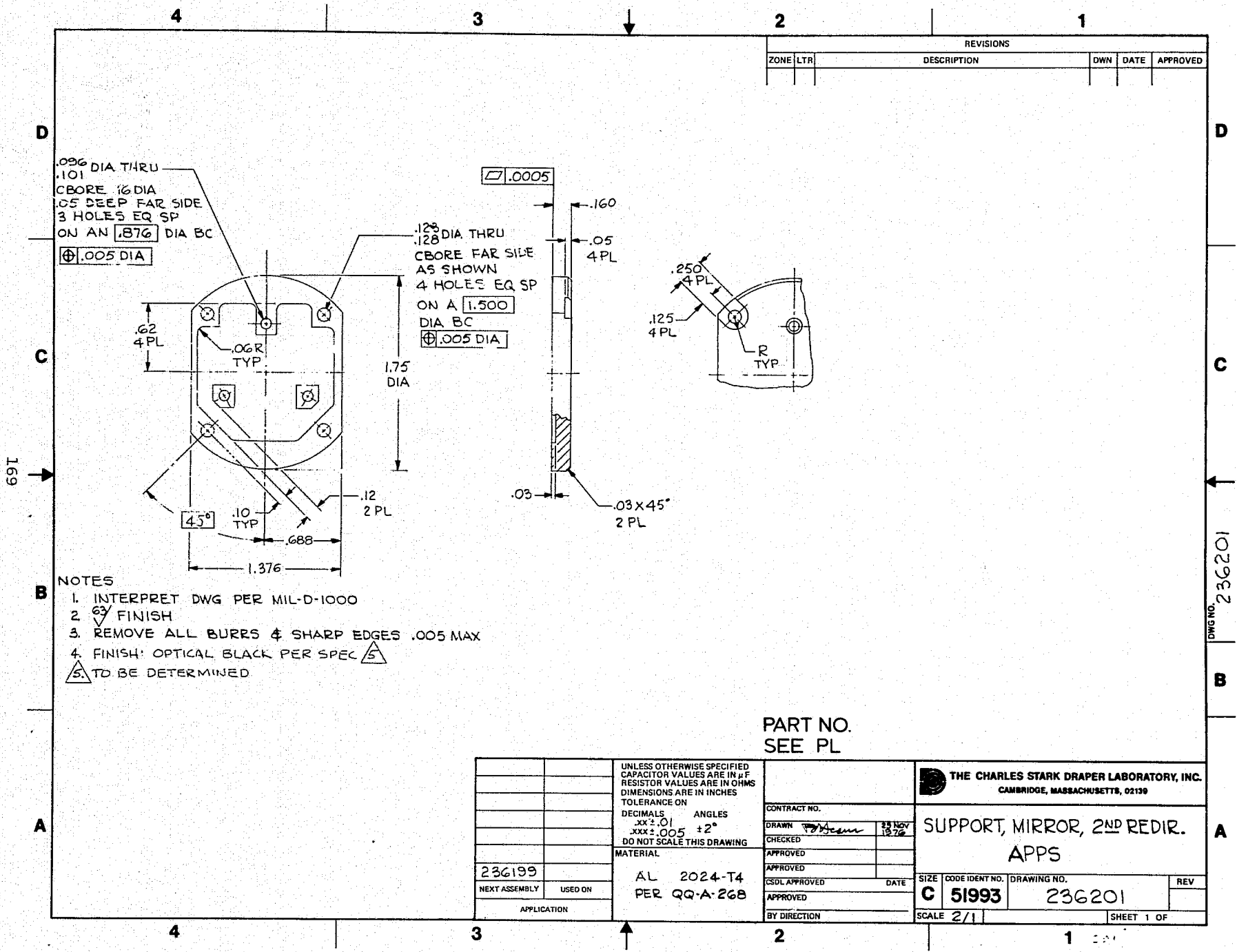
REV									
SHEET									
REVISION STATUS									
THE CHARLES STANK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139									
MIRROR, 2" REDIR. APPS									
SIZE	CODE IDENT NO.	DRAWING NO.					RE		
D	51993	.236200							
SCALE 2/1				SHEET 1 OF					

MIRROR, 2ND REDIR.
APPS

SIZE	QCODE IDENT NO.
D	51993

ING NO. 236200

SCALE 2/1	SHEET 1 OF 1
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.096 DIA THRU
.101
CBORE 1/6 DIA
.05 DEEP FAR SIDE
3 HOLES EQ SP
ON AN .876 DIA BC
Ⓢ.005 DIA

.128 DIA THRU
CBORE FAR SIDE
AS SHOWN
4 HOLES EQ SP
ON A 1.500
DIA BC
Ⓢ.005 DIA

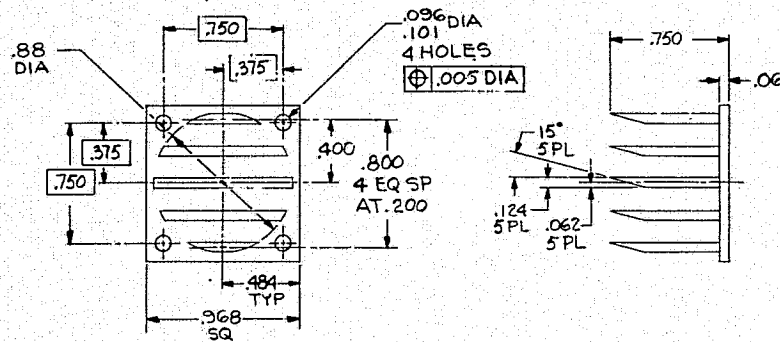
.250
4 PL
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4 PL
R
TYP

- NOTES
- 1. INTERPRET DWG PER MIL-D-1000
 - 2. $\sqrt{}$ FINISH
 - 3. REMOVE ALL BURRS & SHARP EDGES .005 MAX
 - 4. FINISH: OPTICAL BLACK PER SPEC $\triangle$ 5
 - 5. TO BE DETERMINED

PART NO.
SEE PL

		UNLESS OTHERWISE SPECIFIED CAPACITOR VALUES ARE IN μ F RESISTOR VALUES ARE IN OHMS DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS ANGLES xx1.01 .xxx $\pm$.005 $\pm$ 2° DO NOT SCALE THIS DRAWING		CONTRACT NO.		THE CHARLES STARK DRAPER LABORATORY, INC. CAMBRIDGE, MASSACHUSETTS, 02139	
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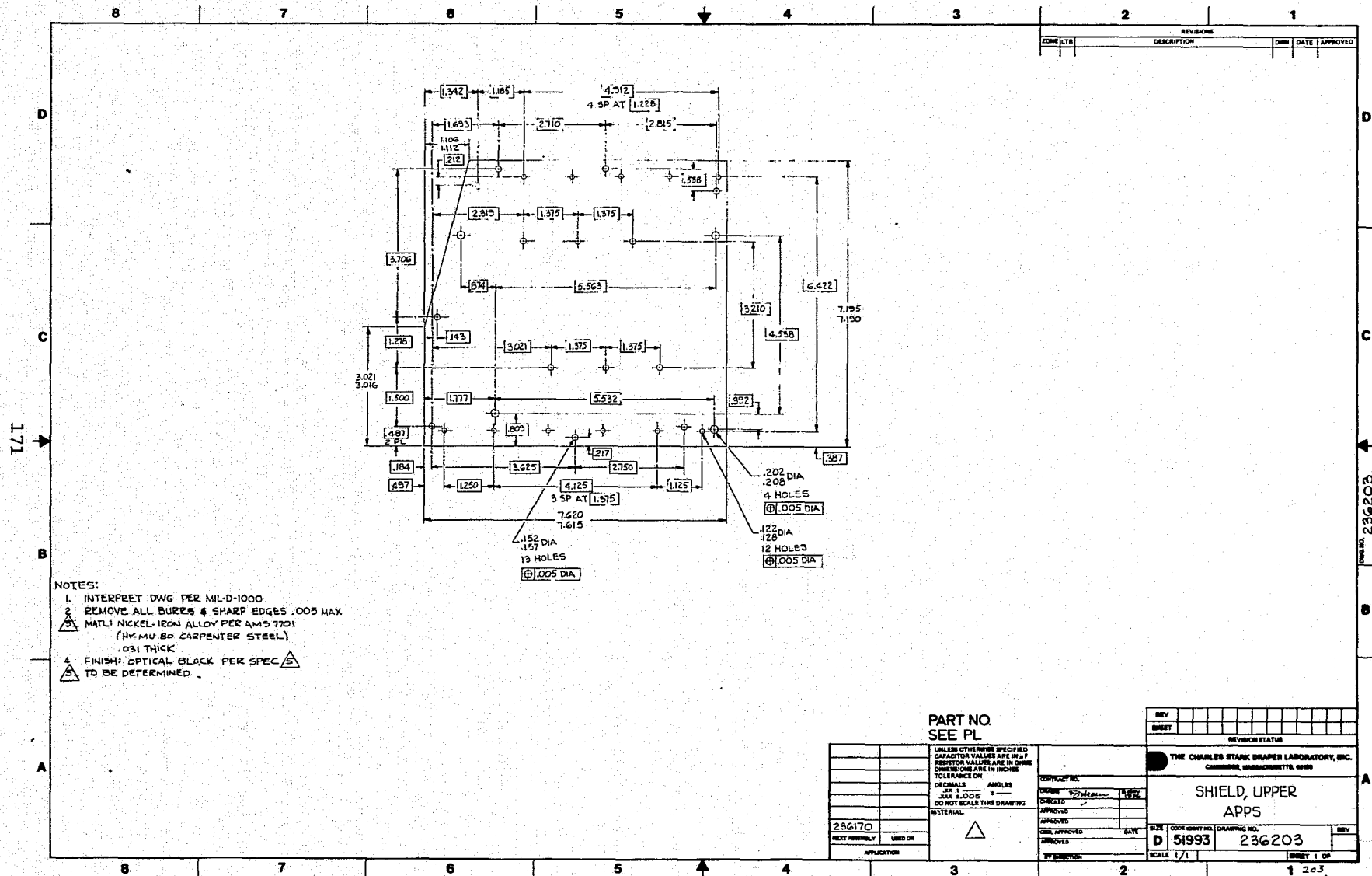
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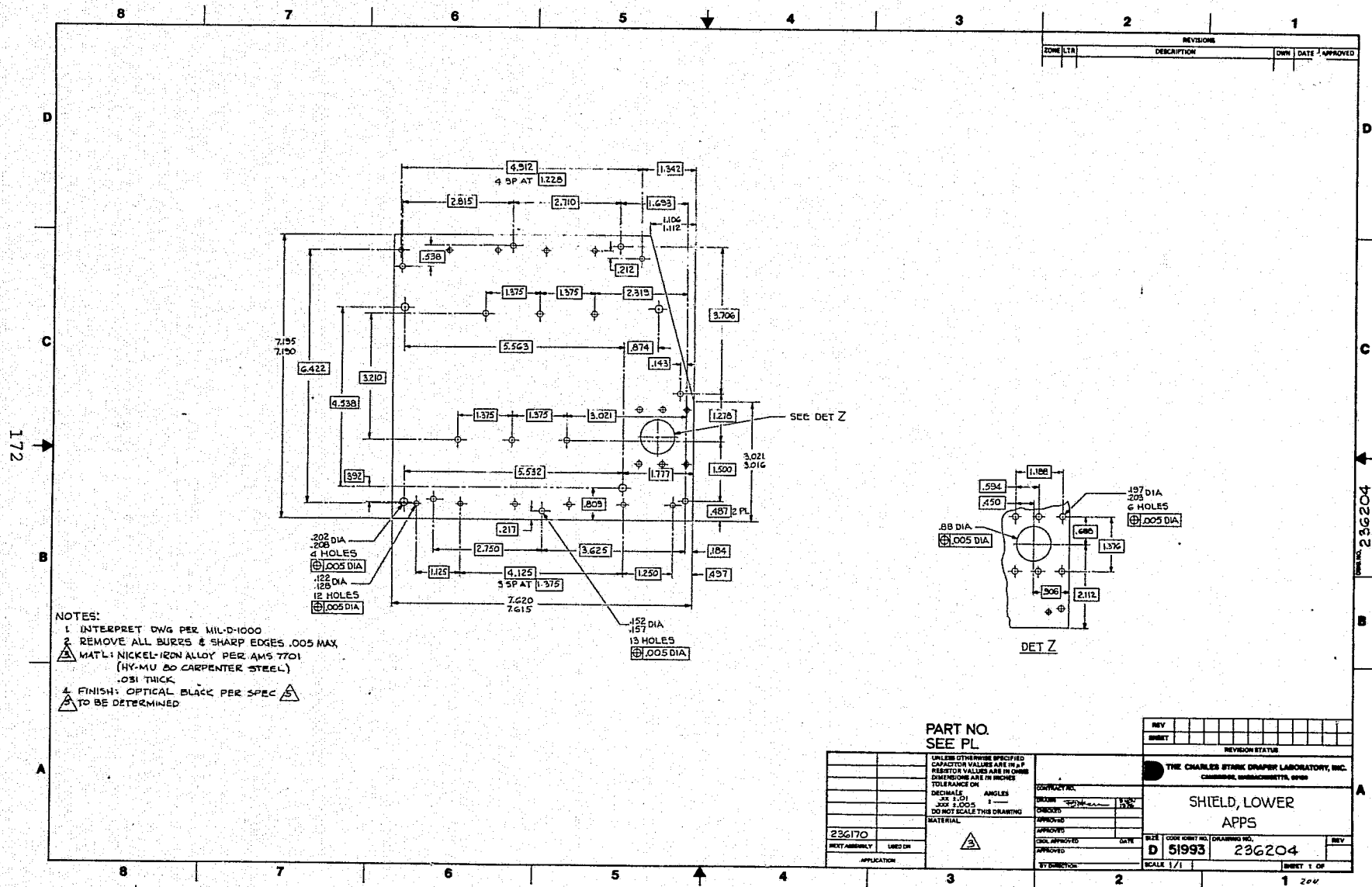
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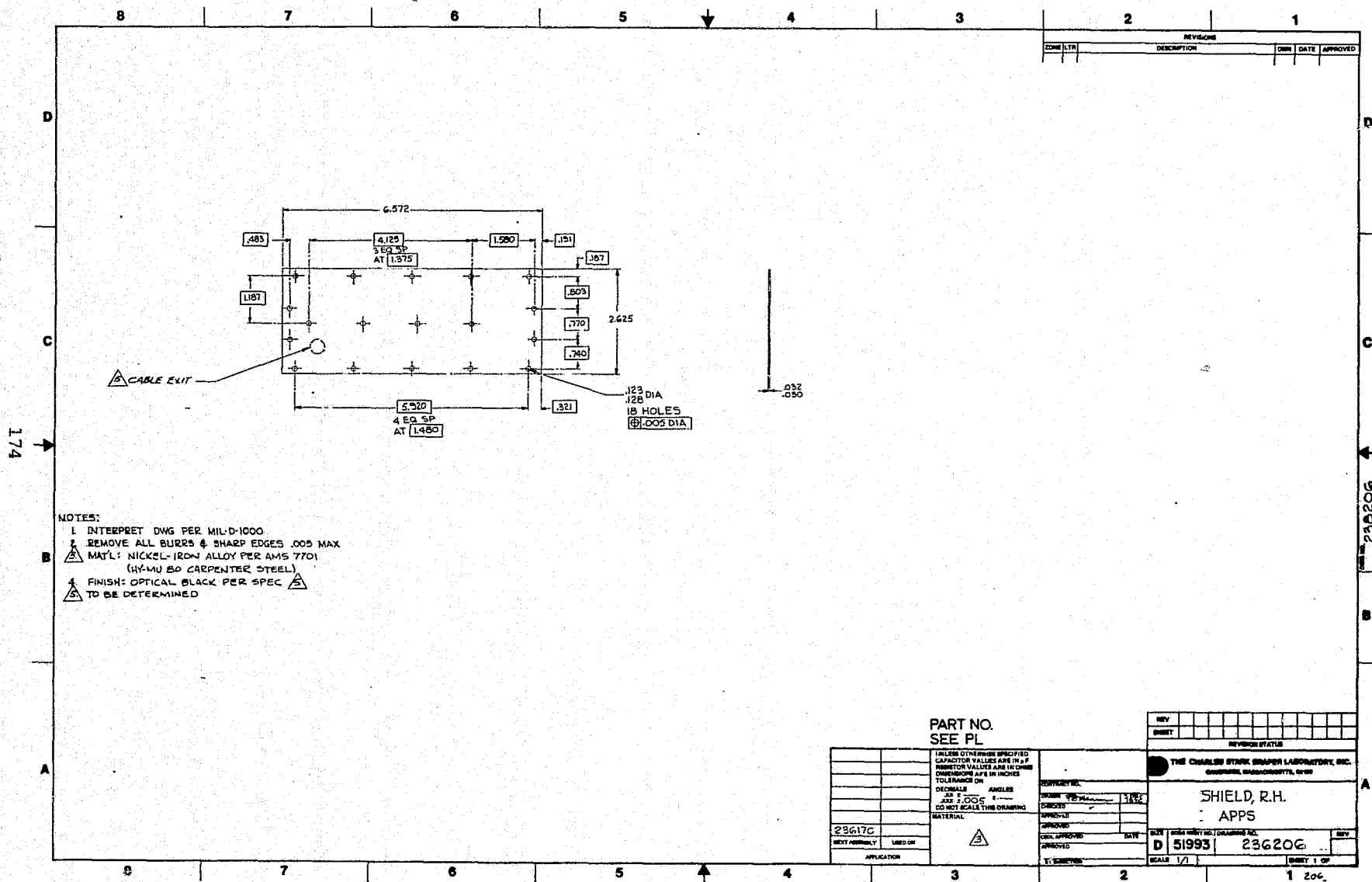
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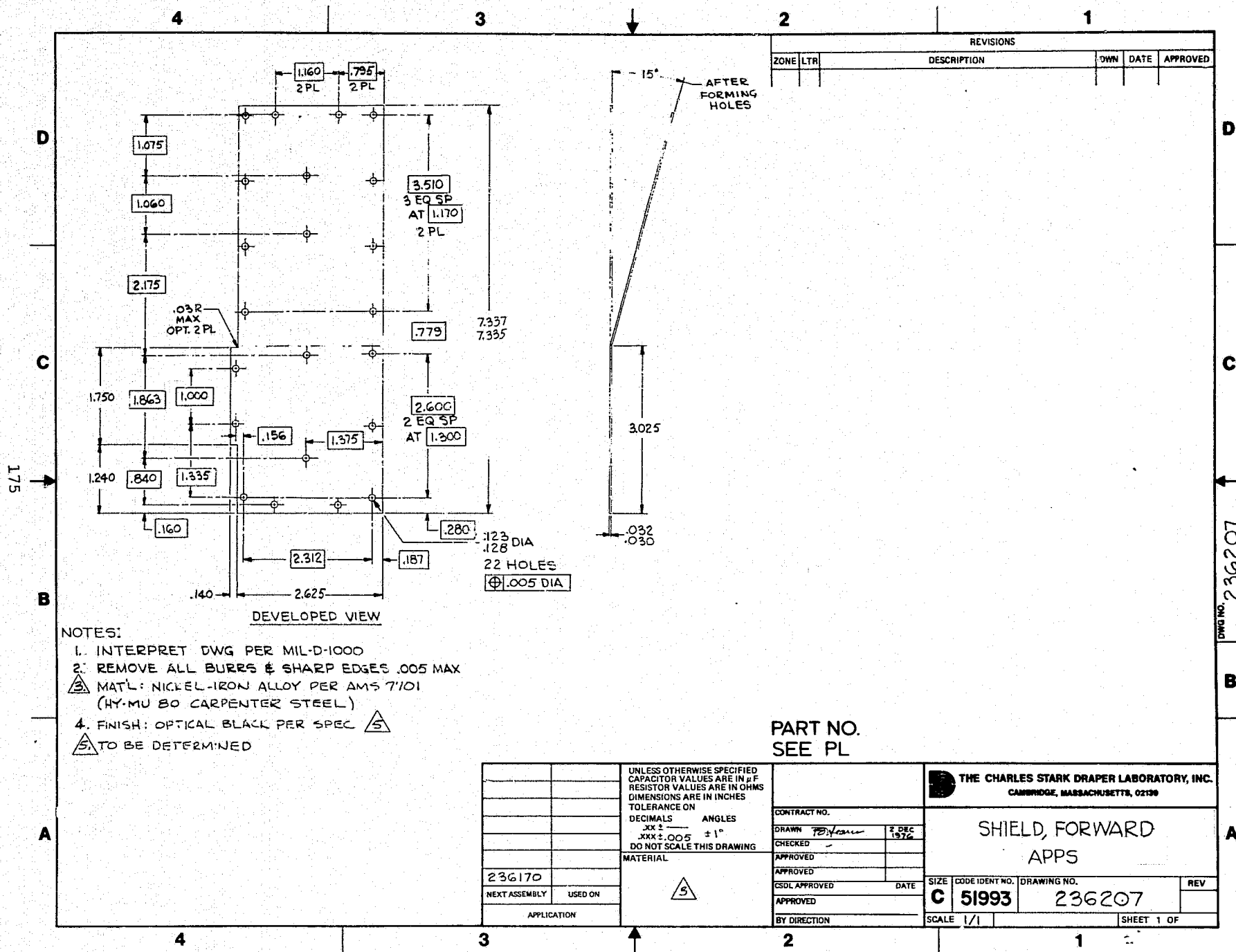
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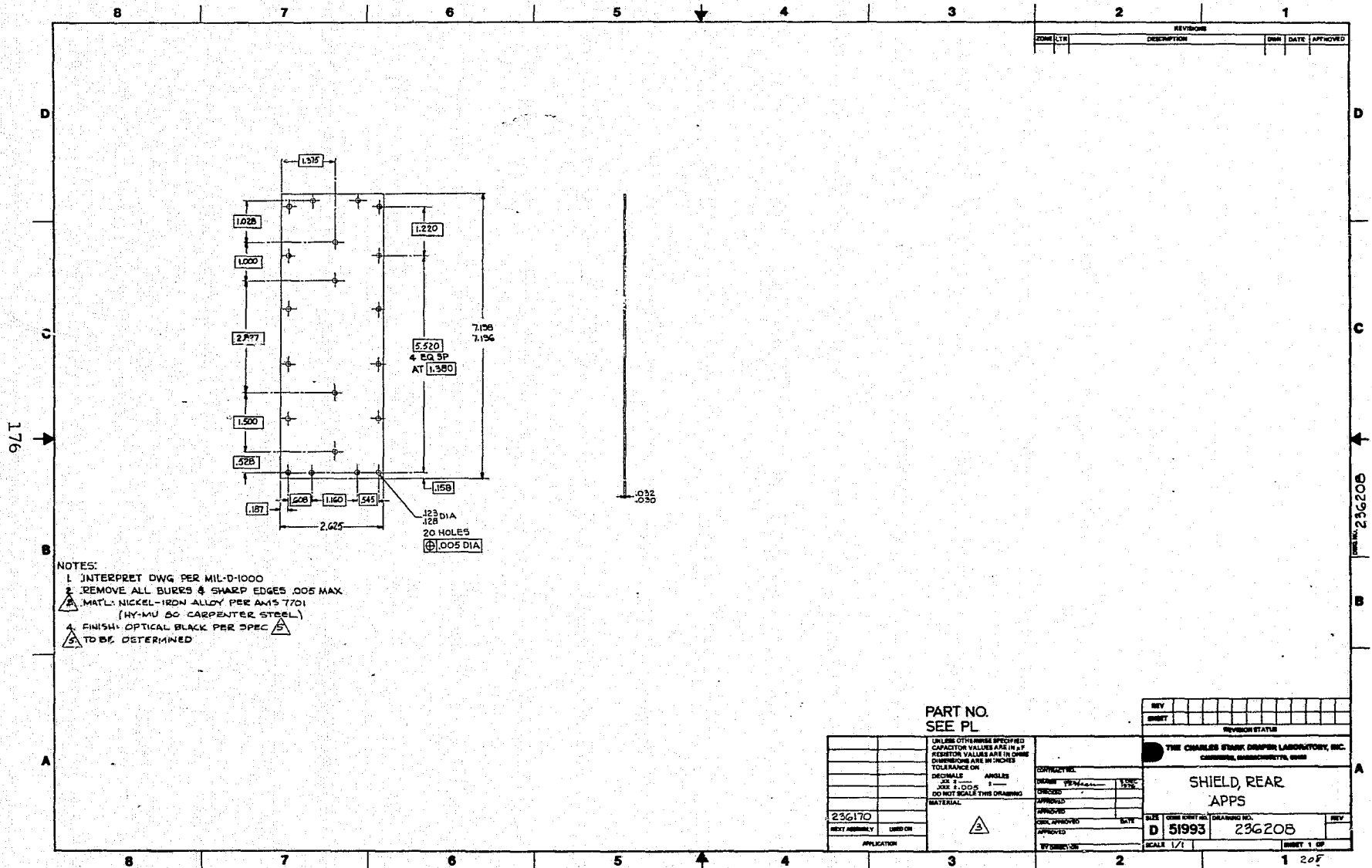
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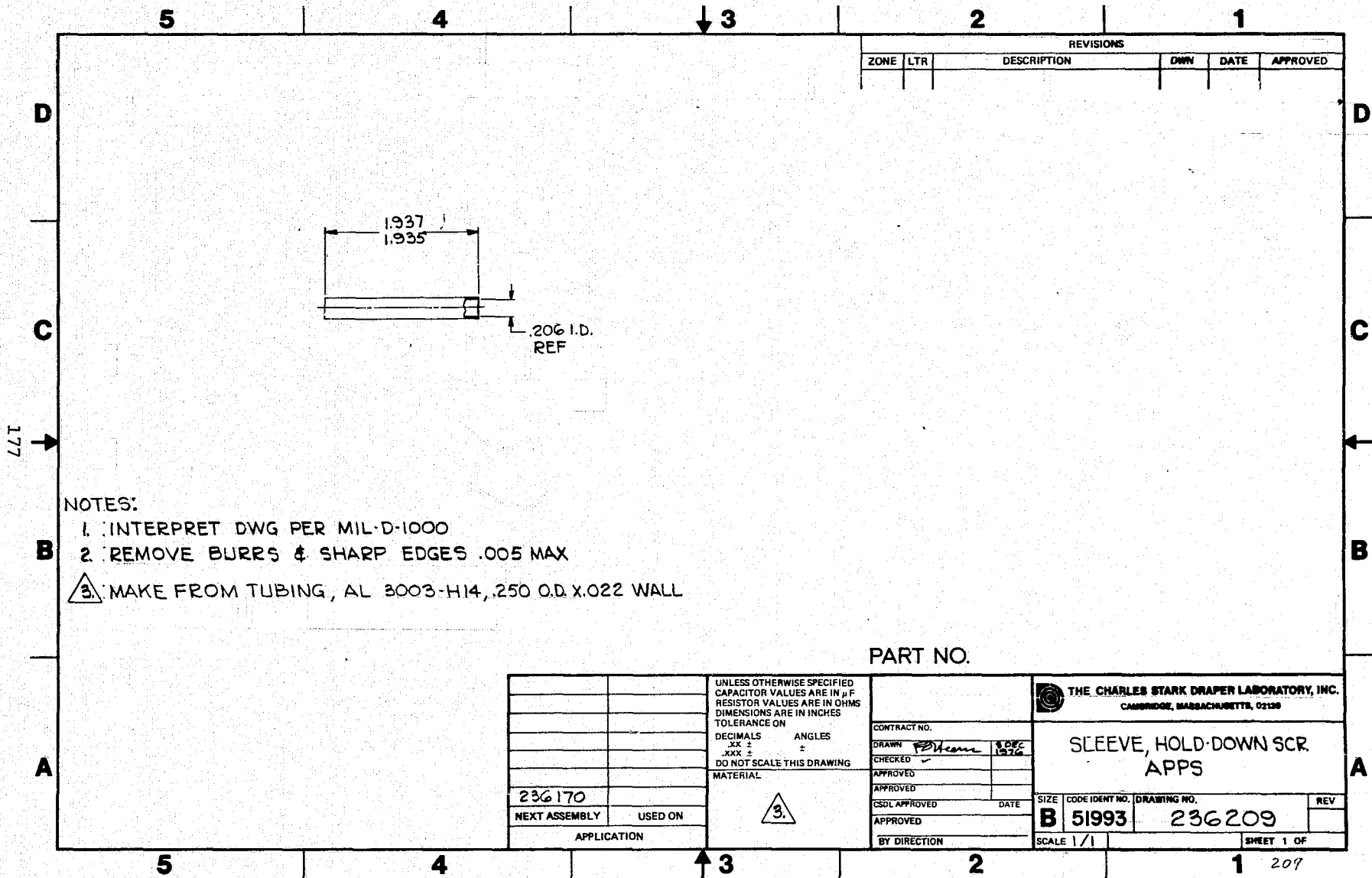


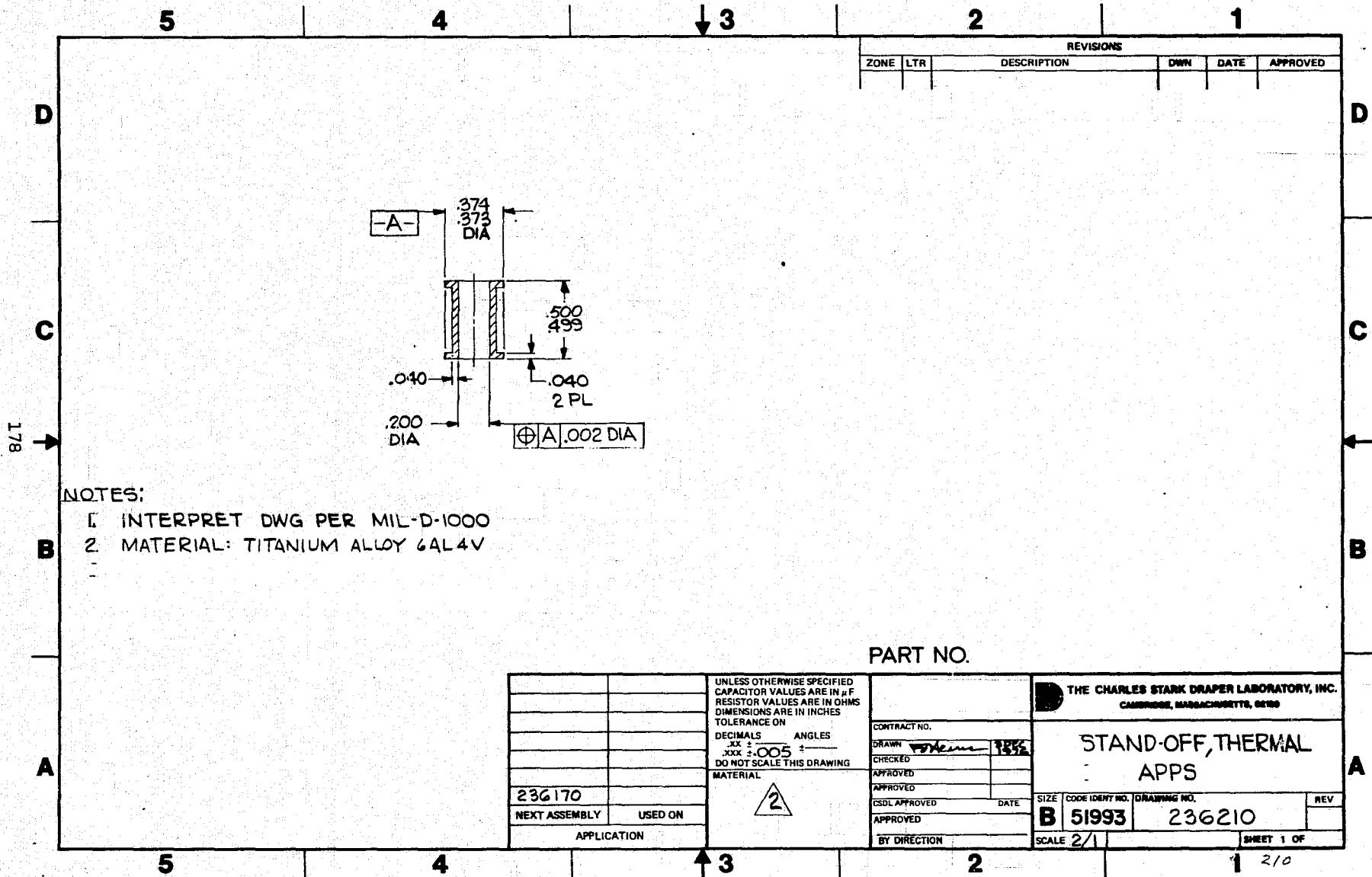




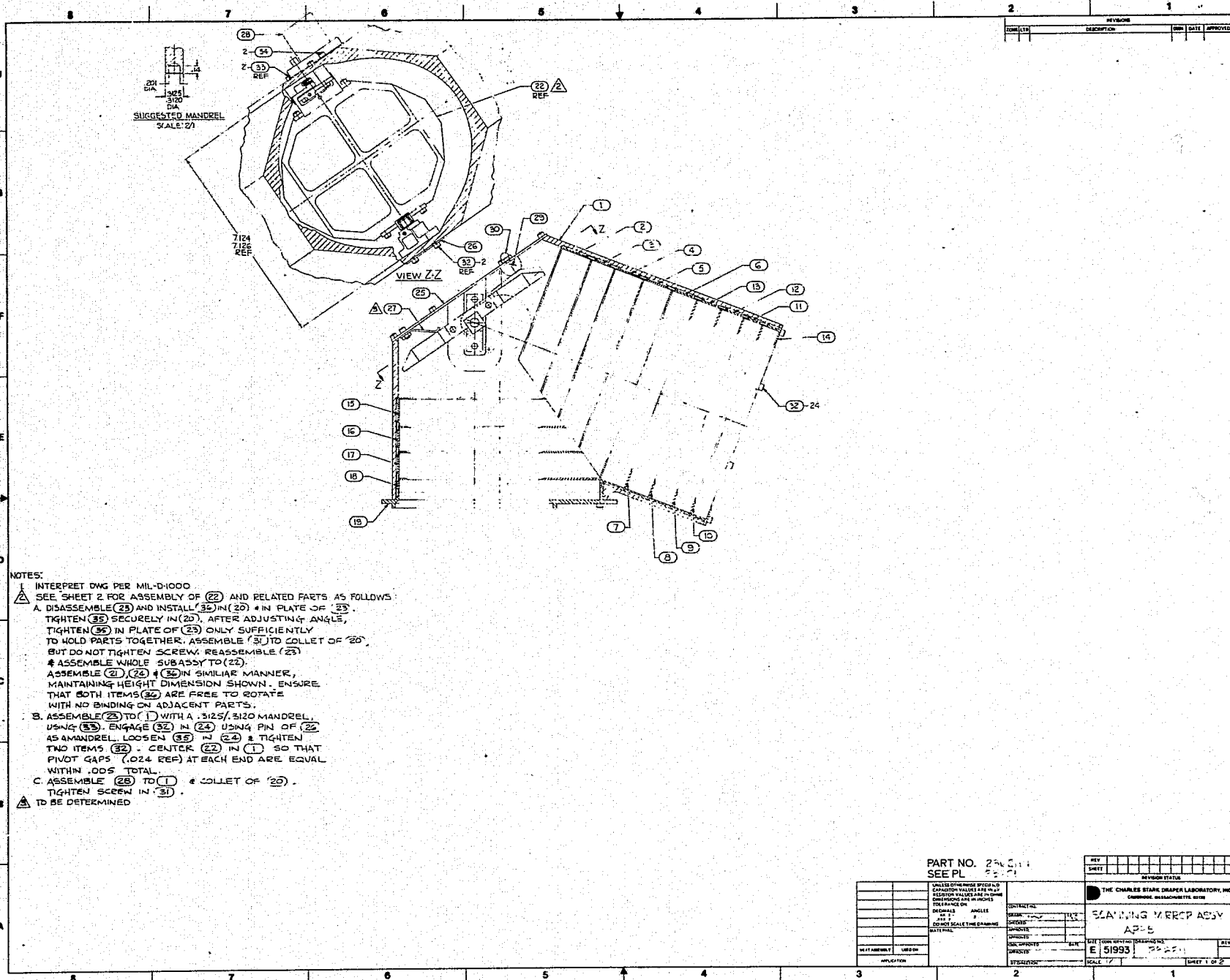






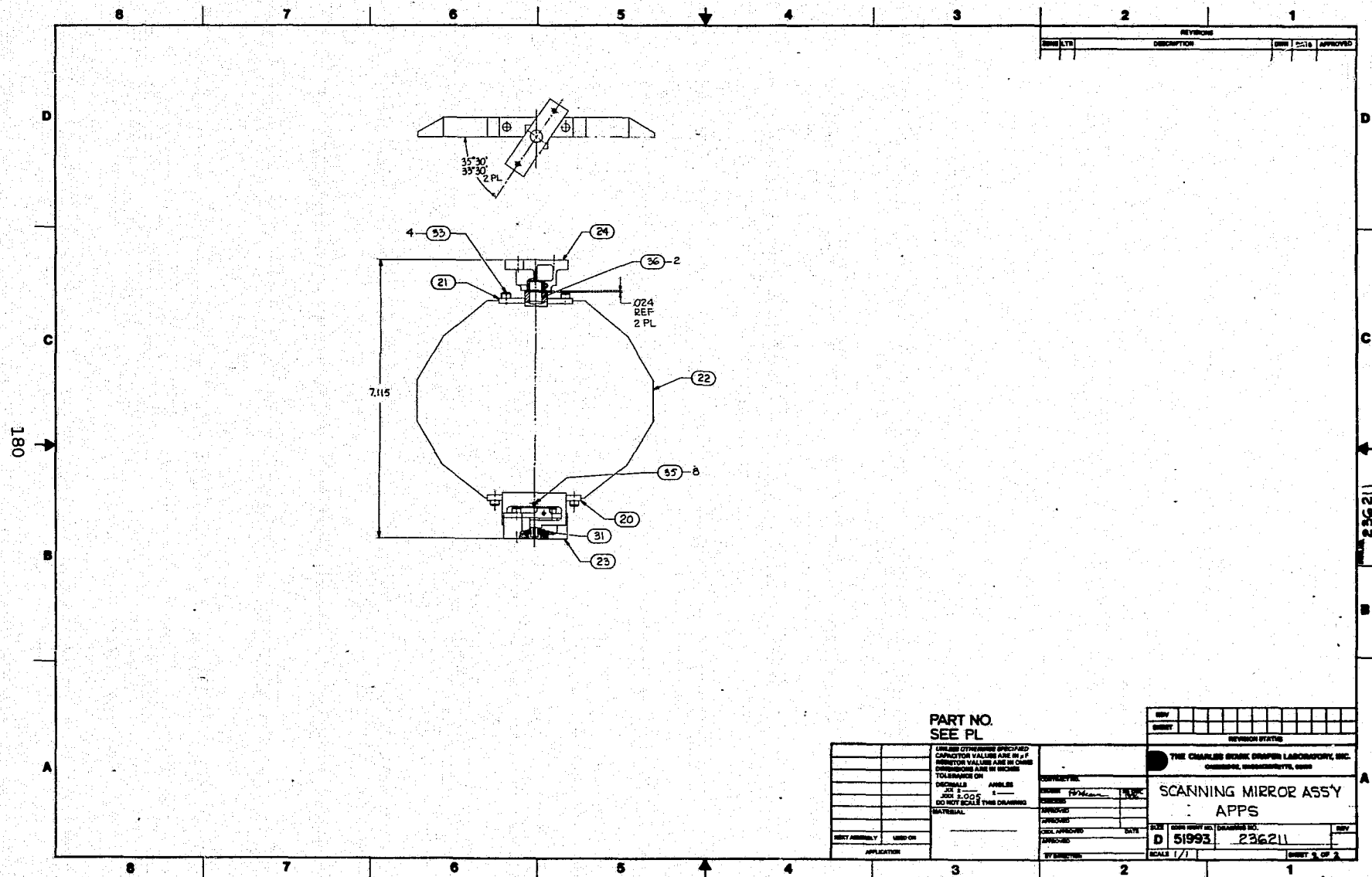


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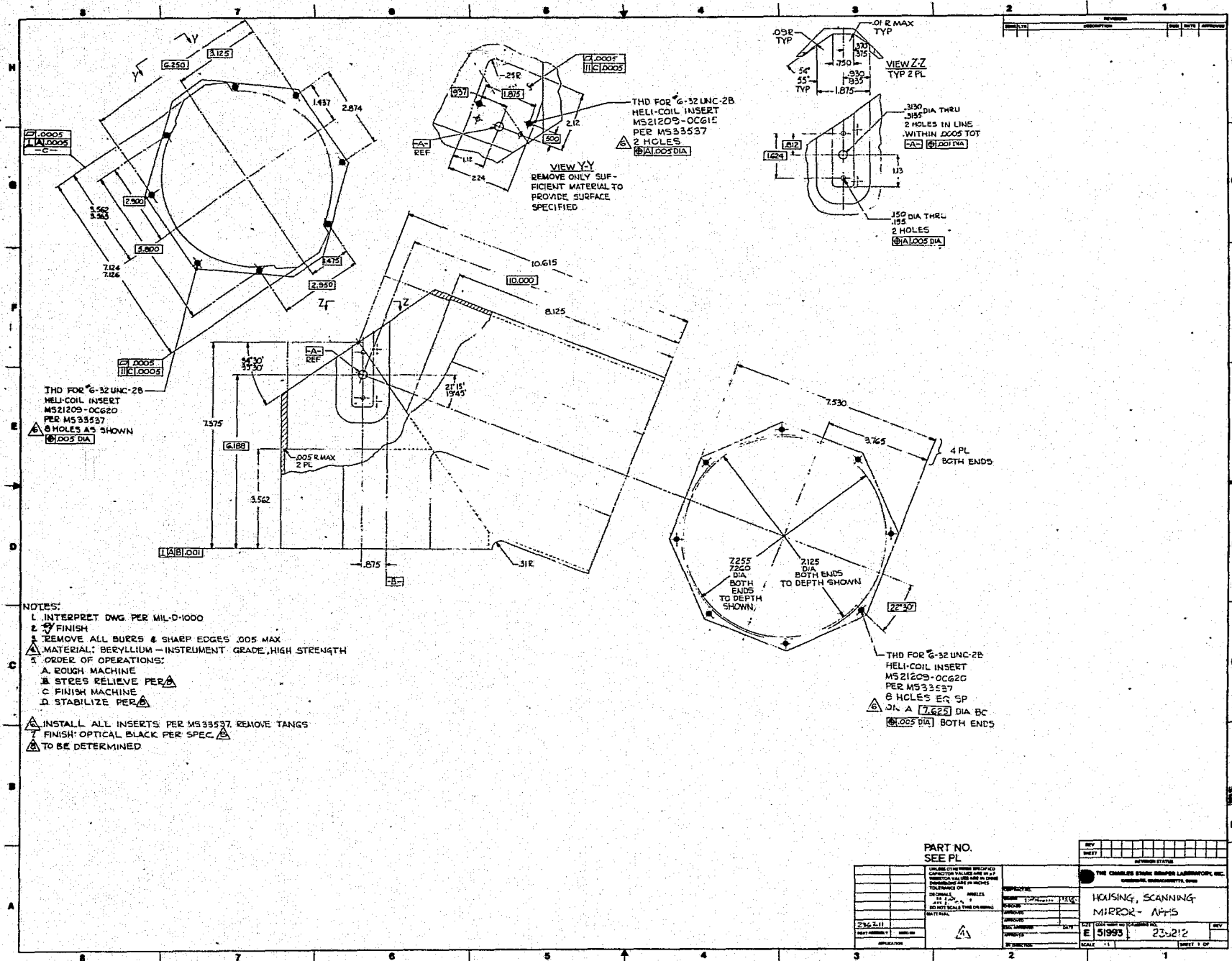
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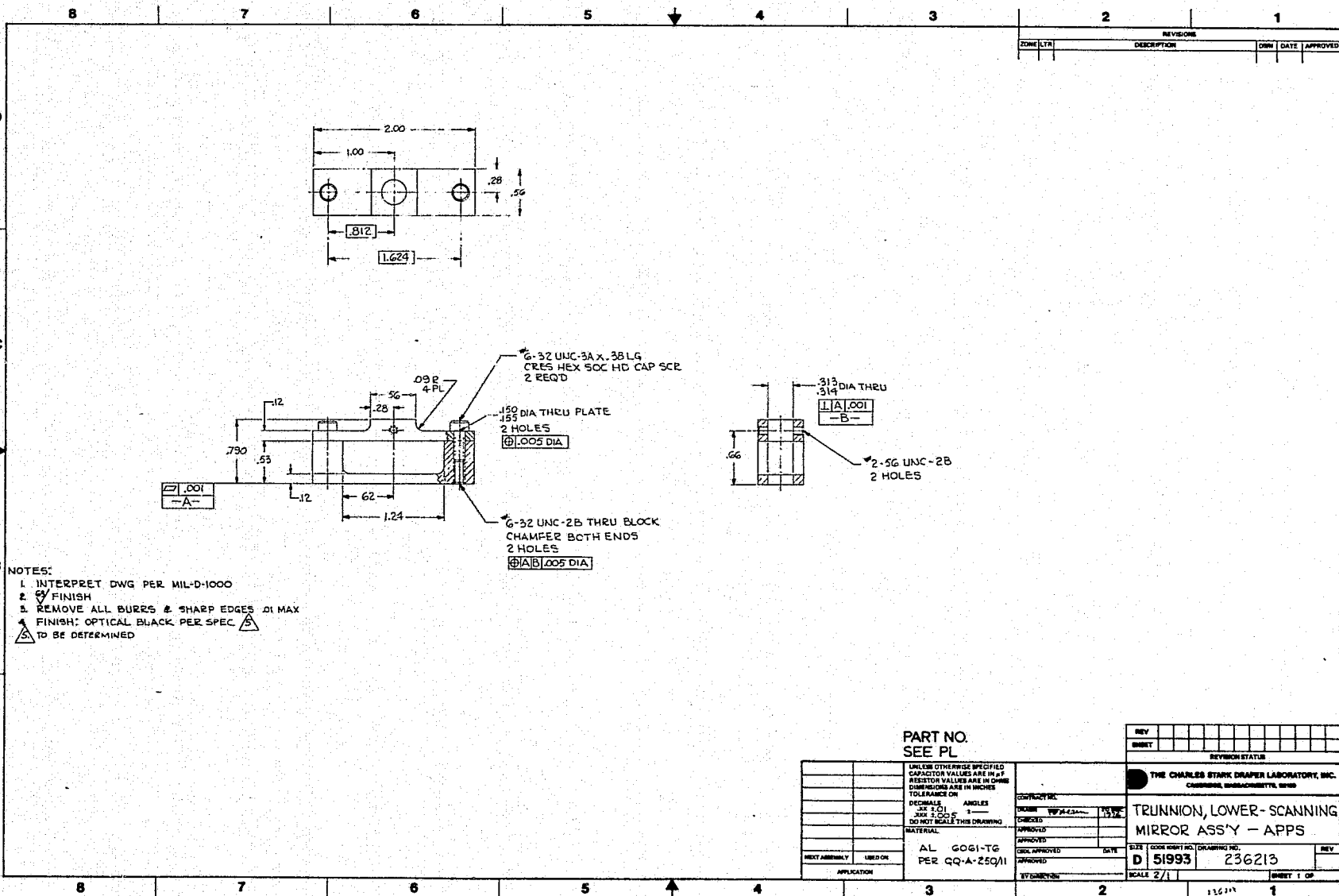
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4					236151-3		BAFFLE, PARTIAL	
5					236152		BAFFLE, FWD. SCAN.	
6					236153		BAFFLE, FWD. SCAN.	
7					236154-1		BAFFLE, FLAT	
8					236154-2		BAFFLE, FLAT	
9	182				236154-3		BAFFLE, FLAT	
10					236154-4		BAFFLE, FLAT	
11					236155-1		SPACER, BAFFLE	
12					236155-2		SPACER, BAFFLE	
13					236155-3		SPACER, BAFFLE	
14					236156		BAFFLE, FWD.	
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18					236158		BAFFLE, REAR SCAN.	
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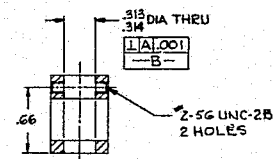
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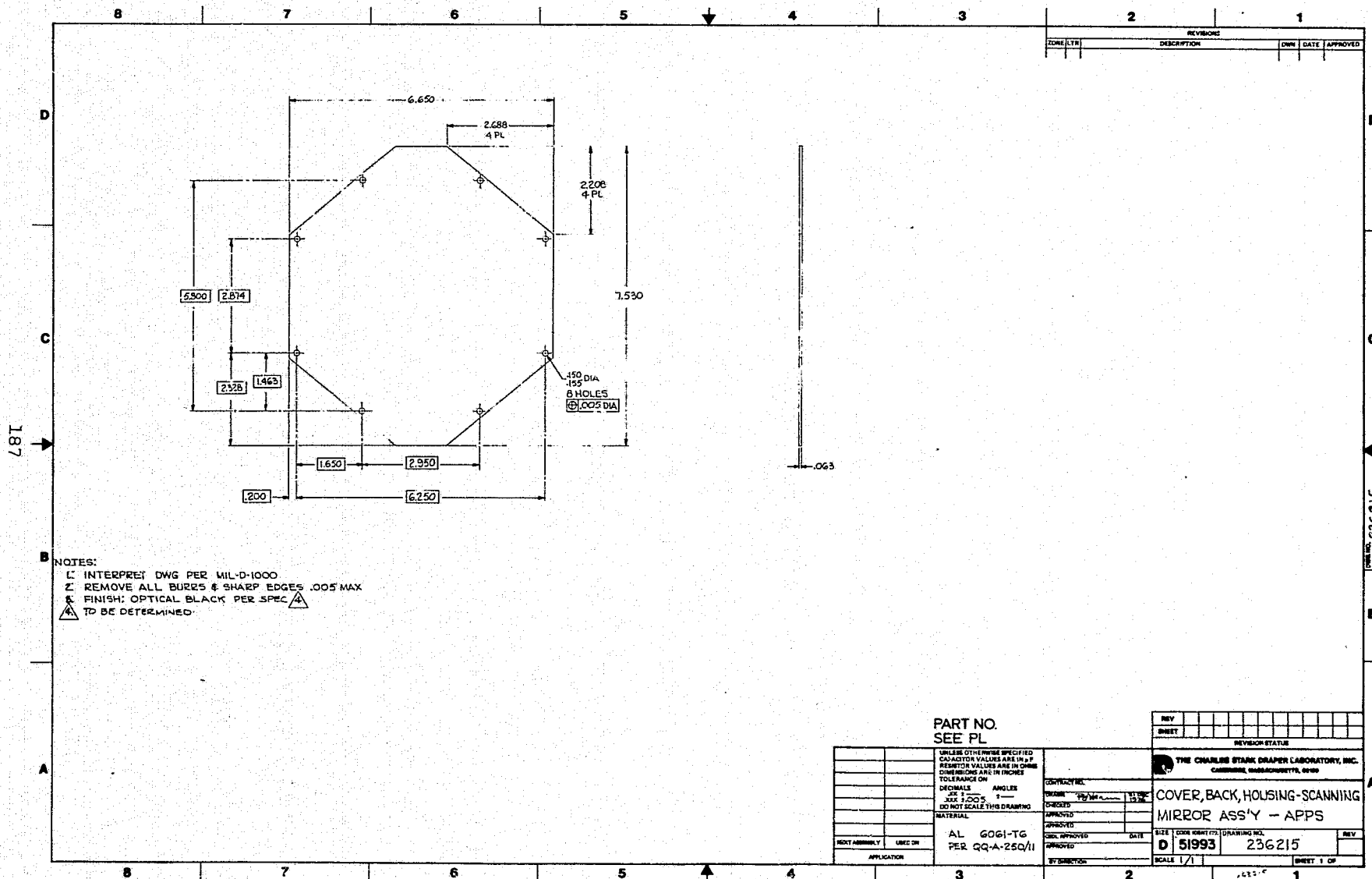
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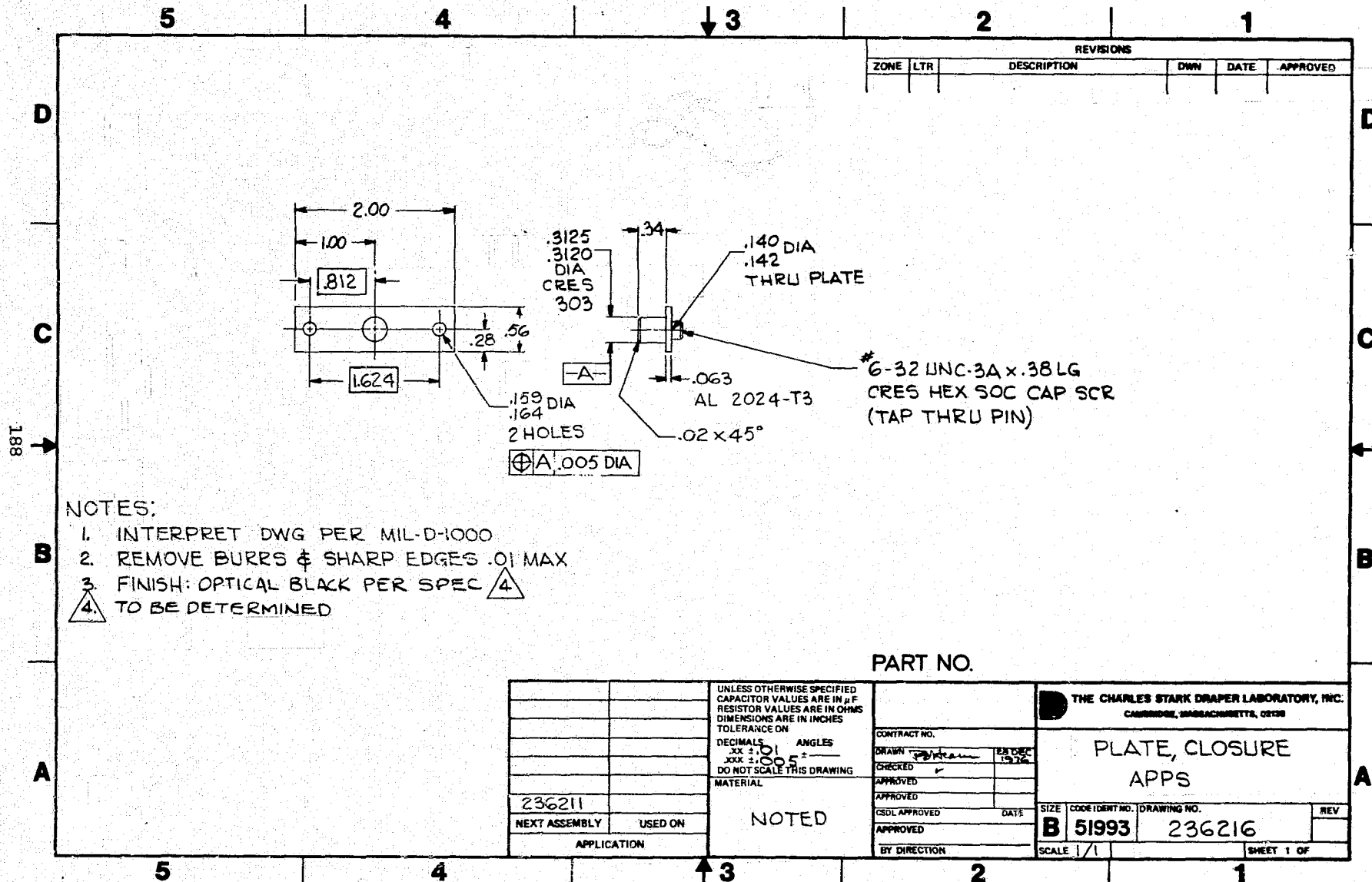


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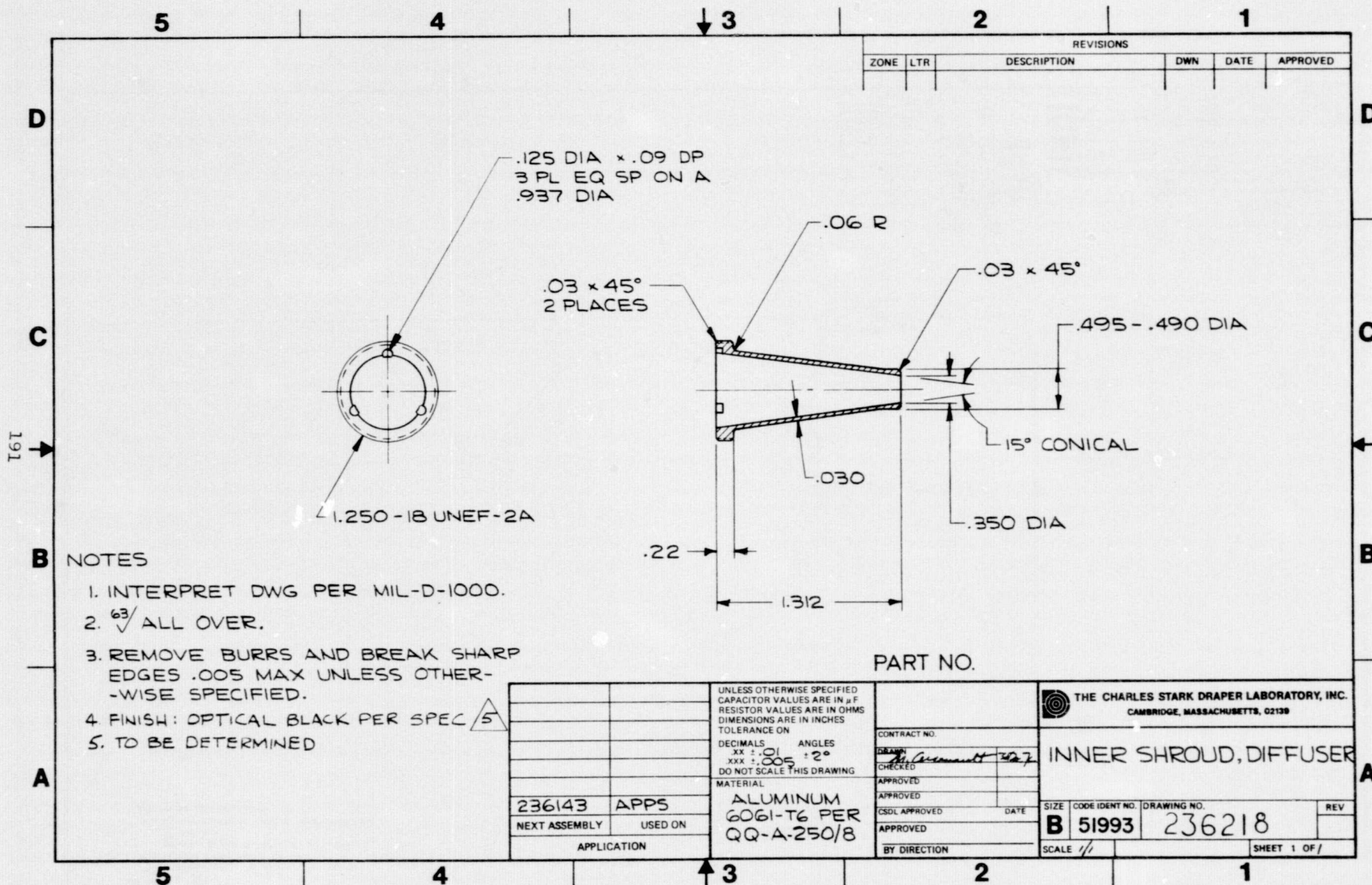
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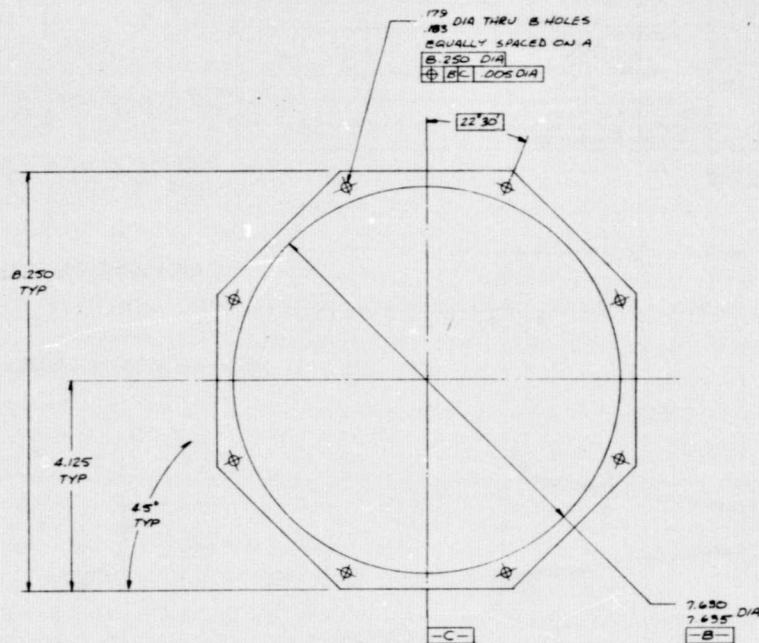


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2				△		INSTALLATION, MOUNT		
3				△		ELECTRONICS ASSY, RH.		
4				△		ELECTRONICS ASSY, LH.		
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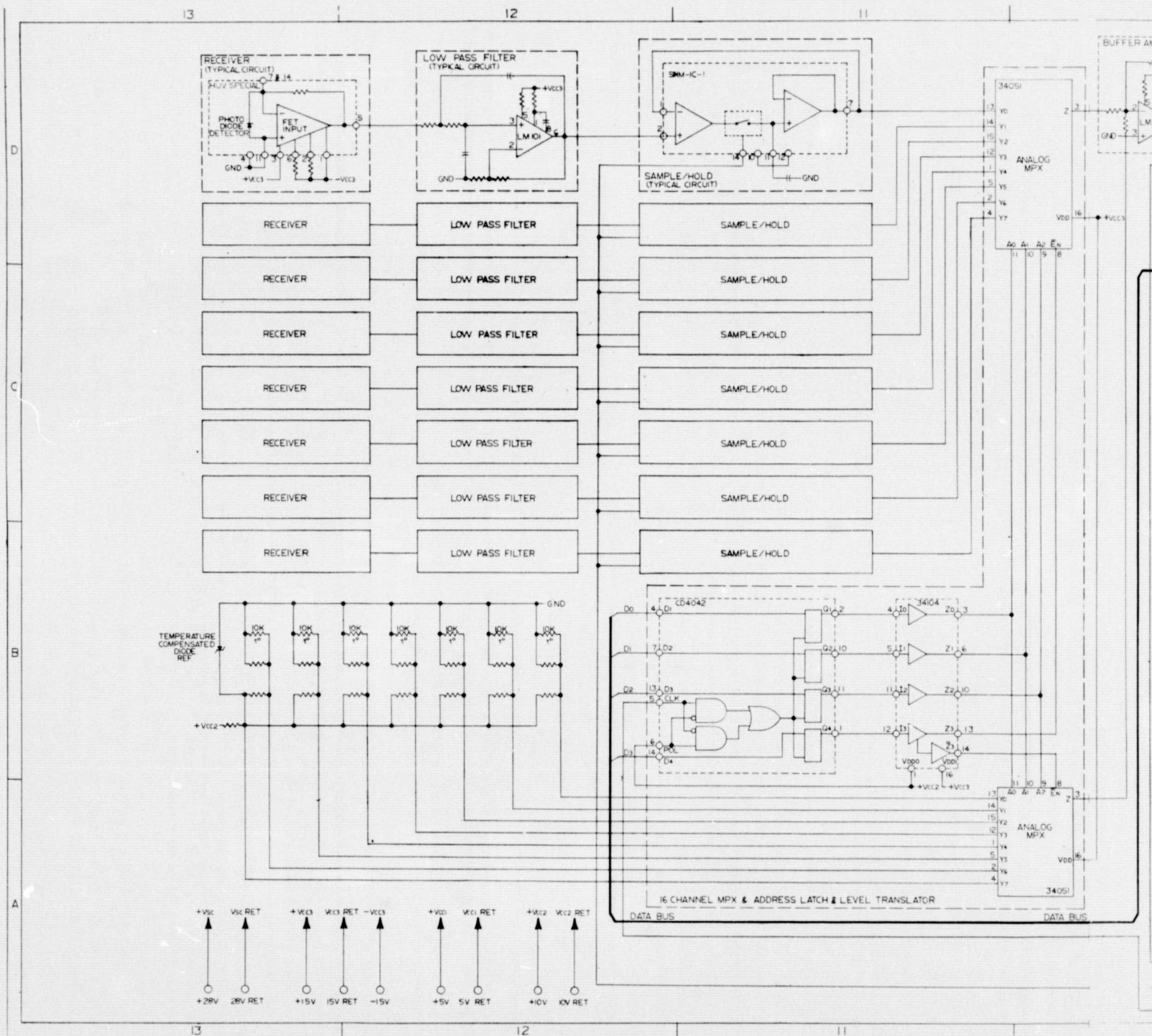
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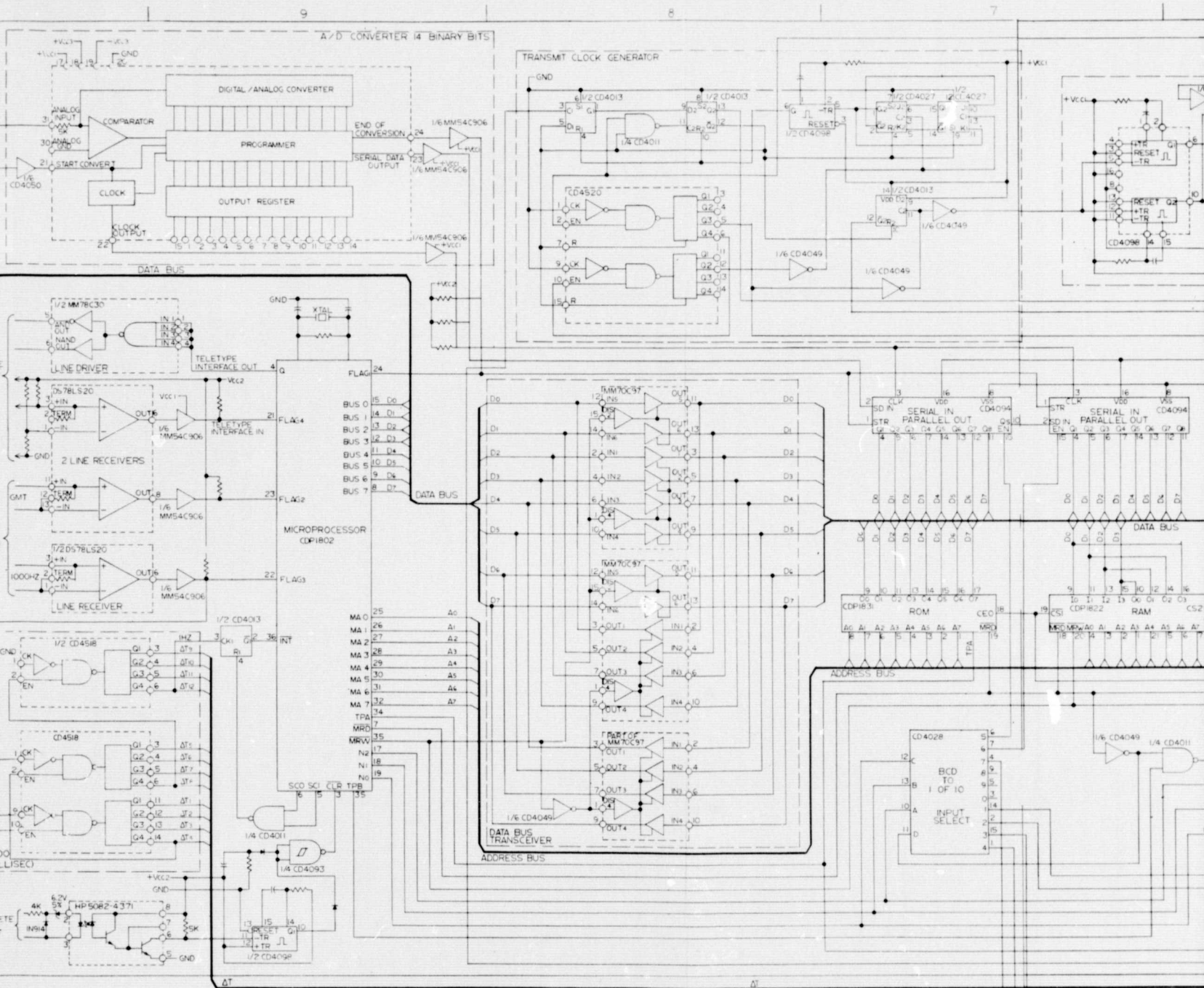
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CAMBRIDGE, MASSACHUSETTS, 02139

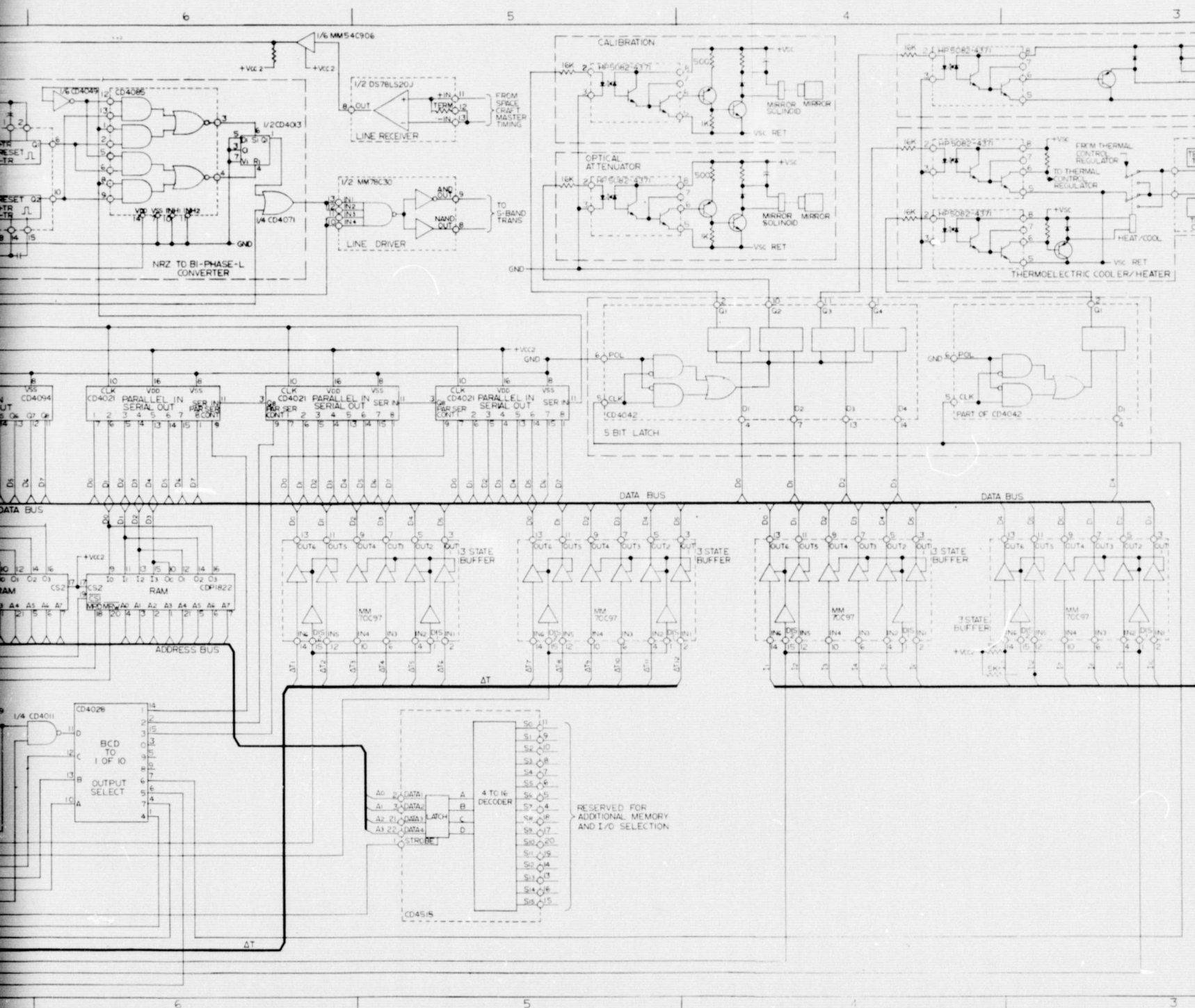
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PRIMARY - APPS

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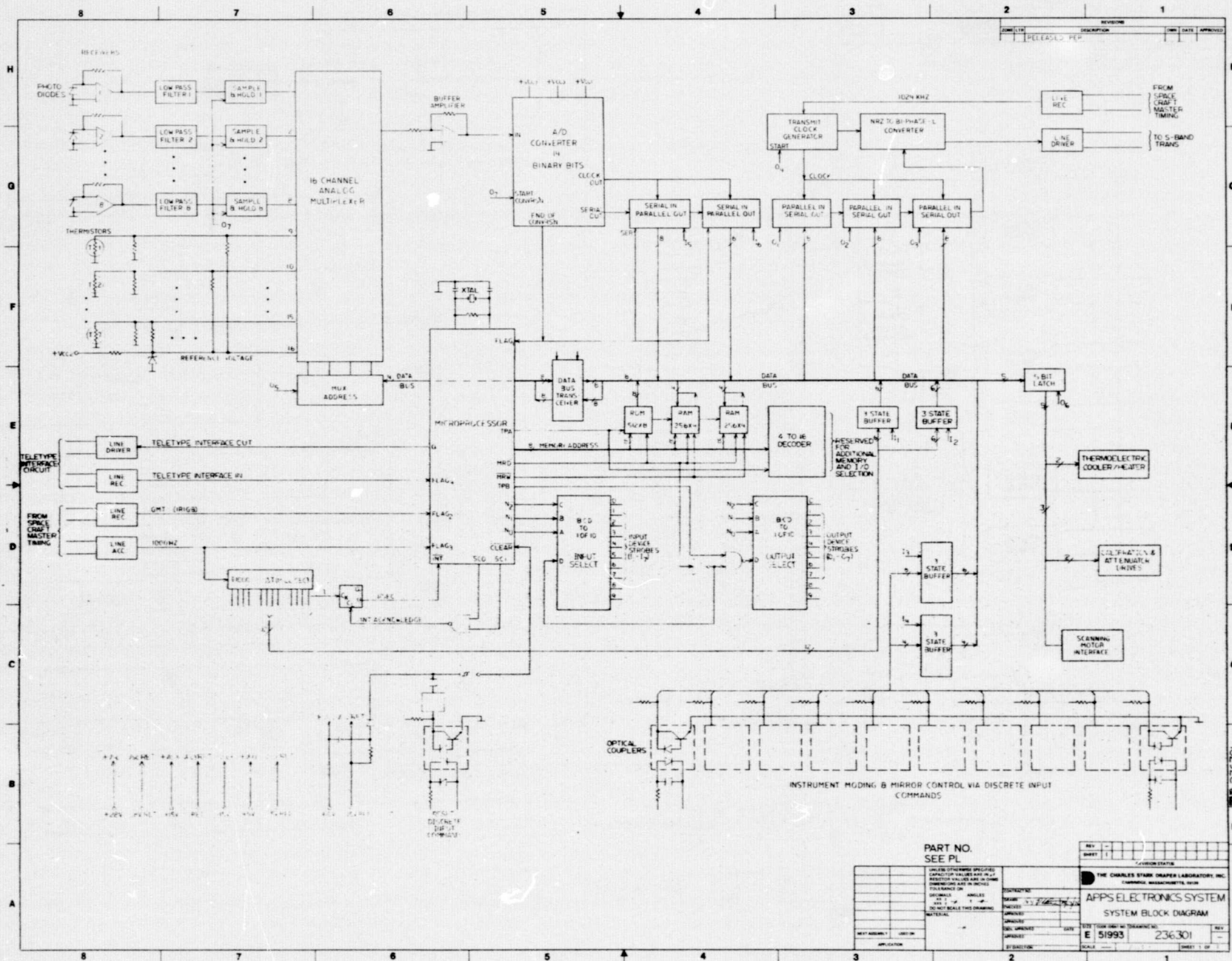
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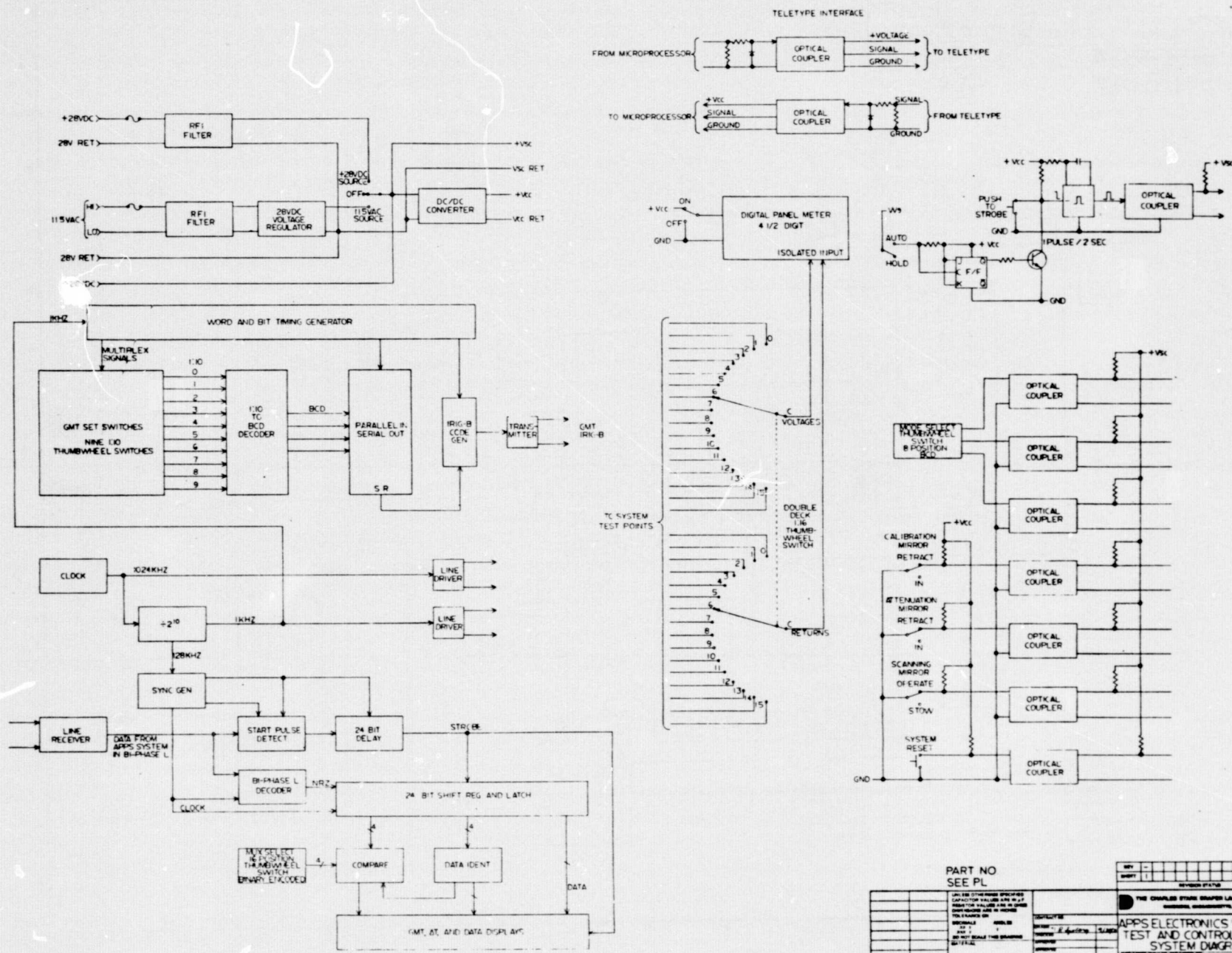






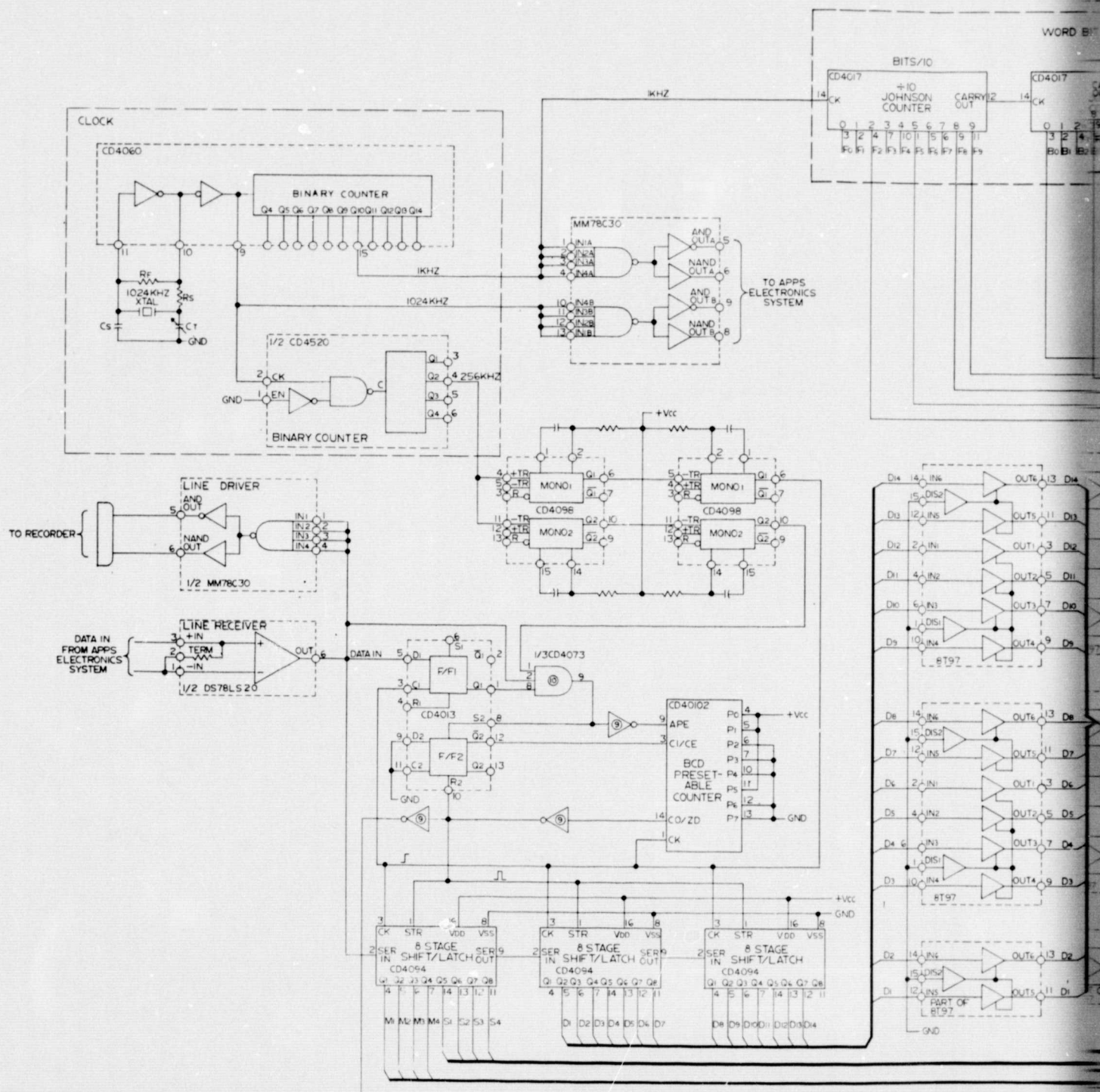
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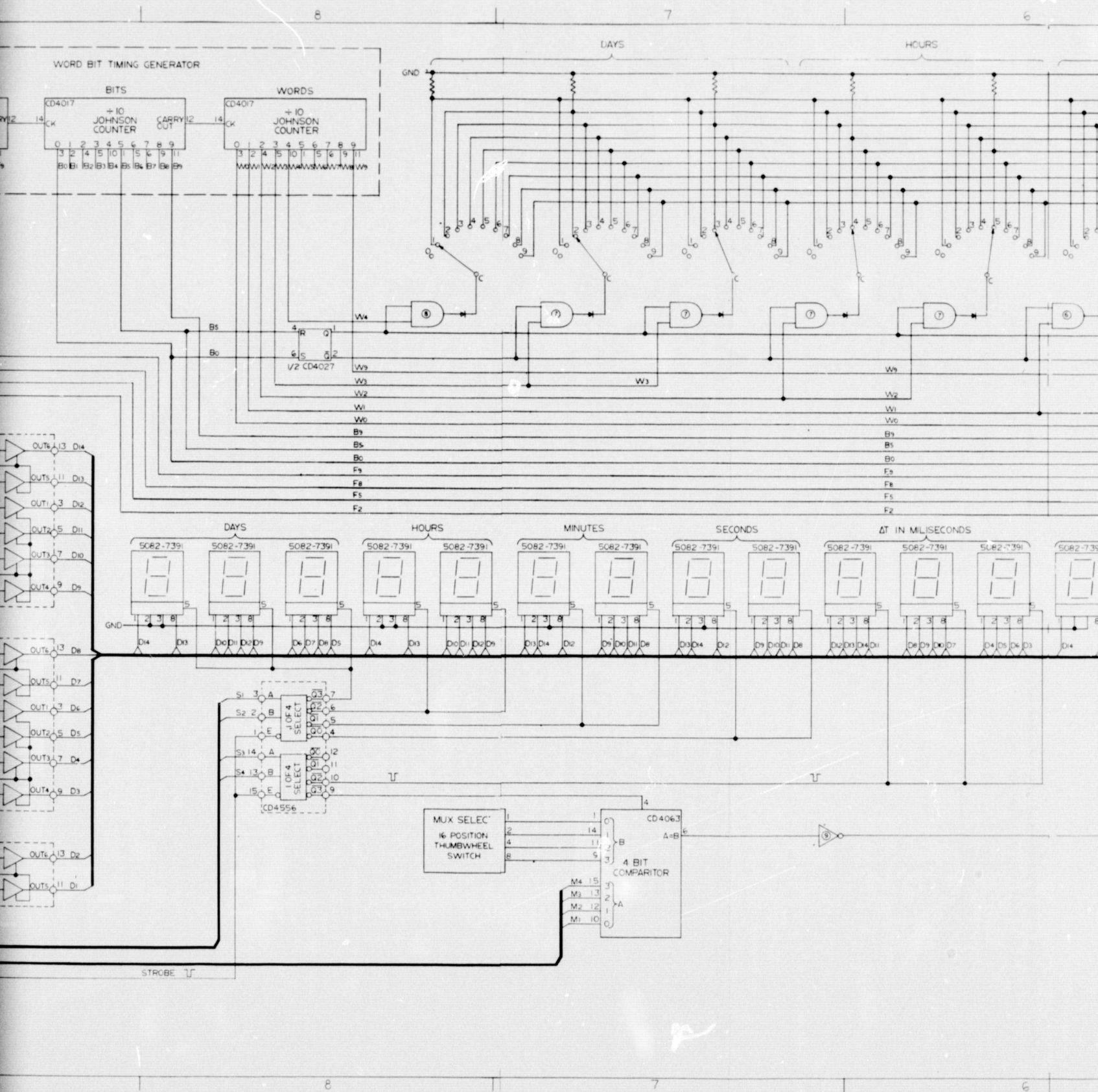


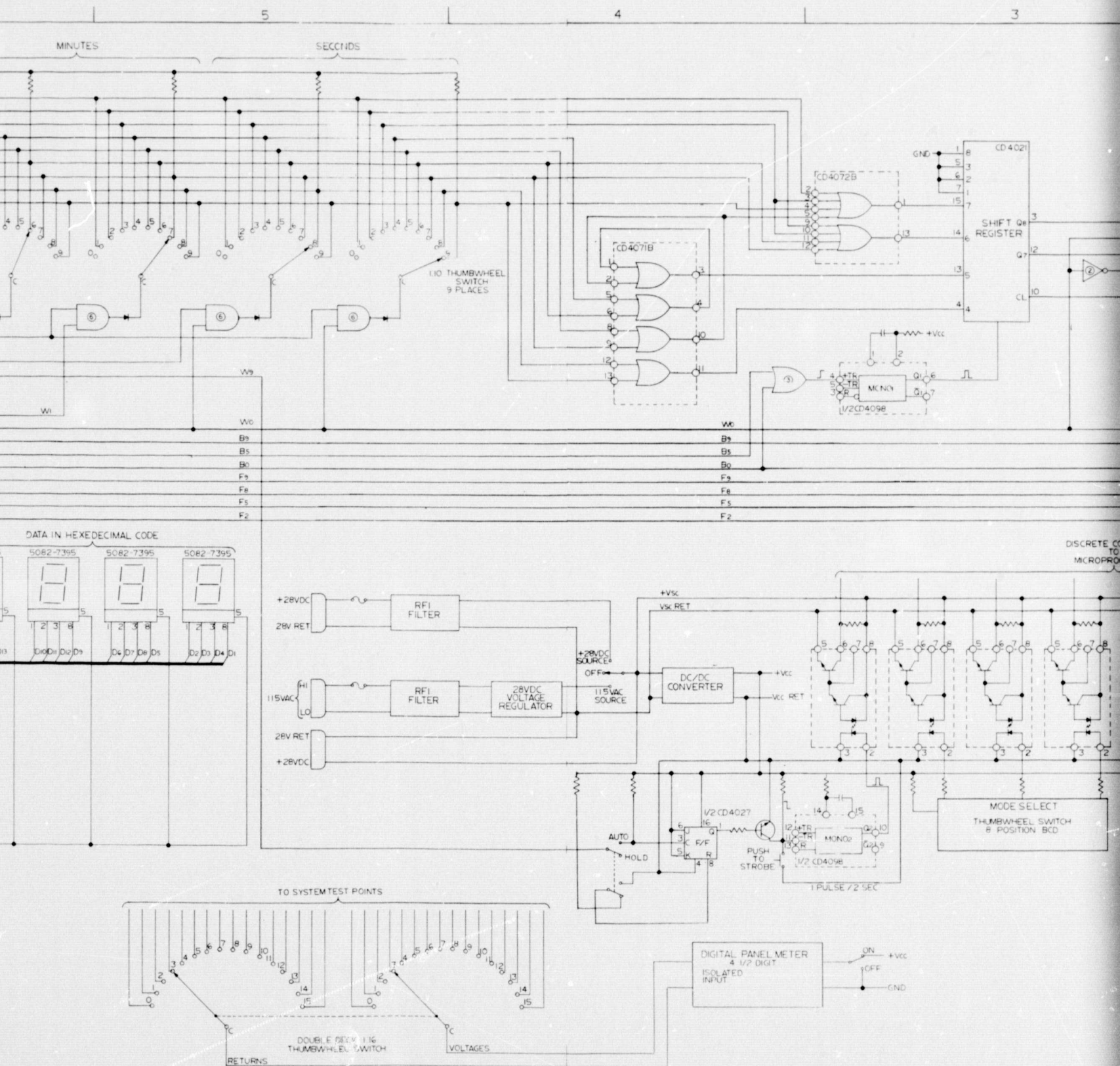


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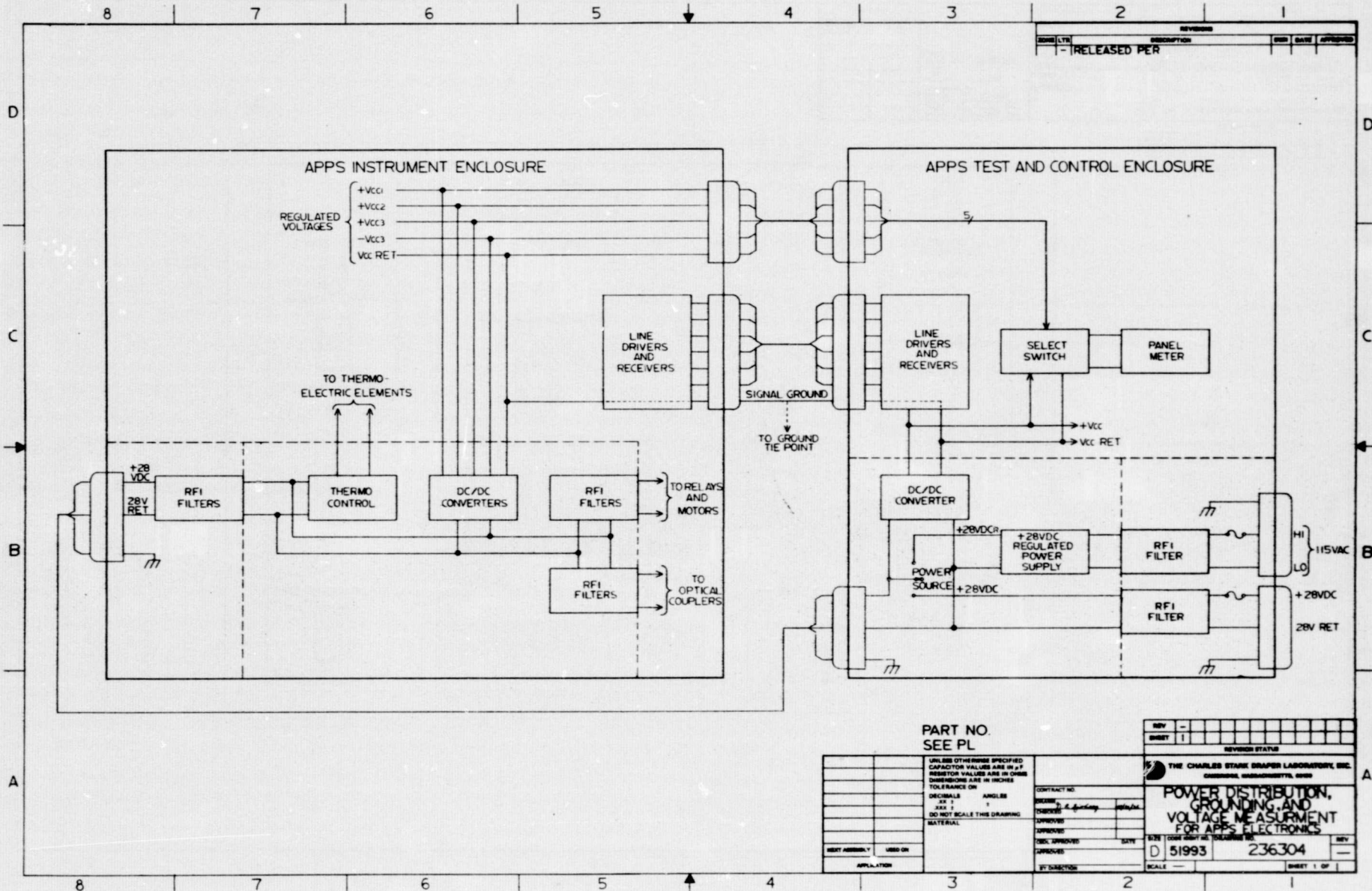
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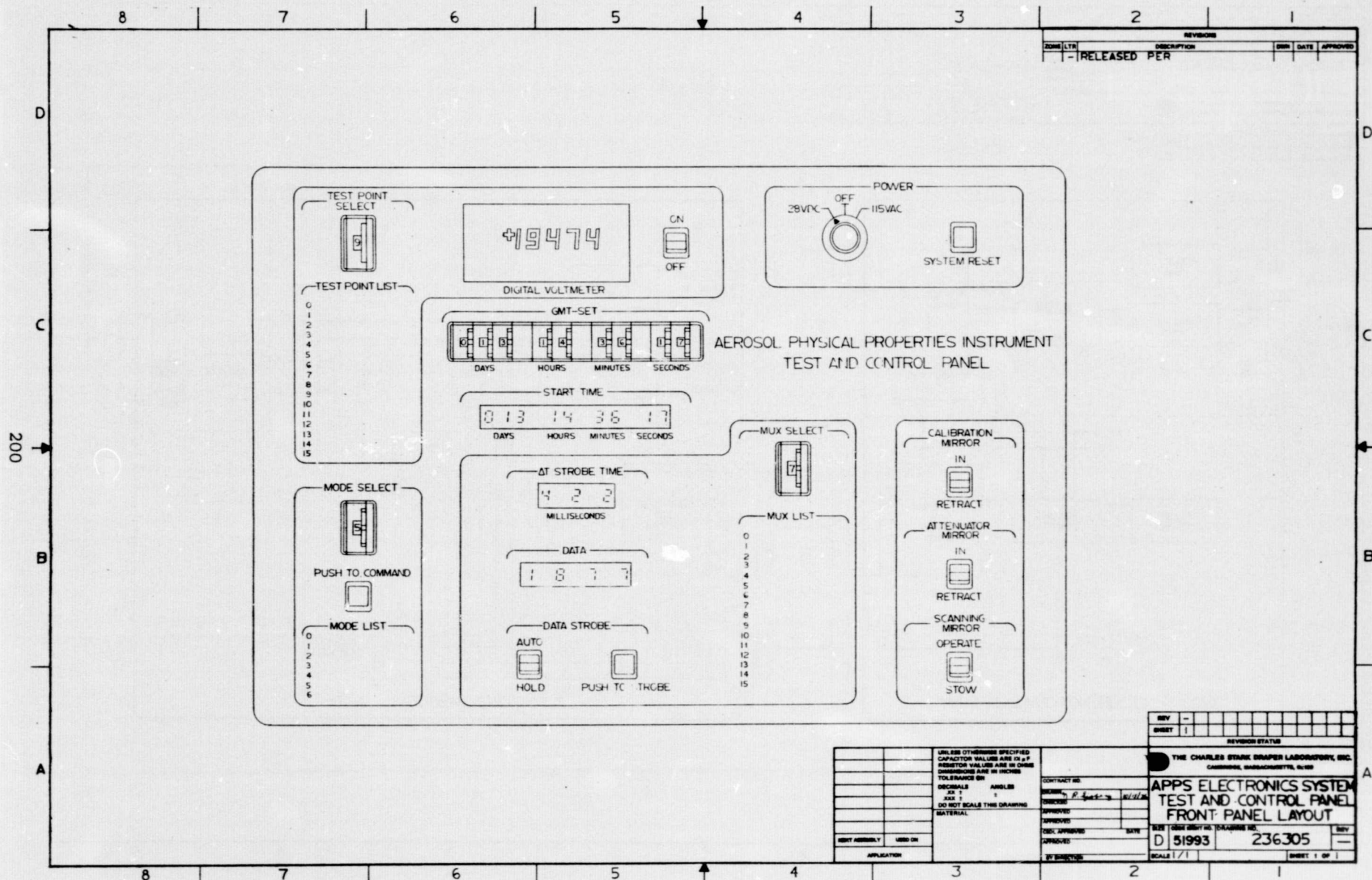






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SECTION 4

ELECTRONIC DESIGN

4.1 ELECTRONIC-SYSTEM REQUIREMENTS

The electronic-detection and signal-processing requirements for the APPS radiometer are governed by the optical characteristics, signal source, and measurement schedule described in the following.

4.1.1 Optical Features

The radiometer's optical system vertically scans the earth's limb with a finite field-of-view, and collects the scattered radiation along the tangent line-of-sight. The collected radiation is then directed to a filter chain where it is sampled in eight discrete spectral bands. Each narrow band of radiation is then focused into separate photodiode detectors. Figure 2-1 is a functional schematic of the radiometer optical train.

There are two additional modes of operation for the radiometer which are actuated by optical switches (movable mirrors). The first, and primary mode of solar calibration, is when the sun directly illuminates the transmission diffuser. Activation of the transmission-diffuser mode optically switches the line-of-sight from the main telescope to the diffuser line-of-sight, and radiance measurements are taken. The second mode of solar calibration is when the line-of-sight of the main telescope directly intersects the sun. During this mode, a neutral-density filter of approximately 10^5 is switched into the main optical path, and radiance measurements are taken. Direct solar calibration is possible in either one of these two modes.

4.1.2 Signal Sources

The sources of the signal to be measured by the APPS radiometer are multispectral limb profiles of the earth's atmosphere. An illustration of the measurement geometry is shown in Figure 4-1.

SIGNAL SOURCE IS THE INTENSITY OF LIGHT SCATTERED BY THE ATMOSPHERE ALONG THE VIEW DEFINED BY THE FIELD-OF-VIEW OF THE OPTICS AND THE SCANNING APERTURE.

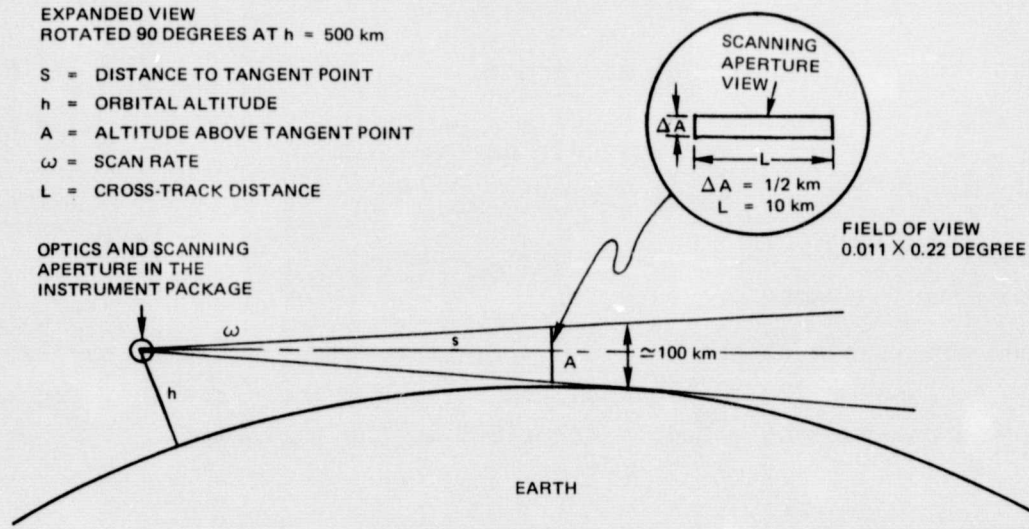


Figure 4-1. Signal source.

Experimentally, as the APPS radiometer scans through the atmosphere, it collects back-scattered solar radiation along the optical line-of-sight at discrete wavelengths. Figure 1-1 illustrates a typical earth-limb-radiance-measurement data set where the intensity of the scattered radiation varies with altitude and wavelength. The measured radiation is dependent upon the absorption and scattering cross sections, and the concentrations of the atmospheric constituents. The variation of the radiance profiles with wavelength, altitude, latitude, season, and measurement geometry, and sun angle provide information to the signal.

4.1.2.1 Spatial Profiles

The spatial frequency cutoff for electronic processing was defined as 1 cycle per kilometer (see Figure 4-2). This specification was based upon the desire to set the spatial frequency near the maximum aerosol spatial structure measured by other direct and indirect remote-sensing techniques in the stratosphere.⁽³⁾

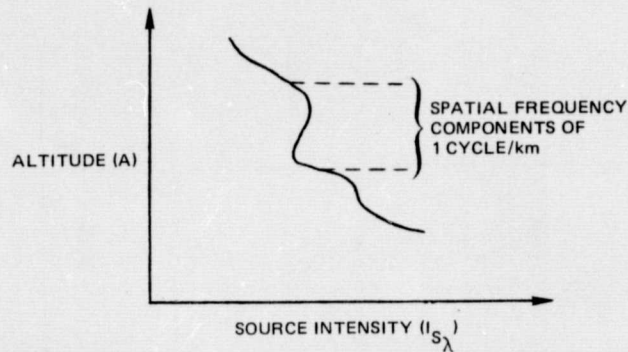


Figure 4-2. Altitude resolution requirements (dictated by the variation in the intensity of the signal source as a function of altitude).

4.1.2.2 Aperture Requirements

To maximize the signal-to-noise ratio of the APPS radiometer, the design was optically maximized to the field-of-view and collecting area within the constraints of spatial resolution, calibration techniques to be used and overall instrument size. Therefore, the aperture requirements of the field stop were set in width by the upper spatial frequency of the signal source (see Figure 4-3 and Section 4.2.1). The horizontal dimension (aperture length) was set by the desirability of having the field-of-view of the radiometer subtend less than one half the sun's disk diameter which would more readily allow the direct solar-calibration mode. These requirements fixed the maximum focal-plane aperture to 0.011 degree by 0.22 degree, which corresponds to an altitude resolution of 0.5 kilometer by 10 kilometers at a 500-kilometer observational altitude.

4.1.2.3 Source Intensities and Receiver Input Power

The maximum source intensities of the earth's limb were obtained from Skylab S-191 limb data, except for the near-ultraviolet region, where theoretical intensities were estimated. These intensities are listed in Column 2 of Table 4-1.

Table 4-1. Receiver Characteristics.

Wave Length	Maximum Limb Intensity	Radiometer Input Power 100 cm ²	Optics Transmission Factor	Receiver Input Power	Receiver Responsivity HUV-1000B	Receiver Signal Voltage Output	Voltage Noise in Output at 25°C	Available Dynamic Range
λ (nm)	I_{λ} $\left(\frac{\mu\text{W}}{\text{cm}^2\text{-srad-nm}}\right)$	I_{ω} $\frac{W}{10^{-9}}$	Tr	I_{ω_R} (3) $\frac{W}{10^{-9}}$	RI (A/W)	$\frac{E_o}{V}$ $\frac{I_{\omega_{\lambda}} R_I R_f}{R_f = 10^9 \Omega}$	e_{no} (5) μV rms $\sqrt{\text{Hz}}$ rms 132 Hz	E_o/e_{no} for $R_f = 10^9$
290	4.8 ⁽¹⁾	7.7	0.46	3.54	0.25	0.89	29 333	2670
350	10.9 ⁽¹⁾	8.7	0.39	3.39	0.17	0.58	" "	1740
400	14.3 ⁽¹⁾	11.4	0.32	3.65	0.16	0.58	" "	1740
500	23.0 ⁽²⁾	18.4	0.29	5.34	0.29	1.55	" "	4650
600	10.5 ⁽²⁾	8.4	0.29	2.44	0.43	1.05	" "	3150
675	12.5 ⁽²⁾	10.0	0.26	2.60	0.50	1.30	" "	3900
777	11.5 ⁽²⁾	9.2	0.24	2.21	0.56	1.24	" "	3720
863	9.3 ⁽²⁾	7.4	0.22	1.63	0.60 ⁽⁴⁾	0.98	29 333	2940

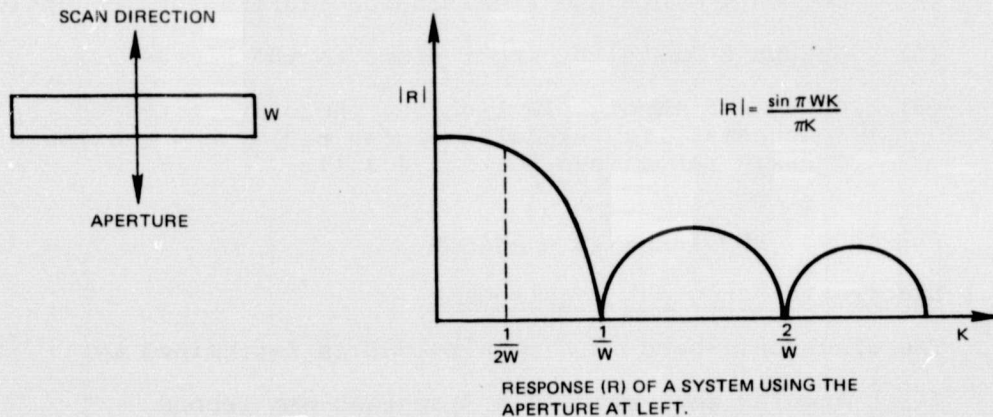
(1) Estimated.

(2) Based on Skylab 78B data.

(3) Optical bandwidth = 20 nm for $\lambda = 290$ nm
= 10 nm for all other λ

(4) Very unstable with temperature above 900 nm.

(5) Measured value.



FOR AN ACCEPTABLE RESPONSE AT A SPATIAL FREQUENCY OF 1 CYCLE/km,
THE APERTURE WIDTH (W) MUST BE:

$$K = 1 = \frac{1}{2W} \text{ OR } W = \frac{1}{2} \text{ km}$$

Figure 4-3. Aperture requirements (dictated by the spatial frequency resolution requirements (1 cycle/km)).

The maximum input radiant power to the APPS radiometer is a function of the source intensity, the clear-aperture area, the solid angle of the field-of-view, and the equivalent optical bandwidths of the filter passband.

$$I_{\omega} = I_{\lambda} A_T \omega_T B_{\lambda} W \quad (4-1)$$

where

$$I_{\lambda} = \text{Maximum spectral radiance of earth limb} \\ = I_{\lambda} \mu\text{W/cm}^2\text{-srad} - \overset{\circ}{A}$$

$$A_T = \text{Telescope clear-aperture area} = 100 \text{ cm}^2$$

$$\omega_T = \text{Field-of-view solid angle} = 0.2 \text{ mrad} \times 4.0 \text{ mrad} \\ = 0.80 \times 10^{-6} \text{ srad}$$

$$B_{\lambda} = \text{Effective optical bandwidth} = 20 \text{ nm for } \lambda = 300 \text{ nm} \\ = 10 \text{ nm for all other } \lambda$$

The input/output characteristics of the receiver system are listed in Table 4-1, and are defined as follows:

- (1) Column 1 lists the wavelengths of interest.
- (2) Column 2 lists the maximum spectral radiance of the earth's limb.
- (3) Column 3 is the computed input radiant power to the instrument using Eq. (4-1). (The actual receiver input power at the diode detector has to take into account the losses in the optical train.)

- (4) Column 4 lists the transmission factors for the optics.
- (5) Column 5 lists the input power to the receivers.
- (6) Columns 6 through 10 list the photodetector-receiver responsivity, signal-to-noise ratio, and available dynamic range (see Section 4.3.1).

4.2 ELECTRONIC REQUIREMENTS - ANALOG

4.2.1 Electronic-Bandwidth Requirement

The electronic-bandwidth requirement is determined by:

- (1) Angular scan rate, $\omega = 3$ degrees per second.
- (2) Distance to the target area, $S = 2524$ kilometers.
- (3) Highest spatial frequency components of the signal source, $K = 1$ cycle per kilometer.

where

$$\Delta f = \omega SK$$

$$\Delta f = (3^\circ \times \frac{\pi}{180^\circ}) (2524) (1)$$

$$\Delta f = 132 \text{ Hz}$$

The scan rate is governed by two principal requirements, resolution and geographical coverage.⁽⁴⁾ These characteristics are related in that:

- (1) The 3σ value of the line-of-sight intensity distribution at 20 kilometers is ± 400 kilometers.⁽⁵⁾
- (2) At $\omega = 3$ degrees per second, the ground-track crossing for successive limb scans of a sun-synchronous spin-stabilized satellite is 853 kilometers.

both of which are less than 1000 kilometers, the value used extensively in establishing large-scale distributions of major atmospheric constituents.

If we require that the ground-track motion during a single scan be no more than the cross-track distance covered by the field-of-view of the scanning aperture, then the relation between the scan rate and the orbital rate is (by definition)

$$\omega_1 S \Delta T \geq \omega_2 R \Delta T$$

where

$$\omega_1 S \Delta T = 100 \text{ km} = \text{altitude scan}$$

$$\omega_2 R \Delta T = 10 \text{ km} = \text{cross-track resolution}$$

or

$$\omega_1 S / \omega_2 R \geq 10$$

$$\omega_1 \geq 10 \omega_2 R / S$$

For a 90-minute orbit, ω_2 is

$$\omega_2 = \frac{2\pi}{90 \times 60} = \frac{\pi}{2700} \text{ rad/s}$$

For

$$R = 6366 \text{ km} = \text{earth radius}$$

$$H_O = 500 \text{ km} = \text{observation height}$$

$$H_T = 20 \text{ km} = \text{tangent height}$$

the slant range S is

$$S = (2R + H_O + H_T) (H_O - H_T)$$

$$S = 2524 \text{ km}$$

Therefore, the scan-rate requirement is

$$\omega_1 \geq 10 \times \frac{\pi}{2700} \times \frac{6366}{2524} = 0.029 \text{ rad/s} = 1.7 \text{ deg/s}$$

A scan rate of 3 degrees per second was chosen for the APPS radiometer design. This rate more than meets the measurement criteria, minimizes the attitude-stabilization requirements, and provides the extensive global coverage desired for large-scale constituent distributions.

4.2.2 Other Electronic Requirements

4.2.2.1 Accuracy

The absolute accuracy of the radiometer's measurements cannot be any better than the absolute calibration standards. Therefore, the absolute accuracy of the receiver will be on the order of 1 percent for each wavelength, with much finer resolution.

4.2.2.2 Resolution and Dynamic Range

Resolution and dynamic range are directly related. Dynamic range is defined as the ratio of the maximum signal to the receiver rms noise. To obtain high resolution in the analysis, a minimum dynamic range of 1000 is desired.

4.3 ANALOG SIGNAL PROCESSING

An analog-signal-processing channel is shown in Figure 4-4. Each of the eight channels consists of a photodiode detector/amplifier combination (radiometer receiver), a low-pass filter, and a sample and hold circuit. The eight channels are time multiplexed into the analog-to-digital (A/D) converter. Seven thermistor networks, which are used to measure the operating temperatures of the radiometer receivers, are also time multiplexed. Each of these analog component specifications is discussed in the following.

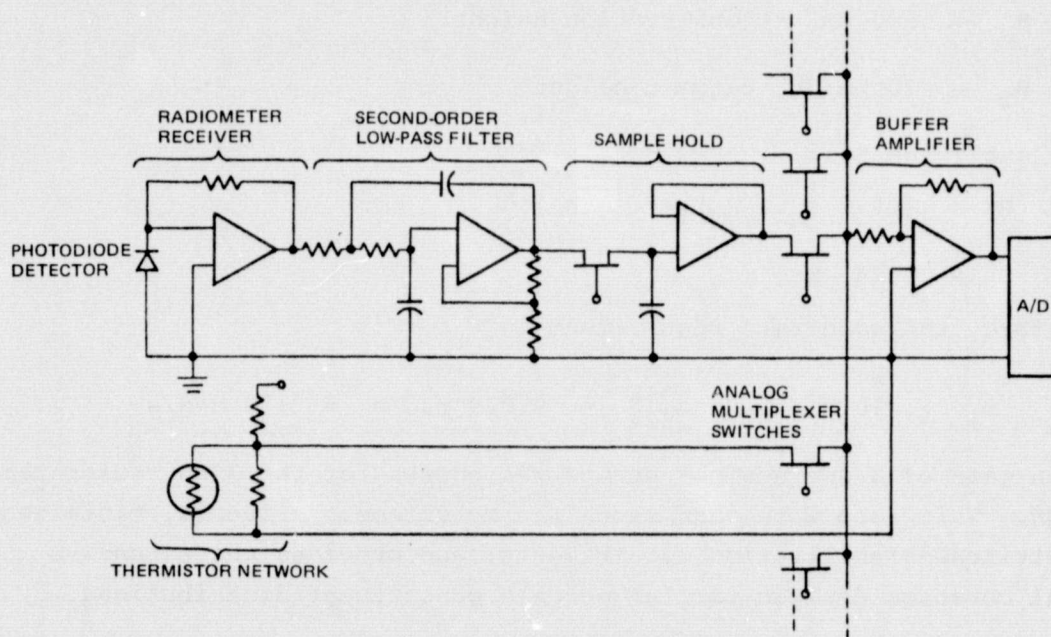


Figure 4-4. Analog signal processing.

4.3.1 Radiometer Receiver

4.3.1.1 Requirements

The receiver characteristics required are:

- (1) Maximum input radiant power (from Column 5 of Table 4-1).
 $I\omega_R = 1.6$ to 5 nanowatts.
- (2) Bandwidth requirements, $\Delta f = 132$ hertz.
- (3) Detector responsivity over the wavelength regions
 $300 \leq \lambda \leq 900$ nanometers.
- (4) Dynamic range = signal/rms noise = $E_o/e_{no} \geq 1000$.

- (5) Detector area > 0.5 millimeter by 1.5 millimeters. The detector area is larger than the focal-plane-aperture image, since it is desirable to keep the measured radiation away from the detector edges.
- (6) Temperature Range — The receivers will be purchased under full military specifications which have an operating temperature range, -55° to $+125^{\circ}\text{C}$. The actual operating temperature range under which the dynamic range requirements have to be satisfied is -20° to $+25^{\circ}\text{C}$.

4.3.1.2 Receiver Selection

The receiver design is shown in Figure 4-5. This low-noise configuration is made possible by the narrow-frequency bandwidth requirements. The receiver consists of an unbiased photodiode operated in the short-circuit photovoltaic mode, an FET input operational amplifier, and a feedback resistor. These three components are mounted on a ceramic-substrate printed circuit. This assembly is then packaged in a gold-plated Kovar case. The case has a quartz window over the ultraviolet-enhanced photodiode. The receiver is offered commercially

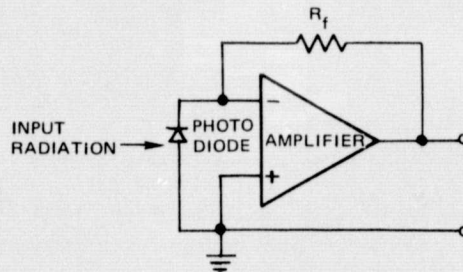


Figure 4-5. Receiver design configuration.

by EG&G with quartz windows in two models: The HUV-1000B, which consists of an EG&G model UV-100B silicon-photovoltaic photodiode, and a high-performance FET operational amplifier; and the HUV-4000B, which consists of an EG&G model UV-444B silicon-photovoltaic photodiode and a similar high-performance FET operational amplifier. The commercial models for both of these receivers are rated for a temperature range from 0° to 70°C , and may also be ordered with full military specifications. The electrical specifications for these two receivers are listed in Table 4-2.

Table 4-2. EG&G operational amplifier/photodiode combinations (HAV & HUV series).

Characteristic	HAV-1000			HUV-1000B			HAV-4000			HUV-4000B			Units and Conditions
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Active Area		5.1			5.1			100			100		nm ²
Spectral Range	350		1150	200		1150	350		1150	200		1150	nm
Responsivity at 900 nm	9.0	9.4		11	12		9.0	9.4		11	12		10 ⁷ VW; R _f = 200 MΩ
Responsivity at 230 nm	-	-	-	3.0	3.5	-	-	-	-	3.0	3.5		10 ⁷ VW; R _f = 200 MΩ
Frequency Range	dc	-	1	dc	-	1	dc	-	0.10	dc	-	0.10	MHz; R _f = 10 kΩ
Noise Voltage at 20 Hz	-	10	-	-	10	-	-	9	-	-	9	-	10 ⁻⁶ W/Hz ^{1/2} ; R _f = 200 MΩ
NEP (900, 20, 1)	-	1.11	-	-	0.87	-	-	0.93	-	-	0.72	-	10 ⁻¹³ W/Hz ^{1/2} ;
NEP (230, 20, 1)	-	-	-	-	3.0	-	-	-	-	-	2.6	-	
Open-Loop Gain	2×10 ⁴	2×10 ⁵		2×10 ⁴	2×10 ⁵		5×10 ⁴	4×10 ⁵		5×10 ⁴	4×10 ⁵		
Bias Current	-	3	50	-	3	50	-	15	50	-	15	50	pA ^{(1), (2)} at +25°C
Offset Current	-	0.5	-	-	0.5	-	-	5	25	-	5	25	pA
Offset Voltage ⁽³⁾	-	10	20	-	10	20	-	3	15	-	3	15	mV
Offset Voltage Drift	-	-	75	-	-	75	-	10	50	-	10	50	μV/°C
Output Resistance	-	80	-	-	80	-	-	80	-	-	80	-	Ω
Slew Rate	-	6	-	-	6	-	-	5	-	-	5	-	V/μs
Supply Voltage	±6	-	±18	±6	-	±18	±12	-	±18	±12	-	±18	V
Supply Current	-	3.4	6.0	-	3.4	6.0		2.2	2.8		2.2	2.8	mA
Power Consumption	-	102	180	-	102	180	-	79	102	-	79	102	mW
Operating Temperature	0	-	70	0	-	70	0	-	70	0	-	70	°C
Storage Temperature	-65	-	150	-65	-	150	-65	-	150	-65	-	150	°C

(1) Without external trim.

(2) Doubles every +10°C.

(3) Adjustable to 0 V with external trim potentiometer.

The recommended design for the APPS receiver is a combination of the electronics of the HUV-1000B and the mechanical package of the HUV-4000B. The electronics of the HUV-1000B give us a 10-to-1 advantage over the HUV-4000B in gain-bandwidth product. At the operating temperatures contemplated (-20° to $+25^{\circ}\text{C}$), there is very little difference between the two receivers other than the gain-bandwidth product. To maintain good temperature control of the diode and amplifier, the HUV-4000B package is recommended. This package, along with the HUV-1000B package, is shown in Figure 4-6. Note that the HUV-4000B package has much more thermal mass than the HUV-1000B, as well as a large heat-transfer surface on one side of the printed-circuit substrate.

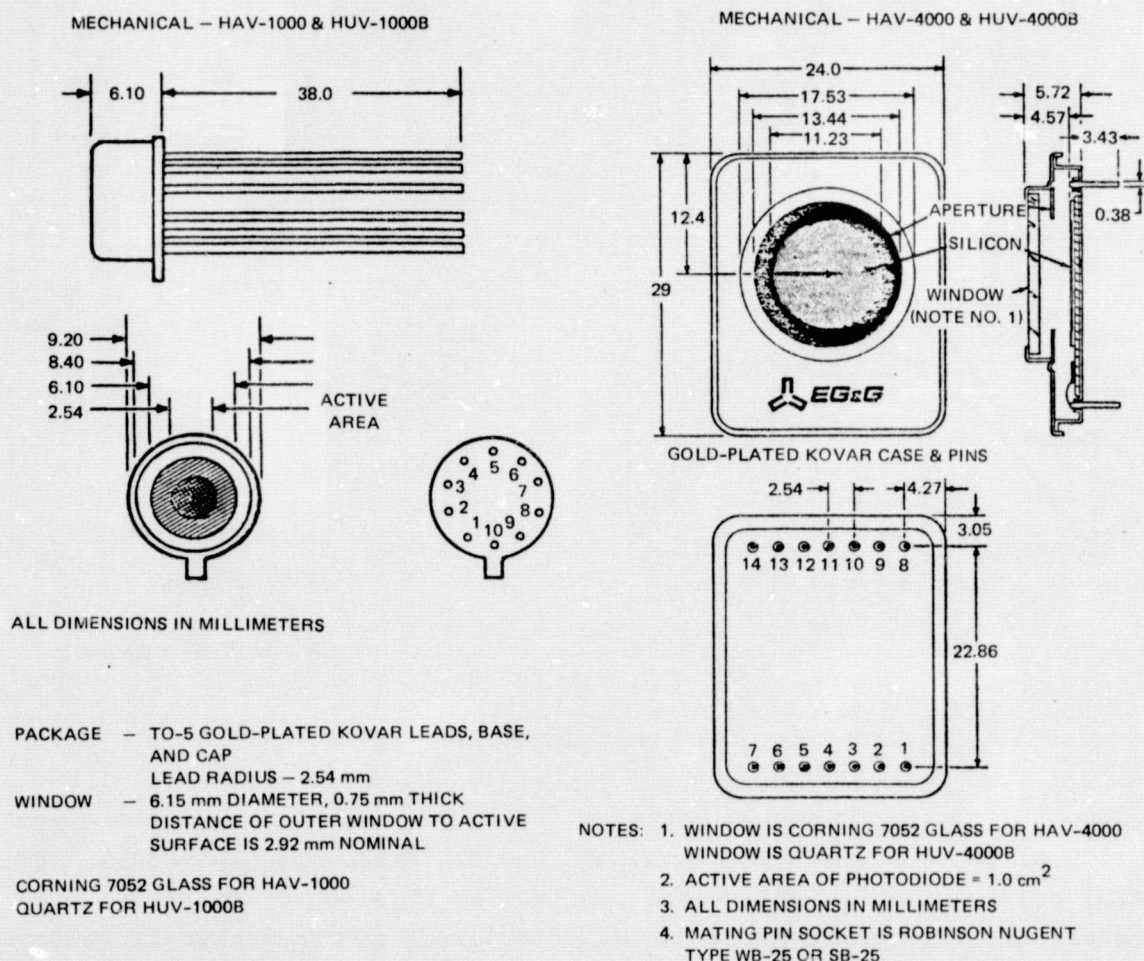


Figure 4-6. EG&G photodiode mechanical specification.

Noise measurements were made on a single HUV-1000B receiver with a 10^9 -ohm feedback resistor. The measurements were made in free air at room temperature after the unit had been allowed to reach thermal stability (approximately 30 minutes). From the peak-to-peak noise, the rms noise is estimated to be 24.5 microvolts per square root of hertz. Allowing for a 20-percent error in this measurement, a worst-case value of 29 microvolts is used to obtain the available dynamic range (see Table 4-1).

Table 4-1 lists the receiver characteristics. Column 6 of Table 4-1 lists the receiver responsivities which were obtained from the published response curves as shown in Figure 4-7. Column 7 lists the receiver output voltage as obtained from the product of the corresponding entries in Columns 5 and 6, and the feedback resistor

$$E_O = I_{\omega} R_I R_f$$

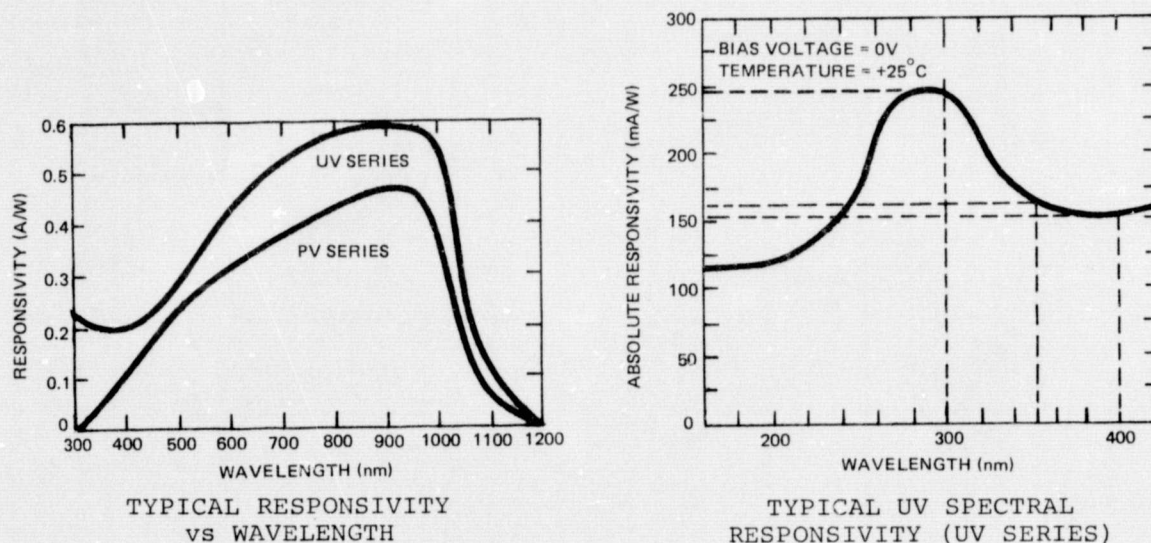


Figure 4-7. EG&G photodiode responsivities.

Column 8 lists the measured noise, which is not a function of the wavelength of the measured radiation, and therefore is a single entry. The total noise in the output of the receiver is obtained by multiplying the per-unit frequency noise by the square root of the system-frequency bandwidth

$$e_{\text{no}(\text{total})} = \left(\frac{e_{\text{no}}}{\sqrt{\text{Hz}}} \right) \sqrt{\Delta f} = 29 \sqrt{132} = 333 \mu\text{V}$$

Column 10 lists the ratio of the entries of Column 7 to the system total noise:

$$\text{Available Dynamic Range} = E_o / e_{\text{no}(\text{total})}$$

The minimum available dynamic range is 1740 for the wavelengths $\lambda = 350$ and 400 nanometers, respectively. Therefore, this receiver and optics design does meet the 1000-to-1 minimum-dynamic-range design specification.

4.3.1.3 Receiver Frequency-Dependent Characteristic

4.3.1.3.1 Gain – The expression for the voltage output of the receiver that takes into account the diode-junction capacitance and the capacitance in the amplifier feedback loop is

$$|E_o| = \frac{I_{\omega R} R_I}{\left[\left(\frac{1}{R_f} + \frac{1}{A} \left(\frac{1}{R_f} + \frac{1}{R_{SH}} \right) \right)^2 + \omega^2 \left(C_f + \frac{C_f + C_j}{A} \right)^2 \right]^{1/2}} \quad (4-2)$$

where

- R_f = Feedback resistance
- R_{SH} = Shunt resistance of diode
- C_j = Diode junction capacitance
- C_f = Capacitance in parallel with R_f
- $\omega = 2\pi f$ = radian frequency
- A = Open-loop gain of amplifier
- $I_{\omega R}$ = Receiver-input power
- R_I = Receiver responsivity (function of λ)

For amplifier gains in the order of 10^5 , this expression reduces to

$$\begin{aligned} |E_o| &= \frac{I_{\omega R} R_I R_f}{(1 + \omega^2 R_f^2 C_f^2)^{1/2}} \quad (4-3) \\ &= I_{\omega R} R_I R_f \text{ for low frequencies} \\ &= I_{\omega R} R_I X_C \text{ for high frequencies} \end{aligned}$$

The cutoff frequency f_c is defined as

$$f_c = \frac{\omega_c}{2\pi}$$

where

$$\omega_c = \frac{1}{R_f C_f}$$

or

$$f_c = \frac{1}{2\pi R_f C_f}$$

for

$$R_f = 10^9 \text{ ohms}$$

and

$$f_c = \frac{159}{C_f} \quad (4-4)$$

where C_f is in picofarads.

Equation (4-4) shows that only a small amount of stray capacitance* between the output and input could severely restrict the available bandwidth of the receiver. For example, a capacitance of 1.2 picofarads limits the bandwidth to 132 hertz, the minimum system bandwidth requirement. Careful circuit layout can limit the stray capacitance to well below 1.0 picofarad.

4.3.1.3.2 Noise - The electronic-circuit model of the operational amplifier and photodiode is shown in Figure 4-8. Figure 4-8 also shows the noise sources for the various parts of this circuit. The definitions of the various components and parameters of the circuit are given in the following.

(1) Photodiode

i_{N_L} = Current noise from stray light

i_{N_D} = Johnson noise current of photovoltaic photodiode
(due to shunt resistance)

* The feedback resistor has a shunt capacitance of $C_f \leq 0.03$ picofarad.

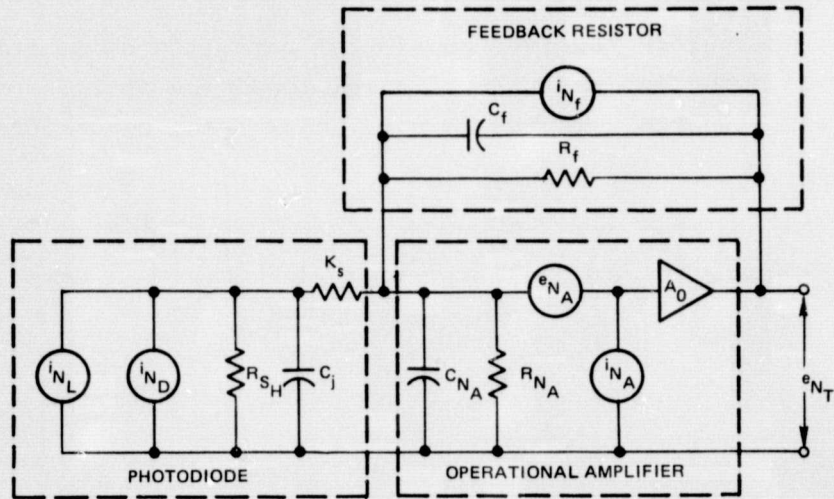


Figure 4-8. Operational amplifier/
photodiode electrical model.

- R_{SH} = Photodiode shunt resistance
- C_j = Photodiode shunt capacitance
- R_S = Photodiode series resistance

(2) Operational Amplifier

- A_O = Noiseless amplifier with frequency-dependent gain
- i_{N_A} = Amplifier input noise current - frequency dependent
- e_{N_A} = Amplifier input noise voltage - frequency dependent
- R_{N_A} = Amplifier input resistance
- C_{N_A} = Amplifier input capacity

(3) Feedback Resistor

- R_f = Feedback resistor - ideal pure resistance
- i_{N_f} = Johnson noise current of feedback resistor
- C_f = Total feedback capacitance (include stray, shunt capacitance of R_f , and any added capacitance)

In any photodiode receiver considered here, the diode series resistor R_S is much less than the parallel impedance of R_{SH} and X_{cj} . Also, C_{N_A} is negligible compared to C_j . Under these conditions, the expression for the output voltage is

$$e_{N_T} = z_f \left[\left(\frac{e_{N_A}}{z_S} \right)^2 + i_{N_A}^2 + i_{N_L}^2 + i_{N_{SH}}^2 + i_{N_f}^2 \right]^{1/2} \frac{V_{rms}}{\sqrt{Hz}} \quad (4-5)$$

where

$$|z_f| = R_f / (1 + \omega^2 C_f^2 R_f^2)^{1/2}$$

$$|z_S| = R_{SH} / (1 + \omega^2 C_j^2 R_{SH}^2)^{1/2}$$

$$i_{N_{SH}}^2 = 4 KT / R_{SH}$$

$$i_{N_f}^2 = 4 KT / R_f$$

$$i_{N_A}^2 = 2 q I_{dc}$$

$$i_{N_L}^2 = 2 q I_L$$

$$e_{N_A}^2 = \begin{array}{l} \text{Mean-square noise of amplifier} \\ \text{Equivalent noise voltage generator} \end{array}$$

$$I_{dc} = \text{Amplifier input bias current}$$

$$I_L = \text{Photodiode current due to stray light}$$

Using these definitions and Eq. (4-5) we get

$$e_{N_T} = \frac{R_f}{(1 + \omega^2 C_f^2 R_f^2)^{1/2}} \left[\left(\frac{e_{N_A}}{R_{SH}} \right)^2 (1 + \omega^2 C_j^2 R_{SH}^2) + \sum i_N^2 \right]^{1/2} \quad (4-6)$$

where the i_N^2 terms are those in Eq. (4-5).

Finally, with the help of Figure 4-9, which shows the amplifier current and voltage noise as a function of frequency, we are in a position to follow the noise-amplitude rms as a function of frequency.

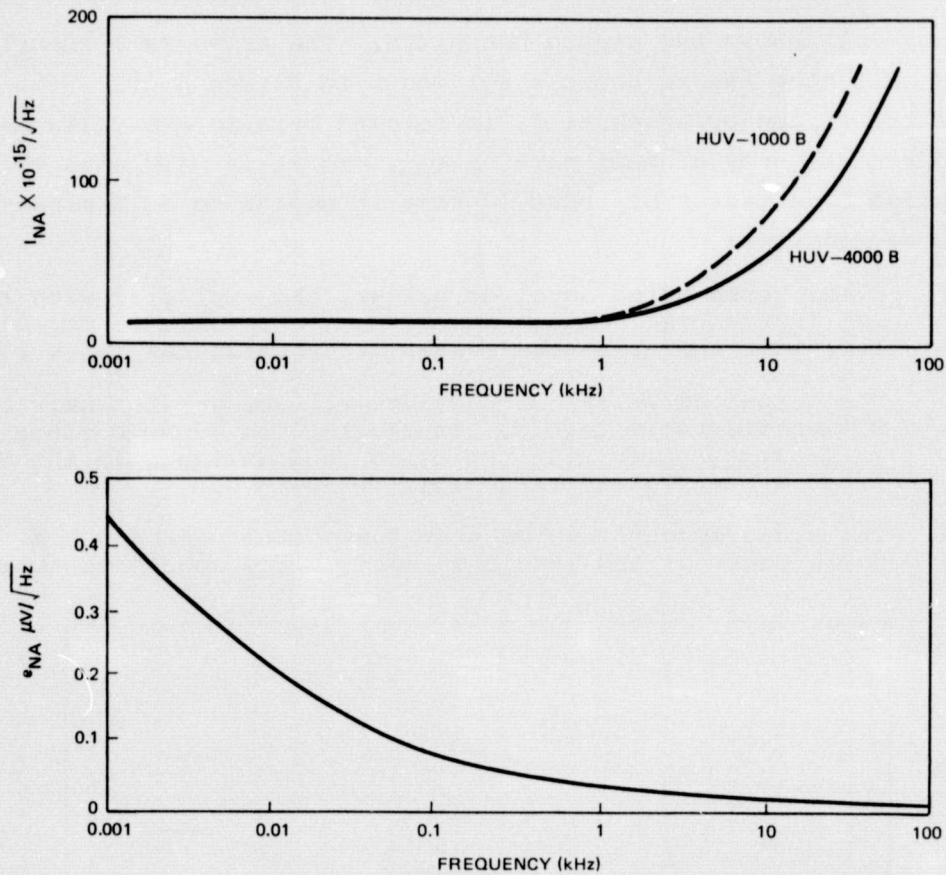


Figure 4-9. Amplifier noise current and voltage characteristics.

At low frequencies less than 1 hertz, the output-noise voltage is dominated by the amplifier-noise-voltage source e_{NA} , which has the characteristic $1/f$ increase. The first frequency break comes at

$$f_1 = \frac{1}{2\pi C_j R_{SH}} = \frac{1}{2\pi \times 150 \times 10^{-12} \times 10^8} \doteq 10 \text{ Hz}$$

At this frequency, the impedance in series with the amplifier-noise-voltage source e_{NA} starts dropping rapidly (see Eq. 4-6). This increases the input-noise current due to e_{NA} . The next frequency break is at the system bandwidth cutoff, f_2 .

$$f_2 = \frac{1}{2\pi C_f R_f} = \frac{1}{2\pi \times 1.2 \times 10^{-12} \times 10^9} \doteq 132 \text{ Hz}$$

From Eq. (4-6), the system bandwidth f_2 attenuates the noise from both the noise-voltage source and the current source. Above f_2 , the next frequency effect is the rapid increase in amplifier-noise current, as shown in Figure 4-9. This occurs at a frequency of about 1 kilohertz,

a frequency well above the system bandwidth. The noise as a function of bandwidth will have the response shape shown in Figure 4-10. Note that the effect of the frequency break at f_1 is delayed because the voltage-noise source represents only a small part of e_{NT} , and it is only when this term is multiplied by a factor of about 10 that it begins to be dominant. The points to be made are:

- (1) Other terms being equal or better, the amplifier with the lowest input-noise voltage should be used. This is especially true when operating the system at temperatures below 25°C .
- (2) The output noise of the receiver will be greater near the system-frequency cutoff. Therefore, the dynamic range at these frequencies will not be as good as those in the mid-band frequencies (1 to 30 Hz).
- (3) The measurement of noise over the system passband includes the noise peaking, and should be used over a spot-check measurement.

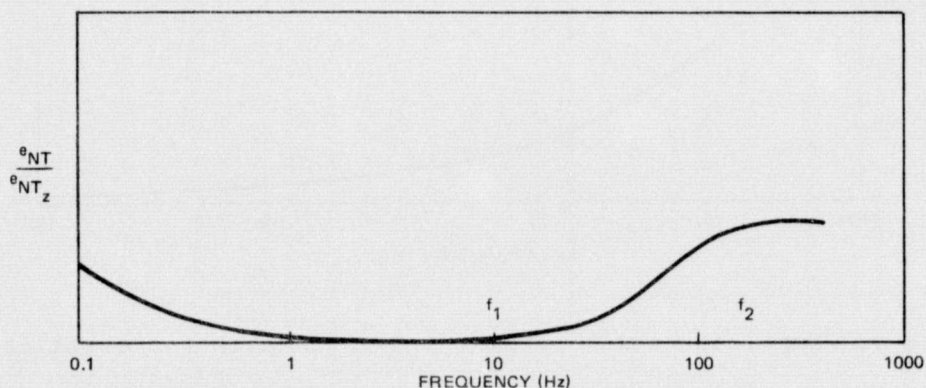


Figure 4-10. Normalized receiver noise characteristics (normalized at 2 Hz).

4.3.1.4 Receiver Temperature-Dependent Characteristics

Of the actions that can be taken to improve the signal-to-noise ratio of the receiver (for a given signal input power), none give better results than the lowering of the operating temperature. Lowering the operating temperature 15°C , from 25° to 10°C would almost halve the rms noise, and therefore double the available dynamic range.

The temperature dependents of the various parameters of the receiver are:

- (1) The amplifier bias current I_{dc} doubles for each 10°C increase in operating temperature.
- (2) The shunt resistance of the photodiode has the temperature characteristic shown in Figure 4-11.

- (3) The temperature dependence of the photodiode is shown in Figure 4-12.
- (4) The temperature coefficient for the feedback resistor R_f is shown in Figure 4-13. For 10^9 ohms the coefficient is -0.1 percent per degree Celsius.

These four parameters are major contributors to the temperature dependence of the receiver. From these characteristics, all parameters move in a beneficial direction when the operating temperature is lowered. Operation between the temperatures 0 to 15°C is recommended. This is achievable, even in the Space Shuttle vehicle, if thermoelectric coolers are employed.⁽⁶⁾

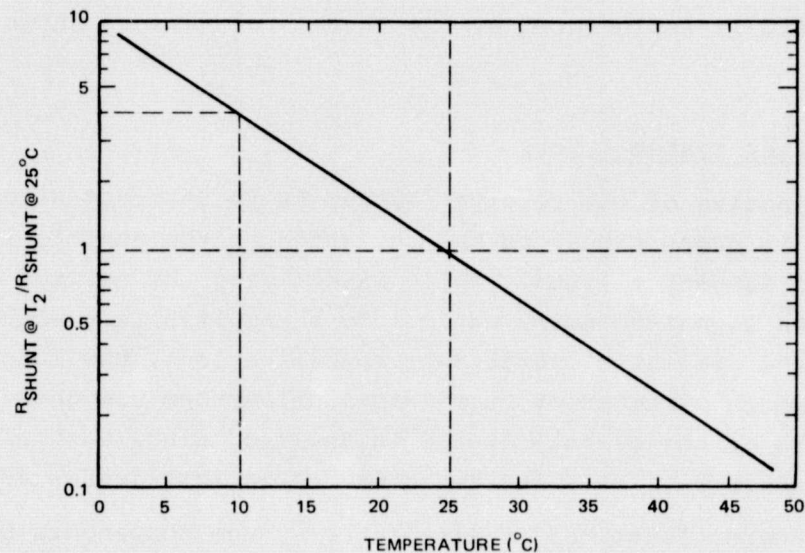


Figure 4-11. EG&G photodiode shunt resistance versus temperature.

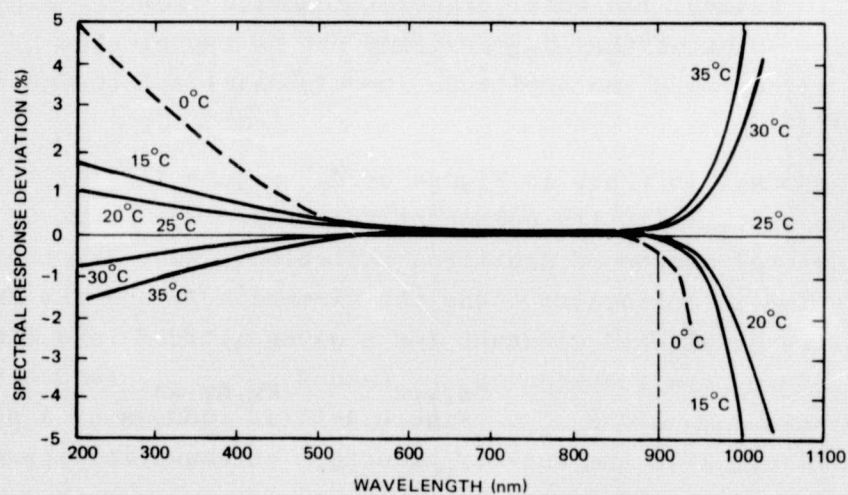


Figure 4-12. EG&G photodiode.

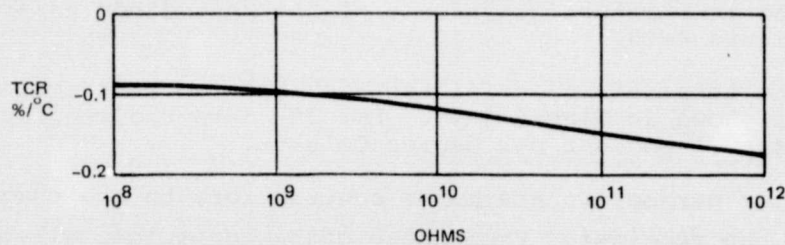


Figure 4-13. Temperature coefficient of feedback resistor.

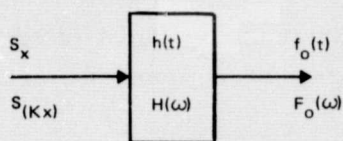
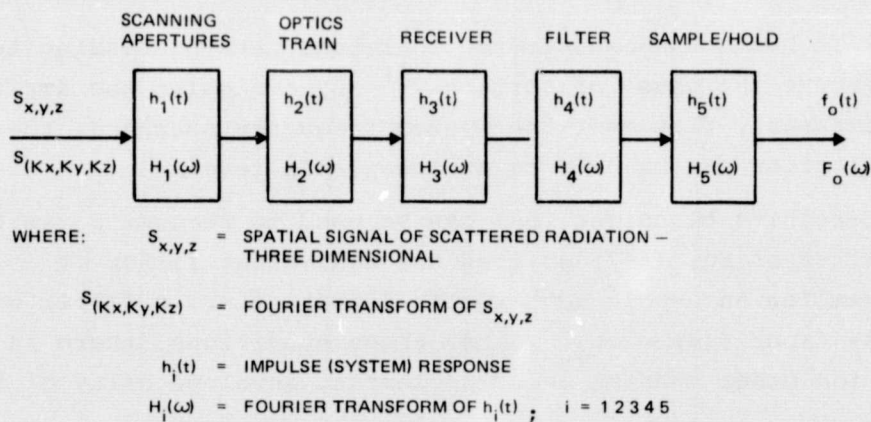
The temperature coefficient of the feedback resistor, and the deviation of photodiode responsivity (Figures 4-12 and 4-13), along with the need to control temperature, dictate the need to measure temperature. This is implemented by the thermistor network shown in Figure 4-4.

4.3.1.5 Receiver-System Errors

The objective of the receiver system is to generate an output voltage that is proportional to the radiation of the earth's limb as a function of tangent altitude, while maintaining the desired altitude resolution and signal-to-noise ratio. To accomplish this with a compact design and realistic operational specifications, the information must pass through a number of less-than-ideal system components. Therefore, analysis of the overall system is desired, since each of these system components will have its own characteristic transfer function.

The transfer functions of all of the system components between the signal source and the A/D converter are linear, and, at least for the duration of a measurement, are time invariant. Therefore, using linear-system theory, the total transfer function from the signal source to the input of the A/D converter can be represented by a single equivalent filter with the amplitude function $A(\omega)$ and the phase function $e^{j\theta(\omega)}$.

This process is shown in Figure 4-14. Figure 4-14(a) illustrates the transfer system with its component features. The input $S_{x,y,z}$ is a three-dimensional source of scattered radiation. However, the line-of-sight radiation is integrated along the dimension Z , and the cross-track dimension Y is considered constant for a given altitude and field-of-view. Therefore, the functions $S_{x,y,z}$ and $S_{(Kx,Ky,Kz)}$ reduce to the single-dimensions S_x and $S_{(Kx)}$. Figure 4-14(a) reduces to a single equivalent filter with the Fourier transform as shown in Figure 4-14(b).



$$\text{WHERE } H(\omega) = H_1(\omega) H_2(\omega) H_3(\omega) H_4(\omega) H_5(\omega)$$

Figure 4-14. APPS transfer functions.

In general, the system functions $H_i(\omega)$ of Figure 4-14(a) are complex frequency functions and can be expressed as

$$H_i(\omega) = A_i(\omega) e^{j\theta_i(\omega)}$$

Therefore, $H(\omega)$ can be written as

$$H(\omega) = A(\omega) e^{j\theta(\omega)}$$

where

$$A(\omega) = \prod_i A_i(\omega)$$

$$\theta(\omega) = \sum_i \theta_i(\omega)$$

The equivalent filter output is $f_o(t)$. Its Fourier transform is

$$f_o(t) = S(Kx)H(\omega) = S(Kx)A(\omega)e^{j\theta(\omega)}$$

Inasmuch as $f_o(t)$ differs from $S_{(Kx)}$, the measured signal is a distorted rendition of S_x .

To obtain $S(Kx)$ from the recorded signal, which is stored digitally and is accessible in the ground computer complex, the signal can be reversed in time and passed through a replica of the equivalent

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4.3.4 Thermistor Network

The thermistor network is based on a design suggested in an Explorer Missions Planners Handbook⁽⁸⁾ and is illustrated in Figure 4-15. The excitation voltage for these networks is derived from a temperature-compensated zener diode. This excitation voltage is itself measured by the A/D converter, and is used as a check on the operation and calibration of the measurement system. The requirements of the thermistor are:

- (1) Accuracy: $\pm 1^{\circ}\text{C}$ over range -20°C to $+35^{\circ}\text{C}$
determined by the receiver responsivity
deviation with temperature
 $\pm 2^{\circ}\text{C}$ over range -55°C to $+125^{\circ}\text{C}$
- (2) Time Constant: 10 seconds maximum, small compared to one rotation at 3 degrees per second (120 seconds).

4.3.5 Analog Multiplexer

The function of the analog multiplexer is to switch a selected signal into the input of the buffer amplifier while preventing crosstalk from the other 15 signal inputs (see Figure 4-4).

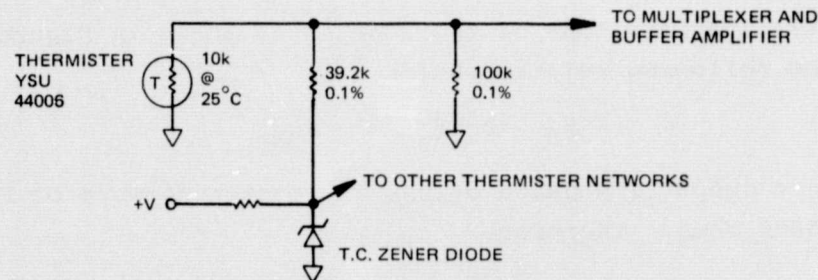
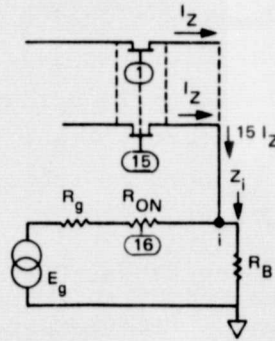


Figure 4-15. Thermistor network.

4.3.5.1 Multiplexer-Switch Leakage Current

Since all signals are low frequency, all the crosstalk is caused by the dc leakage current in the multiplexer switches. Figure 4-16 shows the equivalent circuit of the multiplexer with one of the inputs switched on and the 15 others switched off. The worst-case condition is when the signal from one of the thermistor networks is switched. It is the worst-case because the equivalent signal-generator output impedance of the thermistor network is far greater than any of the other signal sources.



- I_z = LEAKAGE CURRENT OF A SINGLE SWITCH IN THE OFF STATE
- R_B = INPUT RESISTANCE OF THE BUFFER AMPLIFIER
- R_g = EQUIVALENT RESISTANCE OF THE THERMISTOR NETWORK
- R_{ON} = ON RESISTANCE OF A MULTIPLEXER SWITCH
- Z_i = EQUIVALENT RESISTANCE OF THE SWITCHED CIRCUIT AT POINT i

Figure 4-16. Multiplexer equivalent circuit.

The relative magnitude of the impedances shown in Figure 4-16 is such that the following relation holds

$$R_B \gg R_g \gg R_{ON}$$

The equivalent output impedance of the thermistor network of Figure 4-14 at 35°C is 5000 ohms. Therefore

$$Z_i \approx R_g = 5000 \Omega$$

The voltage generated at point (i) of Figure 4-16 by the total leakage current ($15I_z$) is

$$V_1 = 15I_z Z_i = 15I_z R_g \quad (4-7)$$

This voltage represents an error in the thermistor-network output. This error should be less than the voltage output change for the desired temperature resolution of 0.5°C . The voltage output of the thermistor is

$$\Delta V_O = \frac{39.2 V_i \Delta R_T}{(R_T + 39.2)^2} \quad (4-8)$$

where

$$V_i = \text{Zener diode voltage} = 6.2 \text{ V}$$

$$R_T = \text{Resistance of the thermistor at temperature } T$$

The worst case over the range -20°C to $+35^{\circ}\text{C}$ is at 35°C . For

$$T = 35^{\circ}\text{C}$$

$$\Delta R_T = 132 \, \Omega \text{ for } \Delta T = 1/2^{\circ}\text{C}$$

$$R_T = 6752 \, \Omega$$

$$\Delta V_O = \frac{39.2 \times 6200 \times 0.132}{(6.752 + 39.2)^2} = 15 \text{ millivolts}$$

To satisfy the error criterion we have

$$15I_Z R_g \leq \Delta V_O = 15 \times 10^{-3}$$

or

$$I_Z \leq \frac{15 \times 10^{-3}}{15 \times 5000} = 200 \text{ nA}$$

A leakage current per switch of 200 nanoamperes over the operating temperature range of -20° to $+35^{\circ}\text{C}$ is easily achievable with available commercial multiplexers.

4.3.5.2 Switch ON Resistance

The ON resistance of the multiplexer switch is in series with the input resistor of the buffer amplifier. Therefore, any variation in this resistor represents a gain error in the buffer amplifier. However, each analog channel would be calibrated for overall gain so that this error would be taken out. The magnitude of this switch ON resistance should be small compared to the buffer amplifier input resistance, so that any variations due to temperature change would be negligible. One part in 1000 would make it within the accuracy of the buffer amplifier input resistance.

$$R_{ON} \leq R_B/1000 = 250 \, \Omega$$

A summary of the analog multiplexer-switch requirements are given in the following.

4.3.5.3 Analog Multiplexer-Switch Requirements Summary

- (1) Analog signal input voltage range: 0 - 10 volts.
- (2) Switch ON resistance: $R_{ON} \leq 250$ ohms.
- (3) Switch OFF state leakage current: $I_z \leq 200$ nanoamperes.
- (4) Operating temperature range: -20° to $+35^{\circ}\text{C}$.

4.4 ELECTRONICS DESIGN - DIGITAL

4.4.1 Basic Design Decisions

Initially, it was decided to implement a system concept that was adaptable to various mission requirements. Requirements such as data formatting, coding, mirror drives, temperature measurement and control, and system moding would be better handled by a microprocessor-based system than by fixed control logic. The 500-kilometer sun-synchronous orbits contemplated for the operational vehicles made the radiation requirements low enough so that CMOS could be used.^(9,10) This fact, and the availability of a CMOS microprocessor with a broad line of supporting circuits, including read-only (ROM) and random-access (RAM) memory, encouraged the design of a CMOS-microprocessor-based system. The high-noise-immunity and low-power-consumption properties of CMOS made this choice an attractive one.

4.4.2 System Description

Figure 4-17 is the system block diagram. A detailed drawing of the APPS Electronics System as described is given in the Appendix in drawing P/N 236300. This particular system is designed around the interface requirements of the Space Shuttle vehicle. As such, the system has the following features:

- (1) The analog section including all of the system components discussed in Section 4.3 (see Figure 4-17).
- (2) Data-output section (see Figure 4-17). This section receives formatted data in binary form from the CPU via the data bus and the three output registers. The transmit clock generator uses a 1024-kilohertz timing signal obtained from the Space Shuttle master timing system to generate the necessary timing for the output encoder. The output encoder is the block named NRZ TO BI-PHASE-L-CONVERTER. This block converts the no-return-to-zero binary output to the required BI-PHASE-L code, as required by the S-band radio-transmission system. The BI-PHASE-L code has a waveform which is ideal for magnetic-tape recording.

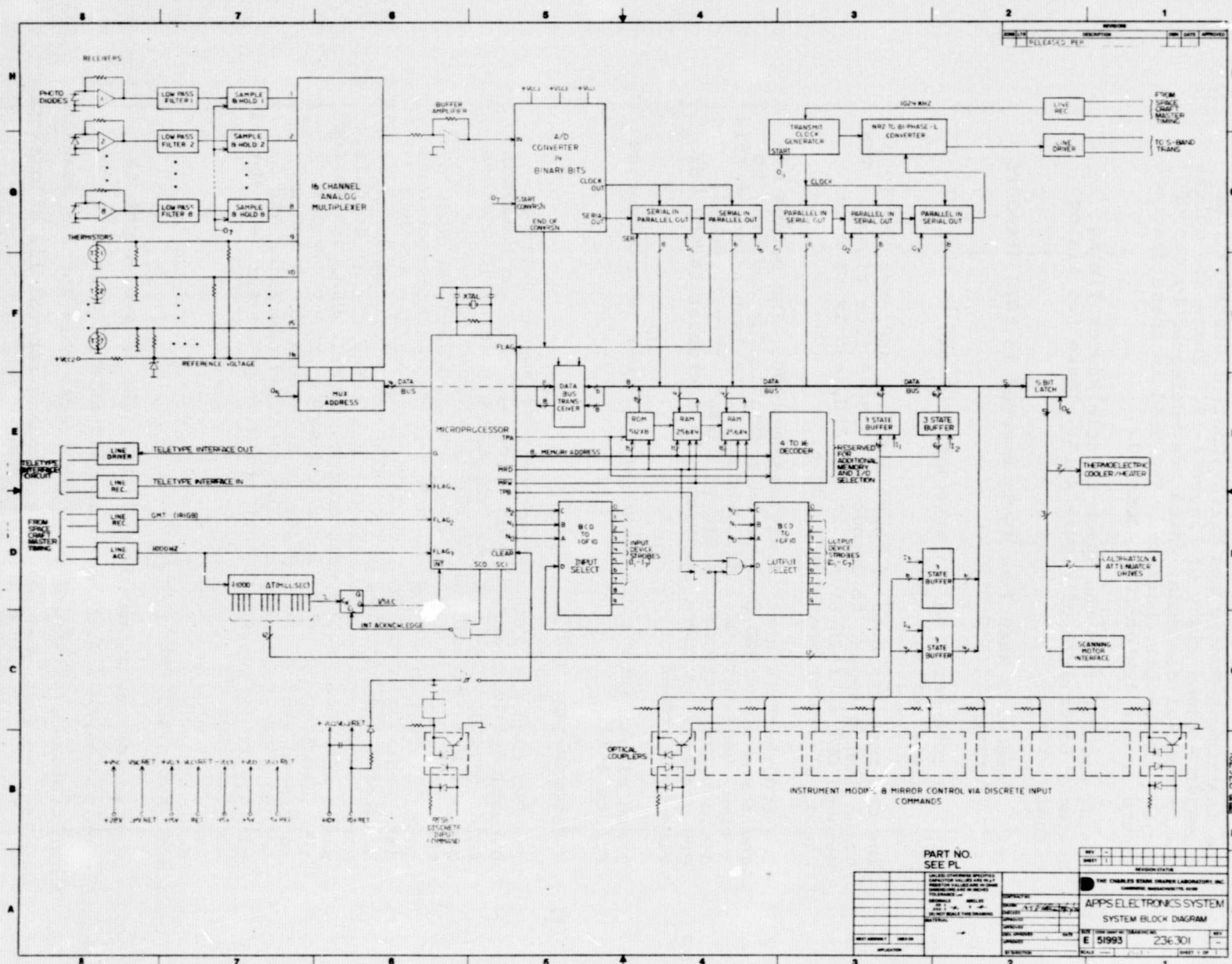


Figure 4-17. APPS electrical systems block diagram.

- (3) Mirror Drives — Right side of Figure 4-17. This block consists of the drive for the two calibration mirrors and the scanning mirror.
- (4) The Instrument-Moding and Mirror-Control Discrete Input Commands — Lower right of Figure 4-17. These are uplink system-control commands, which are monitored by the CPU via the three-state buffers. Included in these discrete inputs is the system-reset command.
- (5) Timing Signals from the Space Shuttle Master Timing System — Lower left of Figure 4-17. These two timing signals are:
 - (a) Greenwich Mean Time (GMT) encoded in IRIG Standard Format B (IRIG-B).
 - (b) A 1000-hertz square wave synchronized to the IRIG-B signal of item (a).

The CPU receives both of these signals, and uses the 1000-hertz timing signal to decode the IRIG-B time signal. The decoded GMT is then stored in the CPU, and is used to encode blocks of measurement data.

The 1000-hertz signal is divided by 1000. The output of the three-stage BCD divider is available for encoding to a time resolution of 1 millisecond. The last stage of this divider generates CPU interrupt pulses every 1 second. The CPU responds to these interrupts by incrementing the GMT time by 1 second.

These signal inputs are found in the lower left corner of Figure 4-17.

- (6) Microprocessor (CPU)

The CPU ties the system together. It has an 8-Bit Bi-Directional Data Bus through which all data and commands enter or leave the system. The CPU has an 8-bit Address Bus which is effectively a 16-Bit Address Bus by using the timing pulses TPA and TPB. The CPU gets its step-by-step instructions from the ROM. It stores and retrieves data from the RAM. The CPU timing pulses MRD and MRW determine the external device READ and WRITE functions. For I/O device control, the CPU has three timing signals, along with the memory read control signal, MRD, allows for the selection of seven input and seven output devices. In Figure 4-17 these I/O device selectors are shown as BCD TO 1 OF 10 selectors. For detailed operation and timing, it is suggested that the Microprocessor User Manual be consulted.⁽¹¹⁾

4.5 DATA RATE AND STRUCTURE

The operation of the system is such that the line-of-sight is scanned through the earth's limb at an angular rate of 3 degrees per second. At an orbital altitude of 500 kilometers, this angular scanning rate is equivalent to a tangent altitude scanning rate of 132 kilometers

per second. The spatial signal has an upper frequency limit of 1 cycle per kilometer, which gives an input signal frequency of 132 cycles per second. The sample rate is a strong function of the presampling filter characteristics. A safe estimate for a second-order filter is five samples per cycle, or a sample rate of:

$$132 \times 5 = 660 \text{ samples/s}$$

Each sample is made up of eight words, one for each wavelength sensor (λ_1 --- λ_8). The data rate is determined by the sample rate, the number of words per sample, and the encoding scheme or data structure.

An example of a data structure that could be used for this system is shown in Figure 4-18. Each limb scan is identified by a block of data containing the time in days, hours, minutes, and seconds (see Figure 4-18). Each measurement sample consists of eight frames, one for each wavelength, and one frame containing time in milliseconds which identifies the particular sample. In addition to the data or time bits, each frame has 4 bits which identify the data type (radiance, temperature, calibration, voltage, etc.) and 4 bits which identify a particular sensor. The data section of each frame consists of 16 bits, and has room for the data (14 bits) plus 2 bits that can be used for parity checks.

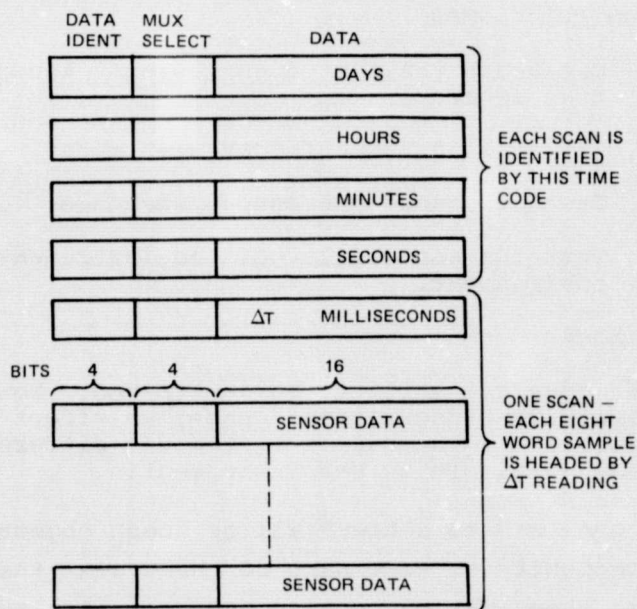


Figure 4-18. Data structure for a limb scan.

With this data structure the data rate is calculated as:

$$\begin{aligned}\text{Data Rate} &= \text{bits/frame} \times \text{frames/sample} \times \text{samples/s} \\ &= 24 \times 9 \times 660 \\ &= 142,560 \text{ bits/s}\end{aligned}$$

A clock rate of 128,000 pulses per second is easily obtainable by counting down the 1,024,000-pulses-per-second timing signal (see Figure 4-17). Using this timing signal allows for a sample rate of 4.5 times the highest system frequency component (132 hertz).

4.6 DISCRETE COMMANDS AND SYSTEM MODING

System control is achieved via the discrete command inputs (see Section 4.4.2.4). These commands are sent from the ground via the telemetry system. An example of a system command list for this system is shown in Table 4-3. Table 4-4 lists the various functions that take place in each of the four instrument modes.

4.7 TEST AND CALIBRATION SYSTEM

4.7.1 Design Philosophy

The objectives of the Test and Calibration System are:

(1) System Objectives

- (a) Calibrate the instrument using a known input radiation source.
- (b) Test all instrument-operation modes.
- (c) Test all input and output channels.
- (d) Test the sensitivity of the instrument to power and environment.

(2) Test Modes

These modes are still to be determined. However, during the instrument-development phase, an effort will be made to minimize the number of test modes different from those already available in the instrument.

The design goal was to achieve all of these objectives without adding circuit complexity to that part of the system that is launched into space. Other than test connectors and a small circuit used during the development stage to communicate with a Teletype terminal, this goal was achieved.

Table 4-3. APPS commands from ground control via telemetry.

1. Power Up }	Turns a Relay On/Off
2. Power Down }	
3. Reset	Reset Microprocessor
4. Calibration Mirror	In
5. Calibration Mirror	Retract
6. Attenuator Mirror	In
7. Attenuator Mirror	Retract
8. Scanning Mirror	Operate
9. Scanning Mirror	Stow
10. Instrument Mode 1	Automatic
11. Instrument Mode 2	Calibration (Transmission Diffuser)
12. Instrument Mode 3	Housekeeping
13. Instrument Mode 4	Calibration (Solar Attenuator)

Table 4-4. Instrument Modes

Instrument Mode 1 - Automatic	Instrument Mode 2 - Calibration (Transmission Diffuser)
Using the radiation measurement of a given wavelength, the microprocessor calculates limb start times and schedules the following tasks: 1. Limb measurements 2. Albedo measurements 3. Radiometer calibrations 4. Temperature measurements 5. Voltage measurements 6. Memory testing 7. Data record and/or telemetry	After having positioned the calibration mirror, using the transmission-diffuser line-of-sight, the microprocessor schedules a series of readings. Each reading consists of a set of radiation measurements and time.
Instrument Mode 3 - Housekeeping	Instrument Mode 4 - Calibration (Solar Attenuator)
In this Mode only temperature and voltage measurements are made.	Same as Mode 2 except Direct Solar Calibration is achieved. After having positioned the solar attenuator, the microprocessor schedules a series of direct solar-calibration readings. Each reading consists of a set of radiation measurements and time.

4.7.2 Test Signals

4.7.2.1 Instrument Input Test Signals

The input test signals needed to test the instrument are the following:

- (1) A calibrated light source to test the receivers.
- (2) A IRIG-B-encoded GMT signal.
- (3) A 1000-hertz square wave synchronized to the GMT signal.
- (4) A 1024-kilohertz square wave.
- (5) Discrete command inputs.

In addition, a source of power equivalent to the spacecraft power, which is controllable over the specified range, is needed.

4.7.2.2 Instrument Output Signals

All output data from the instrument is transmitted to the spacecraft telemetry system over one line in a BI-PHASE-L format.

The only other outputs needed are instrument-power test points so that the radiometer power supplies can be monitored. The teletype input/output is used only during the radiometer-development phase.

4.7.3 Displays and Controls

The displays and controls needed to test and control the system are shown in Figure 4-19.

4.7.3.1 System Power and Reset

At the top right of the control panel is a three-position power switch. This switch is used to select the primary power available at the testing site—28 volts dc or 115 volts 60 Hz. Alongside the Power-Control Switch is the System-Reset pushbutton switch. This switch resets the microprocessor, which, in turn, initializes the system according to the positions of the various control switches on the panel (Mode Select, Multiplexer-Select switch (MUX) Select, etc.).

4.7.3.2 Digital Voltmeter Test Group

This group is located in the upper left corner of the panel. It consists of the following items.

- (1) On/Off Switch. This switch controls power to the Panel Meter.

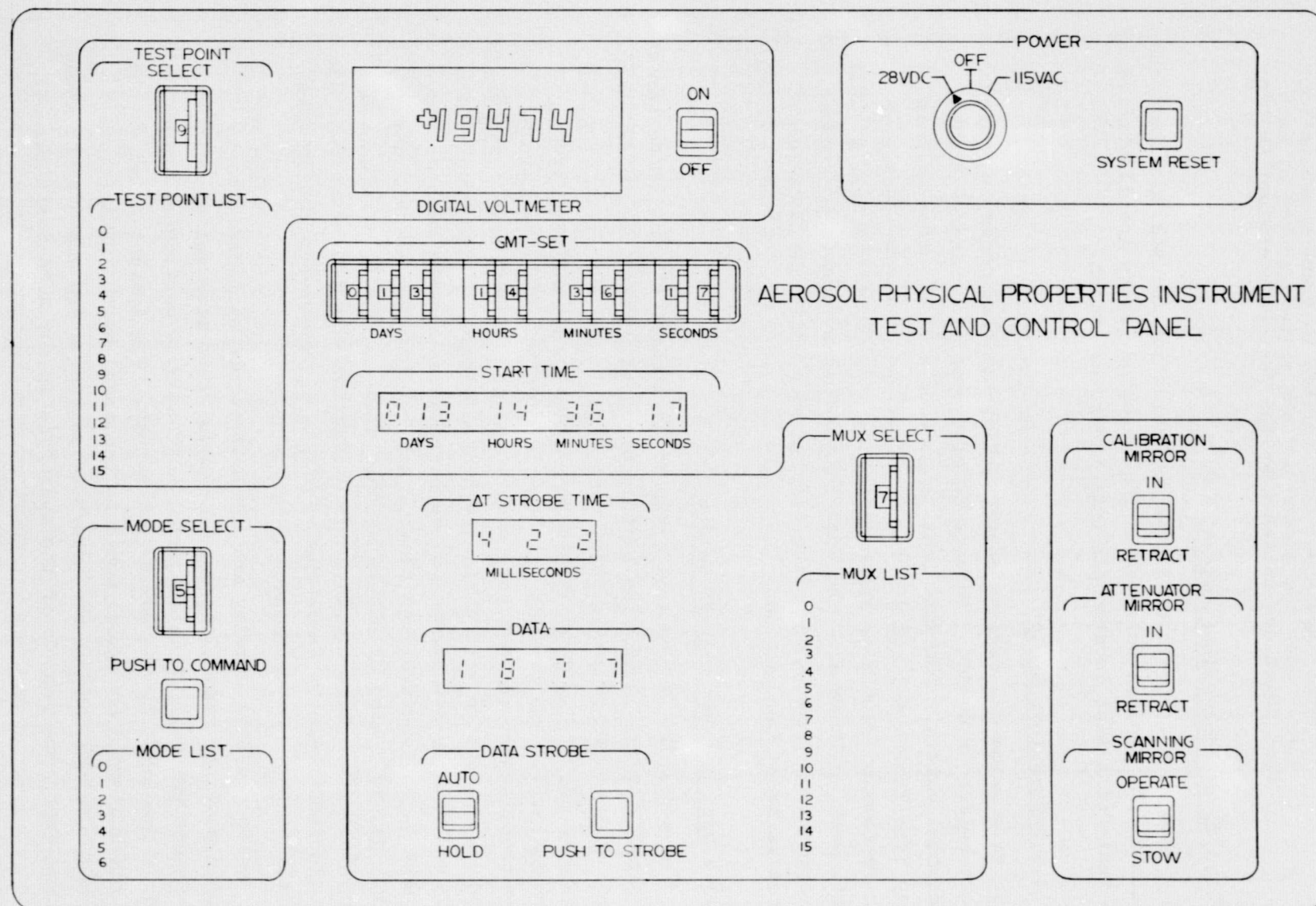


Figure 4-19. APPS control panel.

- (2) Panel Meter. This is a 4-1/2-digit digital panel meter. The meter inputs are dc, isolated to prevent ground-loop noise. Both the ground and the voltage source of each test point are switched by the Test-Point-Select Switch.

4.7.3.3 Test-Point-Select Switch

This is a 16-position 2-pole switch, which is used to select the inputs to the digital voltmeter. The selected inputs are identified by the Test-Point List located directly under the switch.

4.7.3.4 Mode-Select Group

To command the various instrument operational modes, a Mode-Select switch is needed. This is an eight-position binary-encoded thumbwheel switch. The Mode List is located at the bottom of this group (see Tables 4-3 and 4-4 for descriptions of these modes). A Push-To-Command switch is shown in this group, which has not, at this point, been implemented. The idea behind this switch is to prevent the microprocessor from implementing a false mode while the Mode-Select switch is being manipulated.

4.7.3.5 Data Display and MUX Select

This display and control group is located at the bottom center of the panel. On the right side of this group is located the Multiplexer-Select switch (MUX Select). Directly below is the MUX list. The MUX list is simply the list of inputs to the analog multiplexer (see Section 4.3.5). The present list consists of the eight receivers, seven thermistors, and one reference voltage. The MUX-Select switch is a 16-position switch with a binary-encoded output. It is used internally to identify and strobe the selected data into the data display. The data is not decoded from binary, but is displayed as four hexadecimal digits. Also displayed in this group is the ΔT Strobe Time in milliseconds. This display, in conjunction with the Start-Time display (located directly above the ΔT display), represents the precise time that the present displayed data was taken.

Below the DATA display are the DATA-Strobe switches. These switches would be used along with a special test mode set up by the Mode-Select switch. In this special test mode, a particular input would be commanded by the MUX-Select switch. The instant at which the measurements would be taken, would be commanded by the DATA-Strobe switches. In the case of the Auto/Hold switch, a new measurement would be taken every few seconds if the switch is in the Auto position. If

this switch is in the Hold position, a new measurement can be commanded by pushing the Push-To-Strobe button. This feature allows a particular input to be conveniently monitored.

4.7.3.6 GMT-SET

This is a group of nine thumbwheel switches that are used to initialize the microprocessor internal clock. Once these switches are set to the desired start time, this part of the system can be checked by pushing the System-Reset button. When this is accomplished, the GMT-SET data is encoded into the IRIG-B format and transmitted to the APPS Electronics Microprocessor. The microprocessor decodes and stores the GMT time as part of the initialization process. As another part of this initialization process, the microprocessor transmits this start time. This data, encoded at BI-PHASE-L, is received by the Test and Control electronics, where it is decoded into straight binary-encoded decimal, and strobed into the Start-Time display. The first Start-Time display should read within 1 second of the GMT-SET switches. From then on, the Start-Time display will display the real updated or simulated time.

4.7.3.7 Mirror Controls

The Mirror Controls, located on the bottom right of the control panel, are used to override the system operations as called for by the Mode-Select switch.

4.7.4 Test and Control Electronics System and Logic Diagrams

The system diagram for the Test and Control Panel is illustrated in Figure 4-20, P/N 236302. This diagram shows the various subsystems required to implement the test functions as discussed in Section 4.7.3. The implementation of these subsystems in terms of detailed logic design is illustrated in the Test and Control Panel Logic Diagram, P/N 236303.

4.8 POWER

The estimated power needs for the APPS radiometer (not including the Test and Control System) are given in Table 4-5. This estimate includes the power loss in the dc/dc converters. The power converters convert the 28-volt-dc primary power into the +5, +10, +15, and -15 volts dc power used in the digital and linear circuits. The power distribution, grounding and voltage measurements for the APPS radiometer and the Test and Control Panel are illustrated in Figure 4-21, P/N 236304.

Figure 4-20. APPS electronics system test and control panel, system diagram.

Table 4-5. APPS radiometer estimated power.

Circuit Dissipation	
+5 Vdc	1400 mW
+10 Vdc	820 mW
+15 Vdc	2500 mW
-15 Vdc	<u>2500 mW</u>
Total	7220 mW
Assumed Converter Efficiency	65%
Total Electronics Power (7220/0.65)	11.1 W
Scanning Motor and Miscellaneous	5.2 W
Thermal Control	6.1 W
Expansion	<u>0.9 W</u>
Total 28-Vdc Primary Power	23.3 W

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