FOS-UCSD-SE-01
ISSUE: ~~REV. A~~
DATE: 14 JULY 1980

SYSTEMS DESCRIPTION

OF THE

FAINT OBJECT SPECTROGRAPH

APPROVED:

UCSD ______________________ DATE: 20 Sept 80

GSFC ______________________ DATE: ________

ATTACHMENT I

FOS-MMC-SE-Ø1 FAINT OBJECT SPECTROGRAPH

SYSTEMS DESCRIPTION

REVISION A

(MARTIN MARIETTA CORPORATION)

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Approved by:

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Director
FOS Program

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1.0 INTRODUCTION

The purpose of this FOS System Description is to provide the user with the descriptive information needed to understand the Faint Object Spectrograph design.

2.0 SYSTEMS REQUIREMENTS SUMMARY

2.1 Performance Capability

The major scientific goals of the FOS, in conjunction with the Space Telescope, have been discussed in the original technical proposal to NASA (UCSD No. 10002, 8 July 1977). Based on these goals, a comprehensive set of performance parameters have been developed. These parameters provide the basic requirements from which the instrument design is derived. The emphasis in these parameters is to provide a high sensitivity, stable instrument which can be operable in space for a three-year period.

A brief summary of the major observational capabilities is given below:

High Resolution

$R = 10^3$ (+500, -0)

Spectroscopy 114nm $\leq \lambda \leq$ 900nm

Low Resolution

$R = 10^2$ ($\pm$ 50)

Spectroscopy 120nm $\leq \lambda \leq$ 800nm

Spectropolarimetry

120 $\leq \lambda \leq$ 320nm

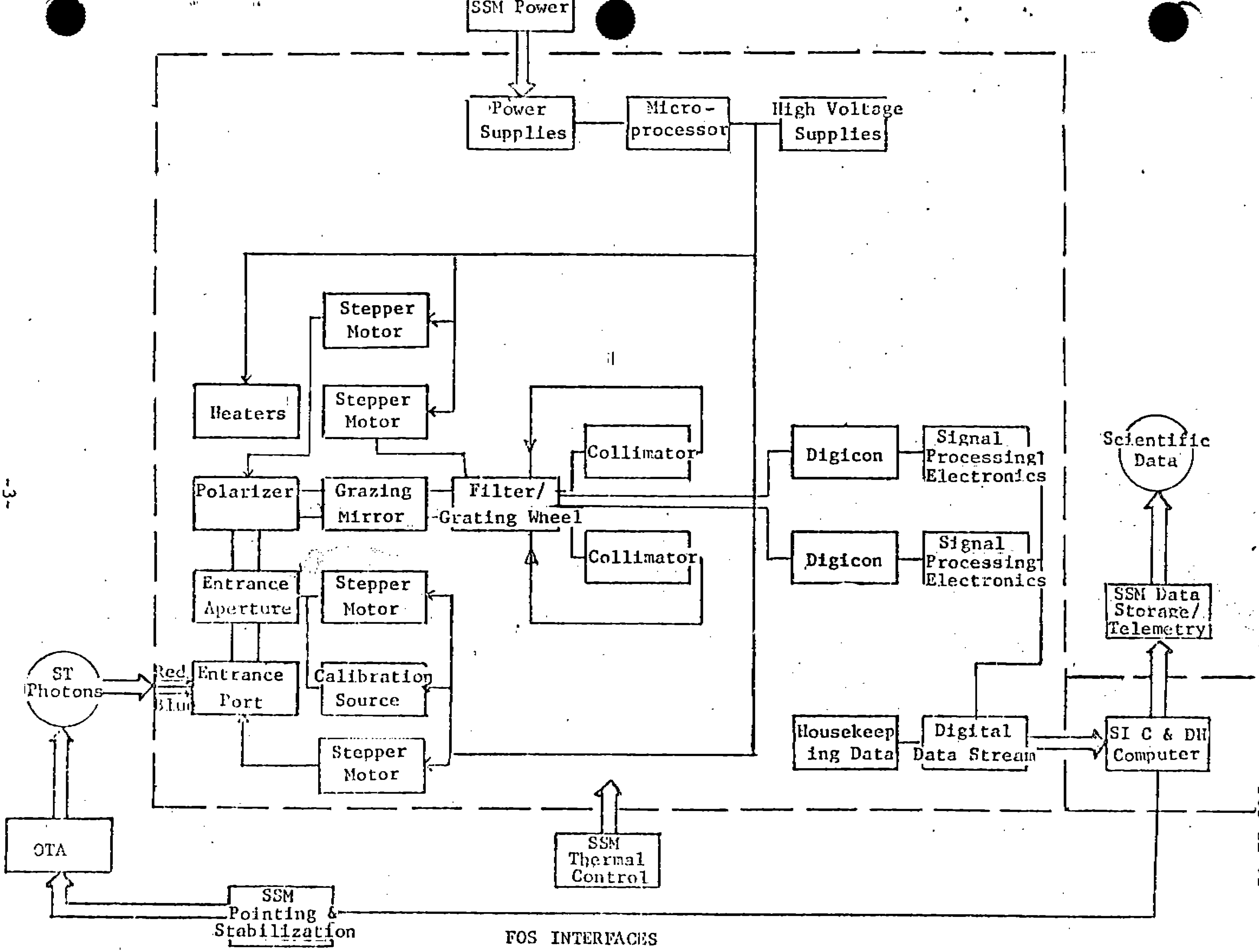
Spectroscopy Mode Efficiencies

120nm $\geq \lambda \geq$ 565.3nm	1.0%
120nm $\geq \lambda \geq$ 200nm	2.0%
200nm $\geq \lambda \geq$ 400nm	7.0%
peak	10.0%

A more detailed summary of these and other requirements is presented in Appendix A of this document.

2.2 Interfaces with ST

The FOS must interface with the ST subsystems as depicted in Figure 2.2.1. The Optical Telescope Assembly (OTA) provides error signals to the SSM for pointing control, the structural mounting and alignment accommodations for the SIs, and the electrical harness for the OTA-SI interconnect to the SSM. Additionally, the OTA provides structural mounting and alignment references for the SSM rate gyro assembly and fixed head



FOS INTERFACES
FIGURE 2.2-1

star trackers. The Support Systems Module (SSM) provides the structural support, electrical power, communications, command decoding/storage/distribution, data accumulation/routing/storage/transmission, timing signals, environmental control and protection, aperture door, light shield, attitude maneuvering, and pointing control for the OTA/SI assembly. Full detail of the interfaces are found in LMSC ICD-02 and are common to all axial SIs.

Compatibility with the ST requires the FOS be limited to an average orbital power use of 150 W/per orbit and a weight of 700 pounds with the center of gravity forward of the midpoint. The FOS will also comply with the load requirements and thermal interface requirements as outlined in the ICD. The environmental requirements imposed by the ICD for contamination, radiation, magnetic control, etc. are also accounted for in the design of the FOS.

2.3 Reliability/Redundancy

The FOS is designed to eliminate any non-structural failure which causes the loss of more than a single detector subsystem.

The FOS electronics system is designed such that there are two each of the following; Low Voltage Power Supplies, High Voltage Power Supplies, Central Electronics, Signal Processors, and Detectors. One system is dedicated to the blue detector and the other to the red detector with an overlap between the two. This is a block redundant electronics system. A loss of a single assembly (i.e., Low Voltage Power Supply) dictates that the system be switched and operated in the alternate spectral range.

There are four optical mechanisms designed into the system: the Entrance Port Assembly, Entrance Aperture Mechanism, the Polarizer Mechanism, and Filter/Grating Wheel Assembly. Three of these mechanisms employ a pin puller which drives them to a preferred operating position in case of failure. Once the pin puller has been initiated, these mechanisms remain in the fail-safe position and are no longer capable of being moved to another position.

The Entrance Port Assembly goes to the full open position, the Entrance Aperture is driven to a position where fail-safe apertures are in the focal plane, and the Polarizer is removed from the optical path. The Filter/Grating Wheel Assembly employs a redundant motor which is engaged with the gear system, but is normally freewheeling. In case of failure of the primary motor, the second motor is used.

Thus, the entire FOS is a block redundant design electronically and has a backup block redundant mechanism system.

3.0 SYSTEM DESCRIPTION

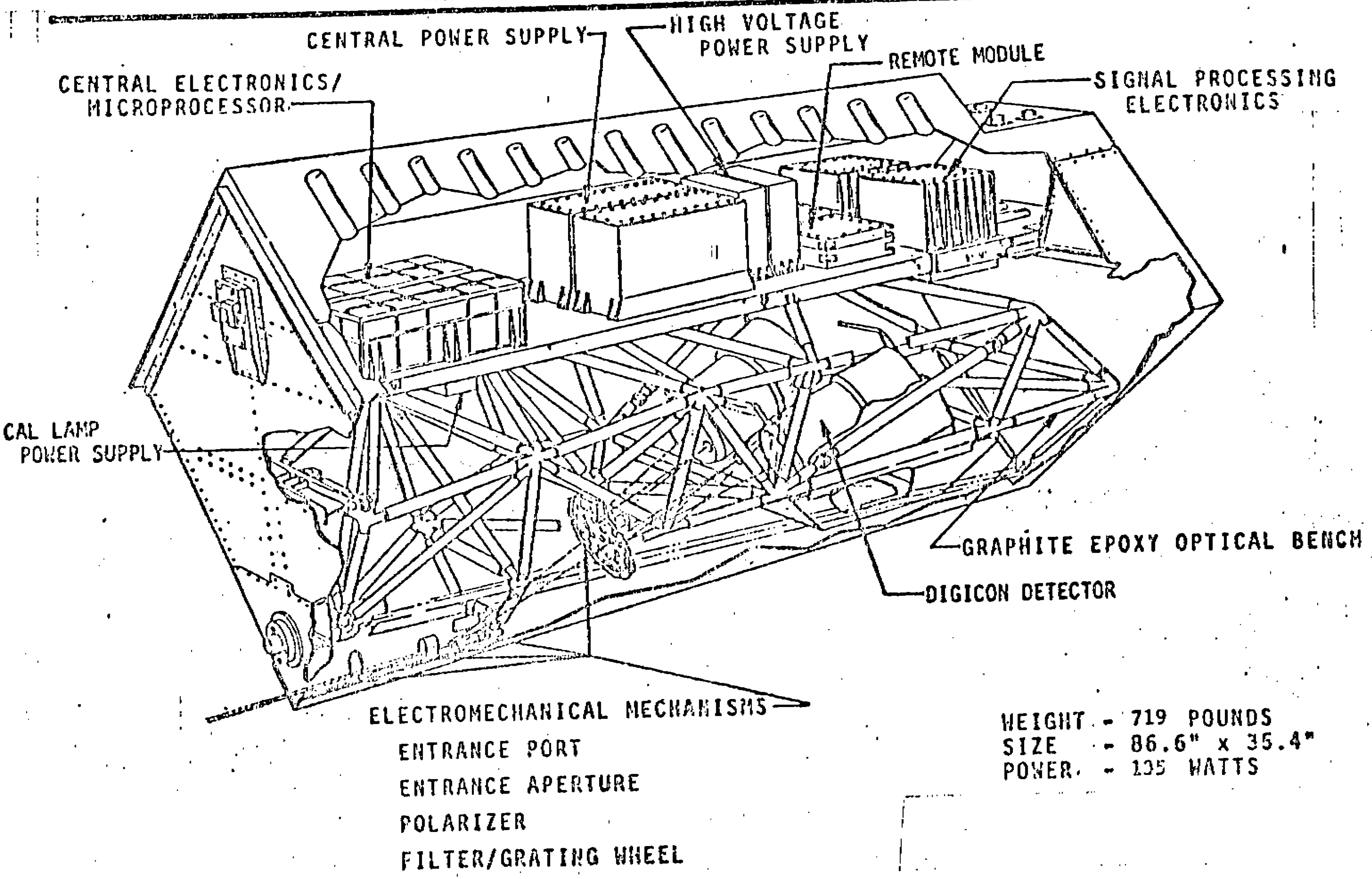
The FOS is designed to provide spectrophotometric data for faint astronomical sources. It will function as an element of the Space Telescope system and as such, it is dependent upon the ST for environmental protection, structural support, electrical power, data management and communications. Its optical system is specifically designed to accept the light beam provided by the ST Optical Telescope Assembly (OTA) as acquired using ST Guidance and Stabilization.

The FOS is designed to fit in axial ST Positions Two or Four and is assigned to Position Two. A three-point attachment latching mechanism holds the instrument in place and provides registration of the FOS apertures where the f/24 beam of the OTA comes to a focus.

Figure 3-1 illustrates the FOS design concept. The major assemblies of the instrument are identified in Figure 3-1 and summarized in Table 3-1.

The structural enclosure of the FOS is made of aluminum honeycomb skin and stringer construction. Sections of the housing act as dedicated radiators for transfer of internally generated heat to the SSM wall heat sink. Externally, there are also hand holds for use by the astronaut and attachment points for ground handling. Guide rails provide assistance for installation and removal with ST during orbital replacement operations. Electrical connectors which can be mated and demated in-orbit are provided at the end. A vent with filter allows for pressure equalization after ground transporation and during ascent and reentry.

A light beam from the OTA enters the FOS through an entry port. The entrance port provides a door to close the system when it is not in use. Next, at the focal plane of the f/24 input beam, is a wheel containing a set of 12 apertures from which an aperture can be selected to use in one of two optical paths. Each of the two optical paths serve oneof the two detectors. A polarization system with rotatable waveplates is available for insertion into the beam as desired. The optical beam is then reflected from a grazing mirror and a collimator onto a grating wheel. This wheel moves appropriate filters and gratings/prisms into the optical paths. The ratio of camera to collimator focus lengths is one-half, thus demagnifying the dispersing element beam by two onto one of the two detectors. One detector is optimized for UV response and the other for a



FOS GENERAL ARRANGEMENT

FIGURE 3-1

TABLE 3.1. Identification of Major Components/Assemblies

	Assemblies	Sub Assemblies	Key Components
1.	Detector Assembly	Deflection/Trim Focus Coils	Coils/Drivers
		Permanent Magnet Focus Assembly	Magnets/Reluctor Rings
		Digicon	Headers
			Diode Array
			Seals
			Faceplate
		Charge Amplifier	Hybrids
2.	Optical Bench Assembly	Optical Bench Structure	
		Mechanisms	Stepper Driver Motors
			Encoders/detents
		Optics/Optical Mounts	
3.	Electronics Shelf Assembly	Bench Shelf/Multilayer Insulation (MLI)	
		High Voltage Power Supplies	
		Central Electronics Assemblies	
		Calibration Lamp Power Supply	
		Remote Interface Units (RIUs)	

TABLE 3.1. Identification of Major Components/Assemblies (cont.)

	Assemblies	Sub Assemblies	Key Components
4.	SI Enclosure Assembly	Front/Aft Bulkheads	External Attach Fittings
		Longerons	Entrance Port Mechanism
		Thermal Radiators/Heat Pipes/ MLI	Heat Pipes/Interfaces
			Thermal Control Circuits
		Shear Panels	
		Optical Bench Attachment Fittings	
		Calibration Optics	

red response. The photocathodes are cooled to lower the dark count and provide improved S/N. They each use a digicon to convert photons to photoelectron events. A permanent magent focuses the electrons onto an array of silicon diodes.

The electronics amplify the charge generated on the diodes and process the data for transmission to the SI Command and Data Handling (C&DH) system. The electronics also provide control of the operation of all FOS subsystems. FOS power supplies condition SSM power as needed. The optics and detectors are mounted on an optical bench structure which is required to maintain extremely fine dimensional stability. In order to maintain dimensional stability under varying thermal conditions, the bench structure is made of graphite epoxy tubes and invar joints. The bench is connected to the FOS shell structure using a nonredundant support which prevents structural loads in the interfacing structure from inducing stress deformations into the optical bench.

The optical elements must be moved into very precise positions in the optical path. The mechanisms which accomplish this are mounted to the optical bench. The grating wheel uses a spring-loaded cam follower and machined detents. The others use encoded stepper motors to achieve accurate positional repeatability. All mechanisms have fail-safe or redundant devices which will avoid debilitating single-point failures.

To obtain the required detector dark count, the photocathode of the detectors must be cooled. Also, precise dimensional stability is required for thermal stability of the structure. The thermal control system consists of sensors, control circuitry, heaters, heat pipes, dedicated radiators, heat isolators and insulation. The detectors are cooled by heat pipes connected from the photocathode and charge amplifiers to dedicated radiators. The system is controlled by selective use of heaters, radiators and insulation tailored to specific needs of system elements.

4.0 SUBSYSTEMS DESCRIPTION

4.1 Optics

The Optical Subsystem reimages light from the OTA focal surface to the detectors with a nominal magnification of 1/2 x. Optical elements are provided to modify the input light to allow determination of the light's spectral content (wavelengths and relative intensity) and level of polarization. The Optical Subsystem provides selectable entrance apertures to select the size and shape of the FOS fields-of-view. Two separate optical paths with the same geometry are provided; one for each of the two detectors, as shown in Figure 4.1-1.

The optical elements available to use (although not necessarily all at the same time) are as follows: A wavelength calibration system composed of two wavelength calibration lamps, a beam combiner, beam steering mirrors and a movable mirror attached to the entrance port mechanism; a set of entrance apertures for each detector; a polarizer assembly composed of waveplates and Wollaston prisms; a beam directing roof mirror (called a grazing mirror); order blocking filters; collimator mirrors; dispersing elements including concave gratings, a prism and mirror assembly and a non-dispersing camera mirror; flat-field light emitting diode sources; and the detector window. Stray light control baffles and zero-order light traps are also part of the Optical Subsystem. The mechanisms that position entrance apertures, the polarizer assembly, and the filters/gratings are considered part of the Mechanism Subsystem. The detector (including its window or faceplate) is considered part of the Detector Subsystem. The Optical Subsystem and Detector Subsystem are mounted to a trusswork "optical bench." The wavelength calibration system is mounted to the enclosure. The optical bench and enclosure are parts of the Structures Subsystem.

Two identical entrance ports are located in the forward bulkhead of the FOS, one for each of the two channels. A mechanism to close the ports is located adjacent to the entrance ports within the FOS.

The entrance ports are followed by a shutter which permits light to enter the FOS when open and which excludes light from entering or escaping the FOS when closed.

OPTICAL GEOMETRY

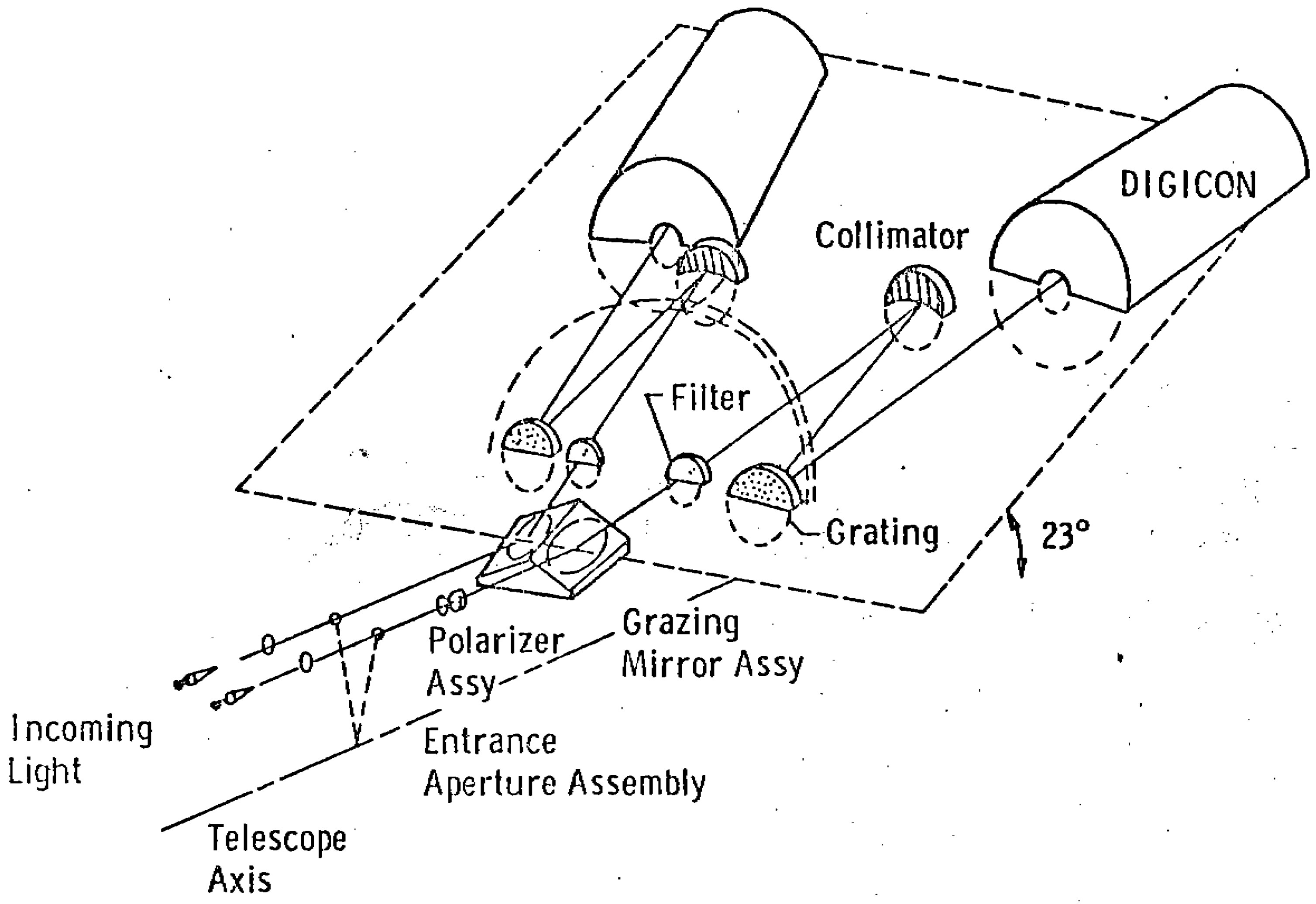


FIGURE 4.1-1

The shutter supports a mirror element which will reflect light from the internal wavelength calibration system onto the entrance apertures.

Two arrays of primary apertures are located around a wheel such that in each selectable wheel position the same aperture configuration lies on the red and blue light paths. The apertures are grouped to minimize the distance between the most frequently used apertures. Each aperture consists of a single hole or a pair of holes. Each hole is either round, square or rectangular.

There are 12 primary aperture positions for each light path. One primary aperture position in each light path blocks the light path for dark-count measurement. Two fail-safe apertures are provided for each light path. The fail-safe apertures may be irreversibly commanded into the light paths, removing the primary aperture wheel permanently from the light paths.

The apertures are oriented so that the final image on the digicon will have the edges of the image parallel to or perpendicular to the diode elements.

The light path (red or blue) shall be selected by pointing the Space Telescope. Aperture positions for the selected light path are selected by commanding the Entrance Aperture Assembly to the desired position.

A polarizer assembly with two sets of polarizer elements designed for different but overlapping spectral ranges is provided. Each set of polarizer elements consists of a rotatable waveplate followed by a dedicated Wollaston prism. Either set of polarizer elements may be placed in either (red or blue) light paths or both light paths may be left clear.

Polarimetric observations may be accomplished with the wide range waveplate covering 120 nm to 335 nm, or the narrow range waveplate covering 120 nm to 187 nm.

Each waveplate is made of two optically contacted pieces of UV grade MgF_2. The net retardation of one plate is one-half wave (180^o) at a wavelength of 121.6 nm and the other plate is one-half wave at a wavelength of 125.6 nm. Transmittance of the waveplates is no less than 0.3 at 121.6 nm wavelength.

The Wollastron prism is an optically contacted sandwich of two pieces of MgF_2. The prisms are geometrically similar but have different crystalographic orientations.

There is a single fixed grazing mirror assembly with two mirror surfaces which reflect light toward each collimator mirror.

The angles of incidence and reflectance of chief rays on each mirror are $11.8^o \pm 2$ arcmin. The grazing mirror surfaces deflect the reflected chief ray through the angle resulting from two successive rotations, first by 23^o and then right for one beam and left for the other beam by 7.353^o.

Both mirror surfaces have reflective coatings with a minimum reflectance of 75% at all wavelengths from .13 to .9 um with an incident angle of 78.5^o.

There is one collimating mirror for each of the two channels to reflect the light bundle to the grating wheel.
The collimators are off-axis sections of paraboloids with focal lengths of 1000 mm. The center of the off-axis section is 119.6 mm from the axis of rotational symmetry.

A rotatable wheel providing the support structure for the filter and dispersion optics allows transmission of the light bundle through the approrpriate filter or blank hole. The light strikes a collimating mirror and is reflected back to one of the dispersion elements or the camera mirror on the wheel. The nine dispersion elements include high resolving power gratings, low resolving power gratings, and a low resolving power prism and mirror. A camera mirror is also provided on the wheel.

The selectable optical systems are available in both the blue and the red light paths. There are six high-resolving power gratings, two low-resolving power gratings, one thin prism and mirror, and one camera mirror.

Blocking filters are used to attenuate grating orders higher than the first to the greatest practical extent consistent with high transmittance of the desired first order. Blocking filters are mounted on the grating wheel 360 mm from the collimator. Blocking filters are not needed for the shortest wavelengths where the digicon faceplates block higher order light.

The chief ray angle of incidence on each of the six high resolution gratings is 7.5°. The range of diffracted angles is ± 1.47° from the grating normal. The gratings are on a fused silica substrate having a nominal focal length of 500 mm. All gratings are blazed for the first inside order and have a minimum resolution of 1000. Gratings are multipartite to meet the required efficiency.

The chief ray angle of incidence on both of the low resolution gratings is 3.475° with a range of diffraction angle from the normal of 2.787 ± .229°. The gratings are on a fused silica substrate. The substrate has nominal focal length of 500 mm. Each grating is blazed for the first inside order and have a resolution of 100 ± 50 at the average wavelength. These gratings are also multipartite to meet the required efficiency.

The low resolving power thin prism has a resolution of 100 ± 50 at the average wavelength. The transmission is .75 from .2 to .9um. The prism is made of UV-grad sapphire. The spherical mirror substrate is a low thermal expansion glass-ceramic. It has a nominal focal length of 500 mm.

There is one camera mirror with no spectral dispersion to be used for the acquisition mode. The camera mirror is an off-axis section of a concave paraboloid with a focal length of 500 mm. The center of the off-axis section is 65.1 mm from the axis of rotational symmetry.

FOS has an internal wavelength calibration system consisting of two lamps which emit spectral lines over the FOS spectral range, and optical elements to transmit the calibration light into both (red and blue) light paths. Calibration light enters the light paths from a mirror on the back surface of the entrance port shutter when the entrance port is closed and does not enter the light paths when the entrance port is open. FOS also has a flat field lamp for each digicon. Light from those lamps irradiates its corresponding photocathode directly without intervening optical elements.

The two Calibration Lamps are gas-filled hollow cathode lamps. The cathode of each lamp contains platinum and chromium. The fill gas is neon. The light exits each lamp through a transmitting window of magnesium fluoride. The lamps emit spectral lines over a wavelength range from 0.11 to 0.90 micrometers. The radiance of each lamp permits wavelength determinations in an exposure time not to exceed 100 seconds (and generally much less). Wavelength determination is done to better than twenty percent of the instrument profile width. Optical elements are provided to direct light from wavelength lamps into each light path (red and blue). Each lamp is usable with each light path. The calibration lamps and optical elements are all mounted on the forward bulkhead of the FOS enclosure. The flat field LED's are mounted on the baffle near the filter/grating wheel.

Stray light is reduced to the minimum practical level through use of low scattering optical surfaces, careful control of particulate contamination, and attenuation of stray light by baffles, light traps, and surface blackening. Attenuation of undesired grating orders is provided by blocking filters or the digion faceplate along with baffles and zero order light traps. There are five baffles made of perforated aluminum sheets coated with black paint. Three baffles are located between the grazing mirror and the filter/grating wheel, one around the filter/grating wheel and one between the filter/grating wheel and the collimator mirror.

Light traps are installed to prevent zero order light from propagating to the detector. Each trap is a wedge-shaped box whose interior surfaces are low scattering black surfaces. The traps are placed close to the front face of the detector, but do not intrude into the desired light beams going to the photocathode.

4.2 Structures

The FOS structural system's primary function is to support the detectors, optical and electrical components through launch and during operation in space. The two major subassemblies are the enclosure and the optical bench. Figure 3-1 illustrates the general arrangement.

The SI enclosure provides the structural, mechanical, electrical, and thermal interfaces with the OTA. The optical bench is supported at three points inside the enclosure. Electrical components are mounted on the shelf, which also serves to separate the enclosure into optical and electrical compartments. The enclosure is the structure to which the majority of the thermal control components are affixed. An exterior view of the assembly is shown on Figure 4.2-1.

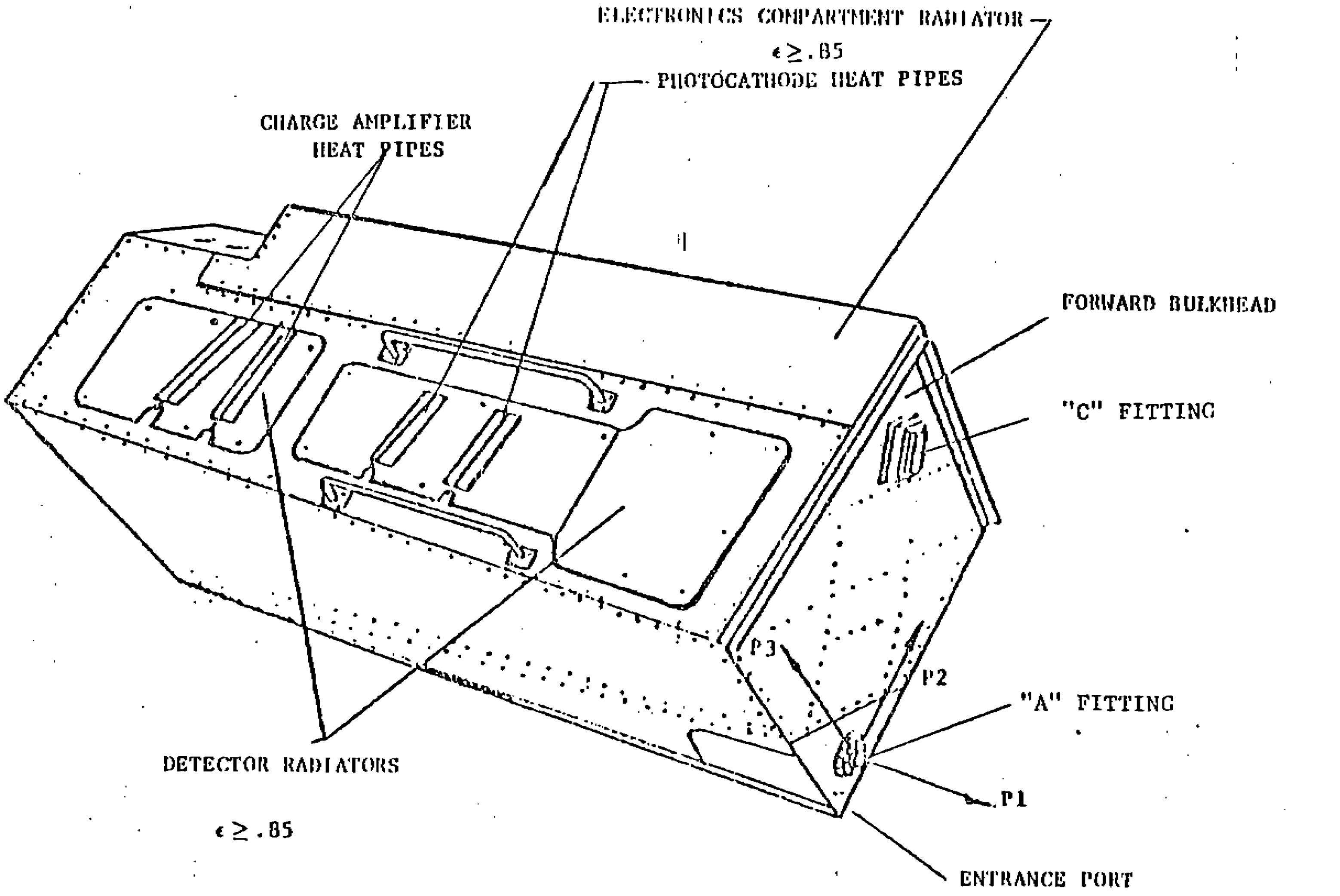


FIGURE 4.2-1 FOS EXTERIOR

The enclosure structure consists of fore and aft bulkheads, two longerons, an electronic equipment shelf, fixed and removable side (shear) panels and corner stringers. The forward bulkhead supports the "A" and "C" registration fittings and the forward guide rails. The aft bulkhead supports the "B" registration fitting and aft guide rails. The aft bulkhead also is the location for the aspirating filter-vent.

The optical bench is a space truss designed to meet structural stiffness and thermal characteristics requirements. It is a true composite structure in that graphite epoxy tube members are bonded to invar welded tube intersections to form the truss structure. The optical bench is mounted in the enclosure with a statically determinate three-point attachment. The forward end of the bench is attached to the forward bulkhead with a ball/split socket mount that is located in line with the forward spherical registration detent (A fitting). At the forward end, an adjustable linkage is mounted tangentially to obtain optical bench rool adjustment and restraint. The optical bench pitch and yaw adjustments and restaints are effected by two adjustable links attached to the aft end. The two adjustable links are in turn attached to a common point on the aft bulkhead in line with the aft spherical registration detent (B fitting). This mounting technique isolates the optical bench from the enclosure and effects a direct structural connection of the bench to the OTA latch mechanism. Hence, thermal and mechanical instabilities of the enclosure will have minimal effect on the alignment of the optical bench.

4.3 Mechanisms

The FOS mechanisms consist of the entrance port, entrance aperture, polarizer and filter/grating wheel. The general arrangement of the four mechanisms and their location on the FOS structure is shown in Figure 4.3-1.

The entrance port mechanism shown in Figure 4.3-2 allows light to enter through both, or closes off, both entrance ports in the forward bulkhead. In the closed position, the mirror on the inboard side of the shutter directs light from the wavelength calibration system to the entrance apertures. The shutter

MECHANISMS

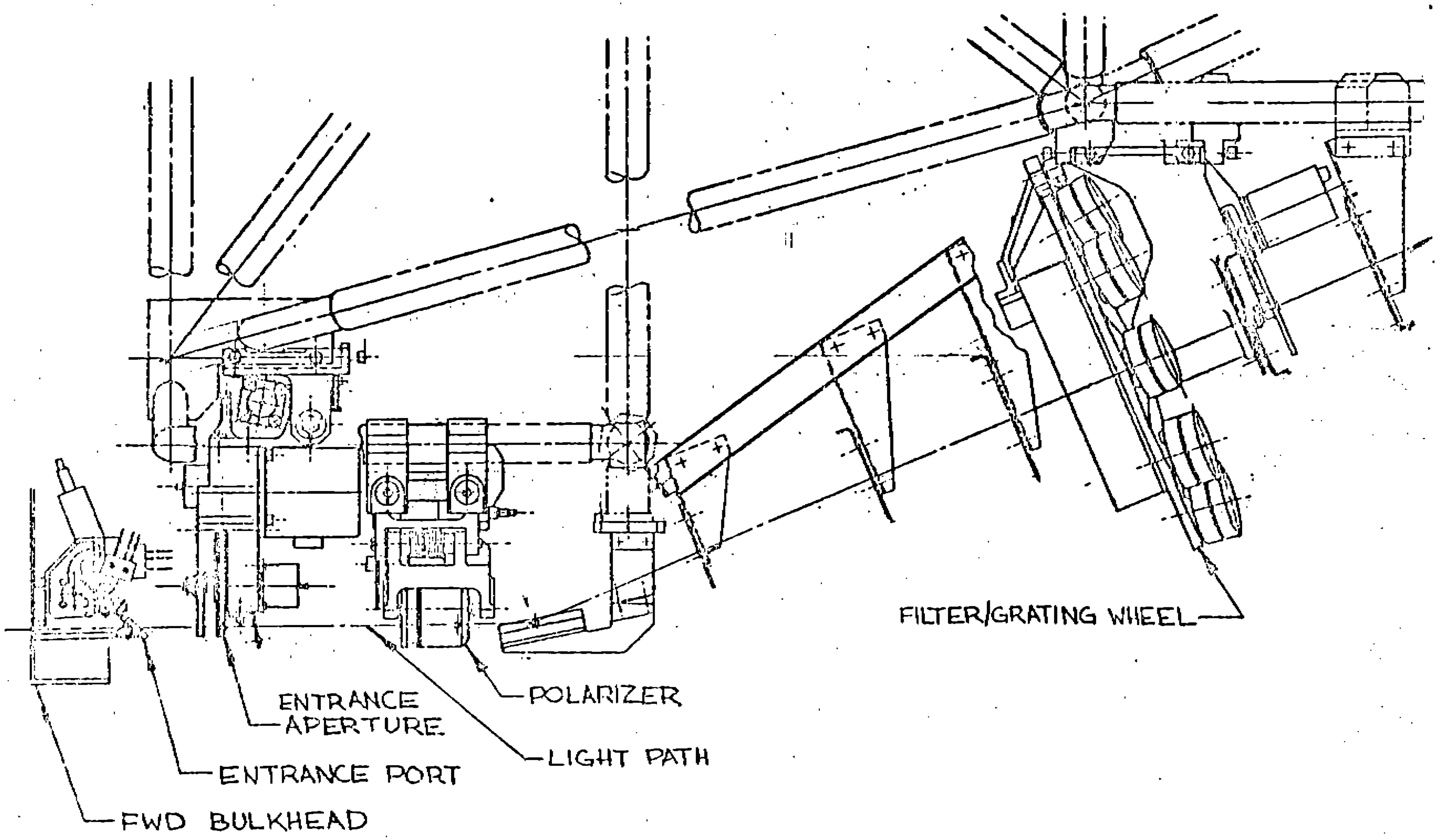


FIGURE 4.3-1

ENTRANCE PORT

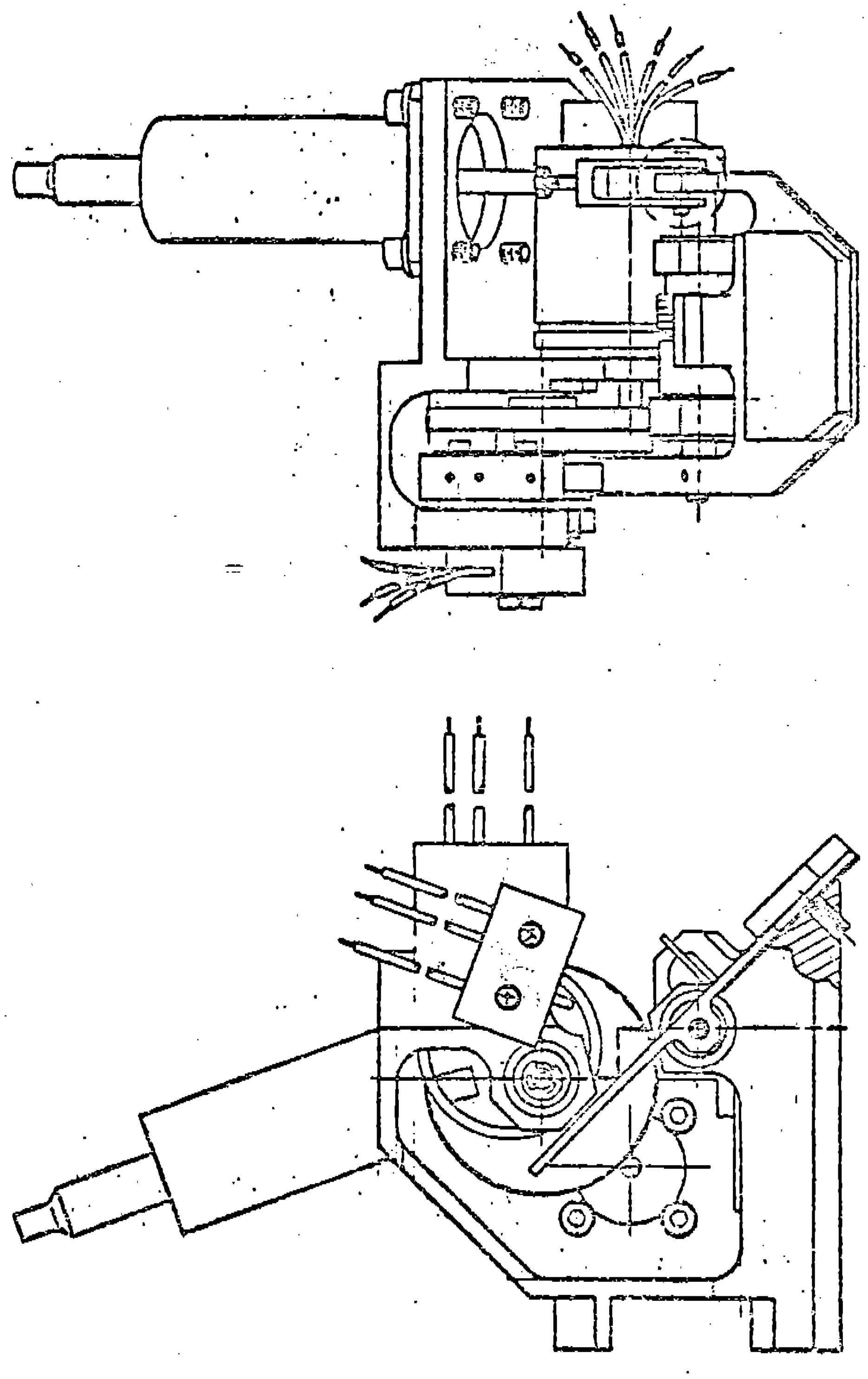


FIGURE 2

is driven by a 90 degree stepper motor through a 12:1 gear reduction and an eccentric bearing. Two mirco-switches indicate open and closed positions. A burn-wire pin puller opens the shutter for fail-safe operation.

The entrance aperture shown in Figure 4.3-3 accurately places any of twelve pairs of apertures into operating position in the light paths. Apertures are arranged around a little over half the perimeter of the aperture wheel. The wheel is driven by a 1.8 degree stepper motor through a two-stage 80:1 antibacklash gear train. Two 8-bit pin contact encoders provide a unique output for each position of the aperture wheel. A burn-wire pin puller allows torsion springs to rotate the aperture mechanism forward removing the aperture wheel from the light paths and inserting a pair of fail-safe apertures into the light paths.

The polarizer shown in Figure 4.3-4 places two waveplate /Wollaston prism pairs in the two light paths or leaves the light paths clear. Each revolution of the polarizer rotates the waveplate 22.5° with respect to the Wollaston prism. The Wollaston prisms are mounted in a rotating cylinder, see Figure 4.3 5, driven by a 90 degree stepper motor through a two-stage 105:1 antibacklash gear train. The waveplates are mounted to a gear within the cylinder in such a way that one revolution of the cylinder results in 1/16 revolution of the waveplates with respect to the Wollaston prisms. Two 8-bit pin contact endcoders provide a unique output for each position of the polarizer. A burn-wire pin puller allows torsion springs to rotate the polarizer up out of the light paths.

The filter/grating wheel shown in Figure 4.3-6 accurately places a set of optical elements (grating, prism or mirror and attendant filter) in the two light paths. A 90 degree stepper motor drives the wheel through a two-stage 90:1 gear train. Accurate positioning is achieved with a spring loaded ball bearing cam detent. A LED/phototransistor array and coded cylinder provides the signal to stop the motor and a unique output for each position of the wheel. The spring load on the ball bearing cam follower is sufficient to overcome the stepper motor residual torque and assure bottoming in the detent for repeatable wheel positioning. A redundant stepper motor which normally free wheels operates the wheel if the primary motor fails.

ENTRANCE APERTURE - CROSS SECTION

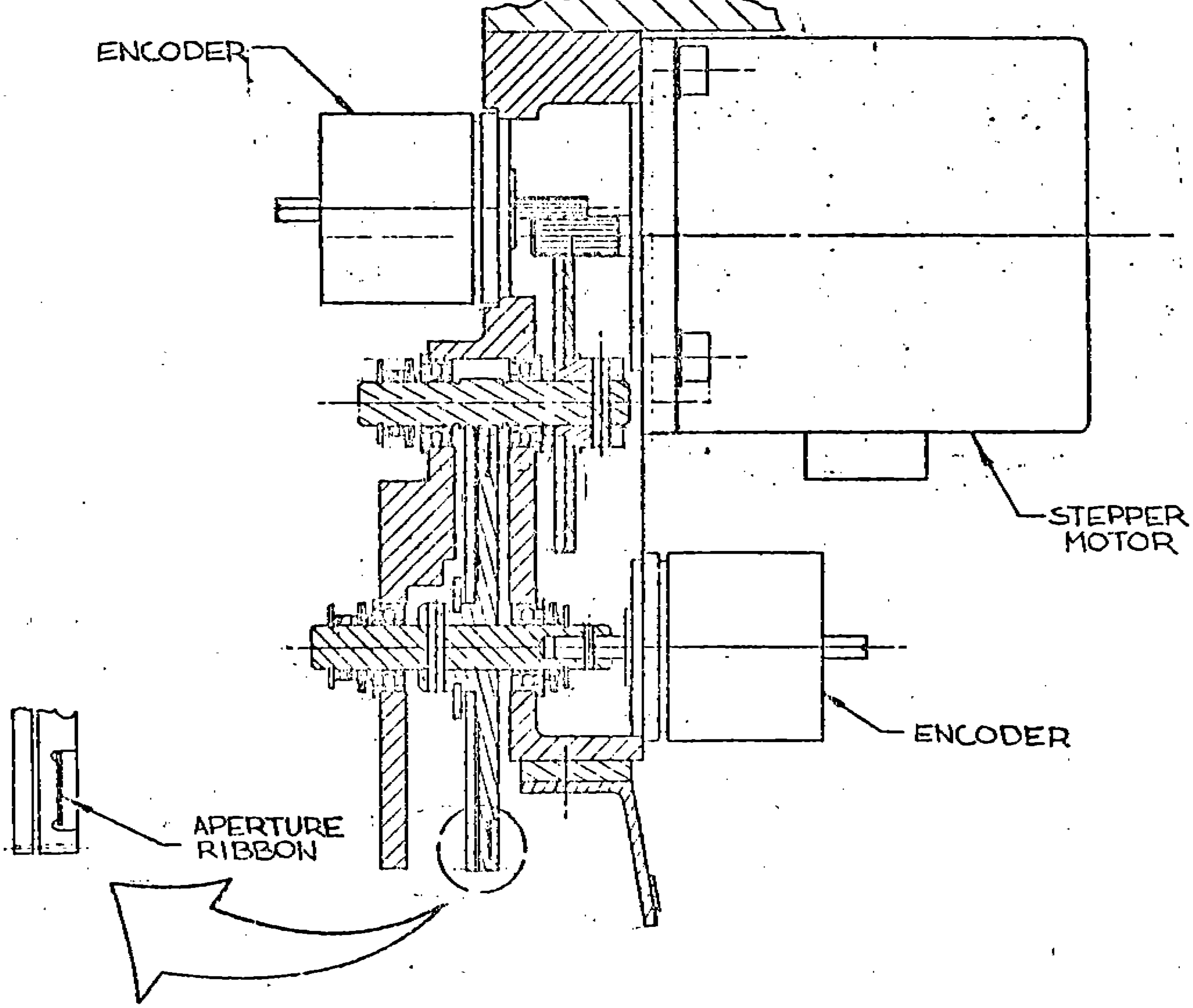


FIGURE 4.3-3

POLARIZER

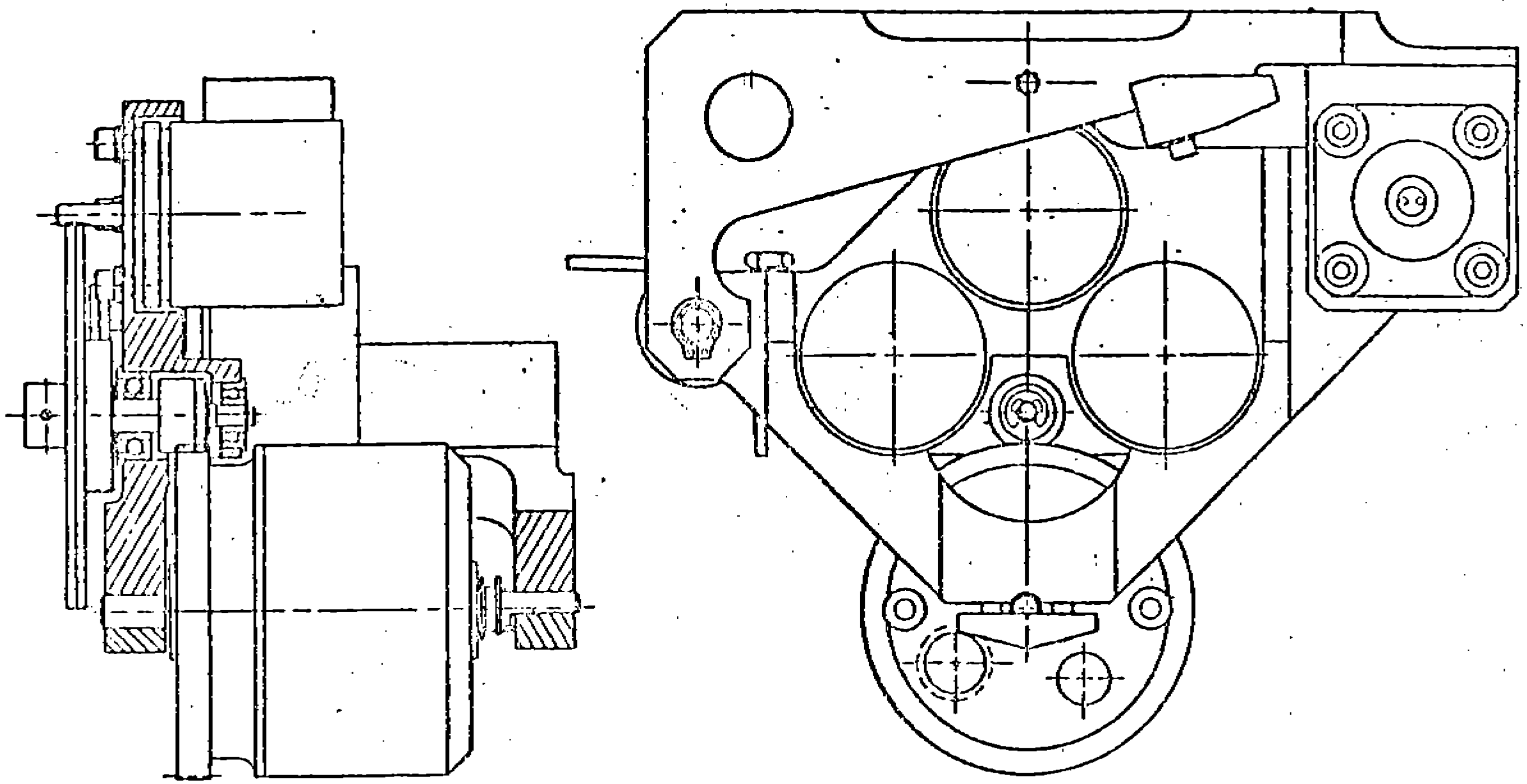


FIGURE 4.3-4

POLARIZER - CROSS SECTION

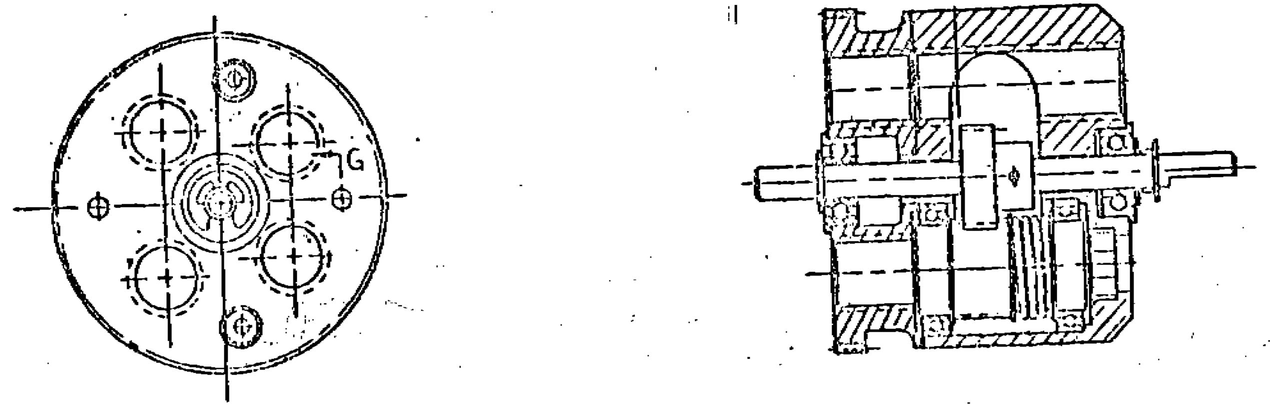


FIGURE 4.3-5

FILTER/GRATING WHEEL

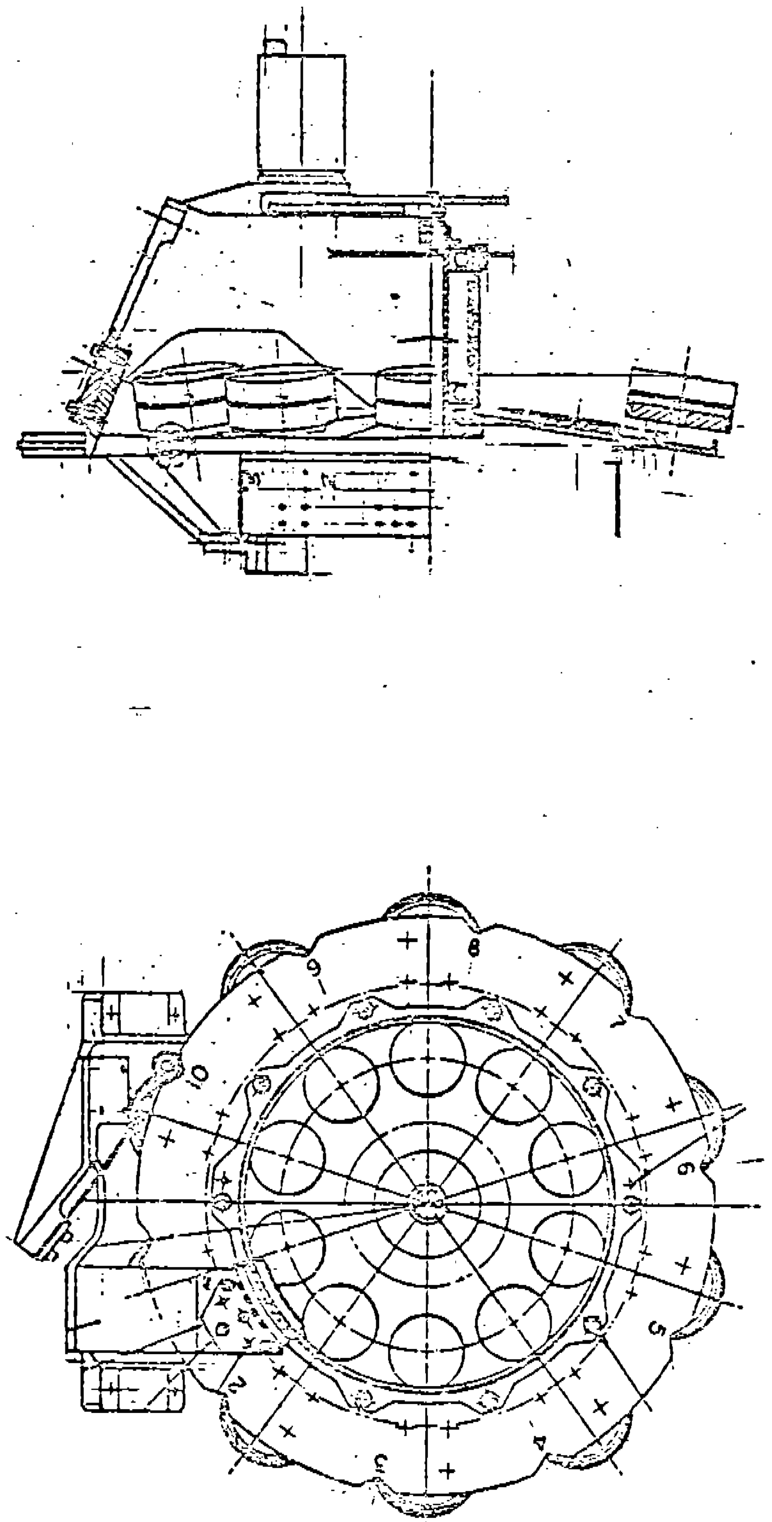


FIGURE 4.3-6

4.4 Detector

The detector subsystem interfaces with the optical subsystem to perform the photoelectron transfer from the light input to output pulses from the charge amplifiers which are sensed by the filter amplifiers of the Analog Signal Processor. The major components and subassemblies of the detector subsystem are shown on Figure 4.4-1.

The detector subsystem consists of two detector assemblies. These assemblies differ only in the photocathode type and faceplate material used. In all other respects, they are identiccal. Each detector assembly consists of a digicon tube, deflection coils, a permanent magnet focus assembly, magnetic shielding, structural details for mounting, joining, and aligning the individual components, temperature sensors, and electrical connectors.

The real image of the optical spectrum is focused onto the photocathode of the detector assembly. The photon flux in this image causes, with a known probability, the emission of a photoelectron flux with the same spatial variation as the photon flux. This photoelectron flux is accelerated in the electric field to an energy of about 22.5 kilovolts. A magnetic field parallel to the electric field reimages this photoelectron flux onto a monolithic array of 512 silicon photodiodes. These 512 diodes are arranged in a single row and preserve the spatial information present in the optical image. The photoelectron energy is absorbed when the particle strikes the silicon diode. This absorbed energy results in a charge pulse of about 8×10^{-16} coulomb or more depending on the electric field strength. These charge pulses are amplified by the charge amplifiers. Since the optical image may appear at more than one location on the photocathode, magnetic deflection coils are available to shift the photoelectron flux in the two directions orthogonal to the optical axis. This permits counting photoelectrons from a substantial area of the cathode. The major components of the detector assembly are:

Digicon - The digicon is the basic photodetector. It includes a vacuum envelope, an optical faceplate on which the photocathode is deposited, a diode array, a header on which the diode array is mounted and which provides 520 electrical feedthroughs, a high voltage cable, a set of accelerator rings, encapsulation for high voltage insulation, and a tube housing.

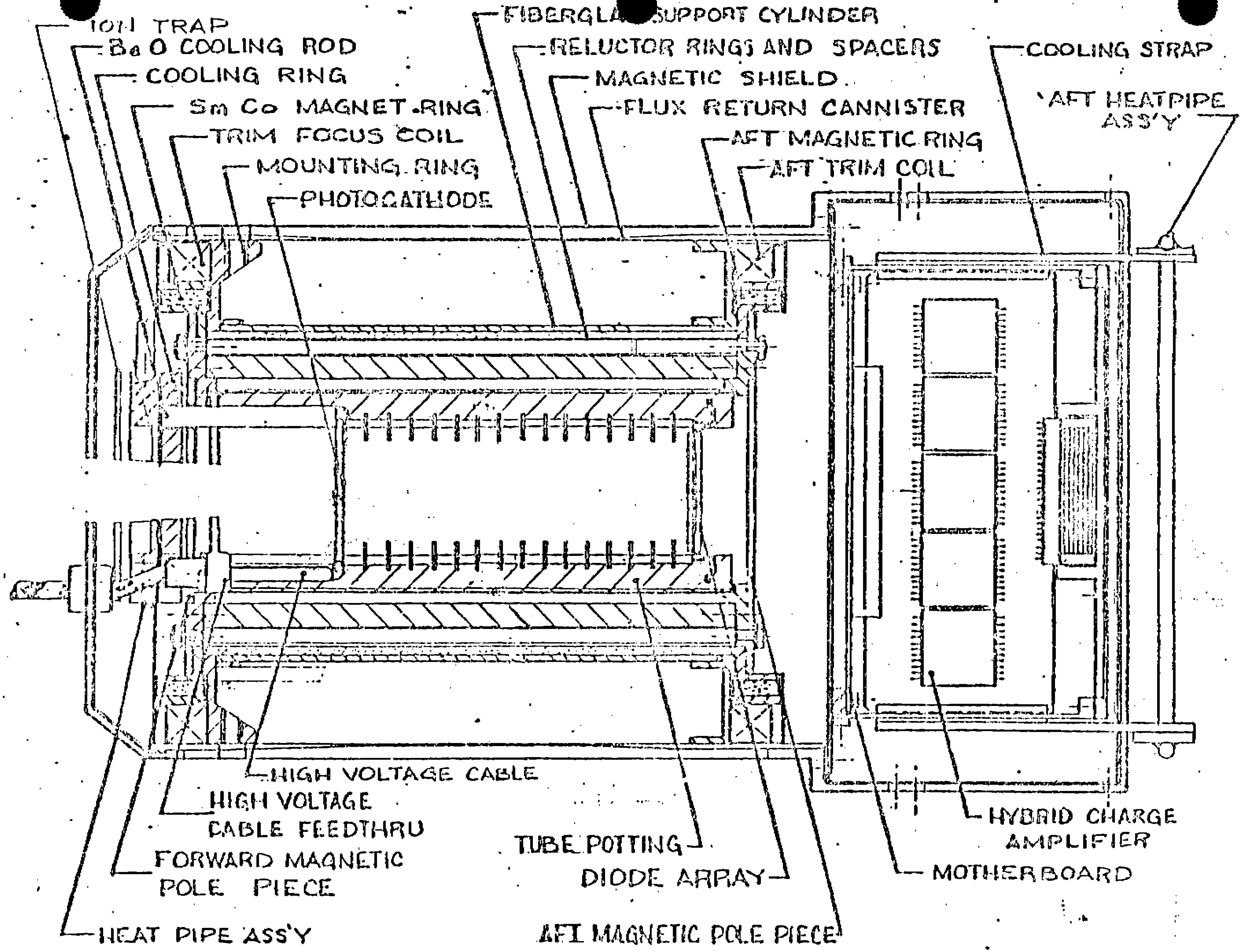


FIGURE 4.4-1

DETECTOR SUBSYSTEM

The digicon tube body is a brazed assembly of 96% alumina rings and copper accelerator rings. The tube header is attached to the tube body by a copper cold weld of the header and body copper flanges. The window is sealed to the tube body after cathode generation by means of hot indium-bismuth seal.

A resistive potential divider is connected to the accelerator rings. The individual resistors are distributed around the tube circumference to avoid concentrating the dissipated heat on one side of the tube. A maximum of 0.4 watts is dissipated at the normal operating level of 22,500 volts. A lead will be brought out from the voltage divider near the anode. This lead serves as a voltage readout monitor during ground testings. The transfer characteristic is about 2.5 volts out for 25,000 volts in. The tube and resistive divider is encapsulated to prevent high voltage breakdown.

Beryllium oxide parts are deeply embeded into the encapsulant in order to conduct heat from the divider axially to the heat sink which is attached to a heat pipe. On the outer surface of the tube housing is an electrostatic shield.

There are two types of digicons used in the FOS which differ only in their faceplate and photocathode materials. The photocathodes are KCsSb (bialkali) on UV grade magnesium fluoride and Na_2 KSb(Cs) (trialkali) on fused silica (Suprasil I). The minimum quantum efficiency as a function of wavelength for these cathodes is shown on Figure 4.4-2. Photocathode uniformity is expected to be as good as $\pm$ 5%. The expected thermionic emission for these cathodes is shown in Figure 4.4-3 as a function of temperature. The emission is expressed in terms of counts/sec/diode. The maximum allowable dark count rate per diode is also shown.

The tube header consists of a multilayer ceramic and dielectric substrate with wirebond pads on two levels. Metallization for wirebond pads and conductive traces is electroless gold plated over thick film tungsten. A copper flange is brazed onto the outer circumference of the top ceramic layer for attachment to the tube. There are 512 wire bond pads arranged in two rows, 128 per row, on each side of the diode array die attach pad. Each wire bond pad is four mils wide, located on eight mil centers. There are 520 silver solder pads brazed to the bottom ceramic layer. In addition to 512 signal feedthrough, there are four common connections and four ground connections.

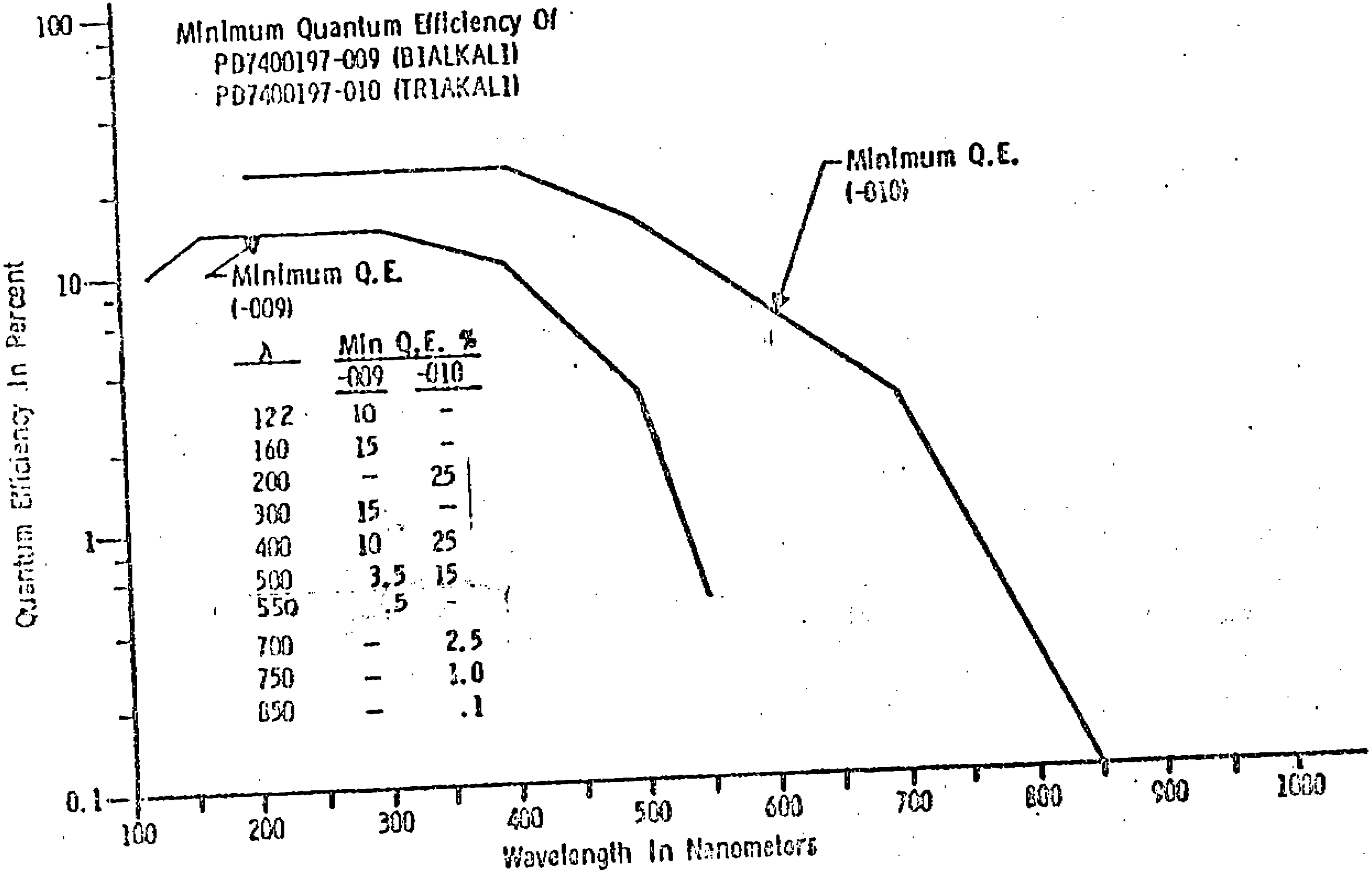


FIGURE 4.4-2 DETECTOR QUANTUM EFFICIENCY

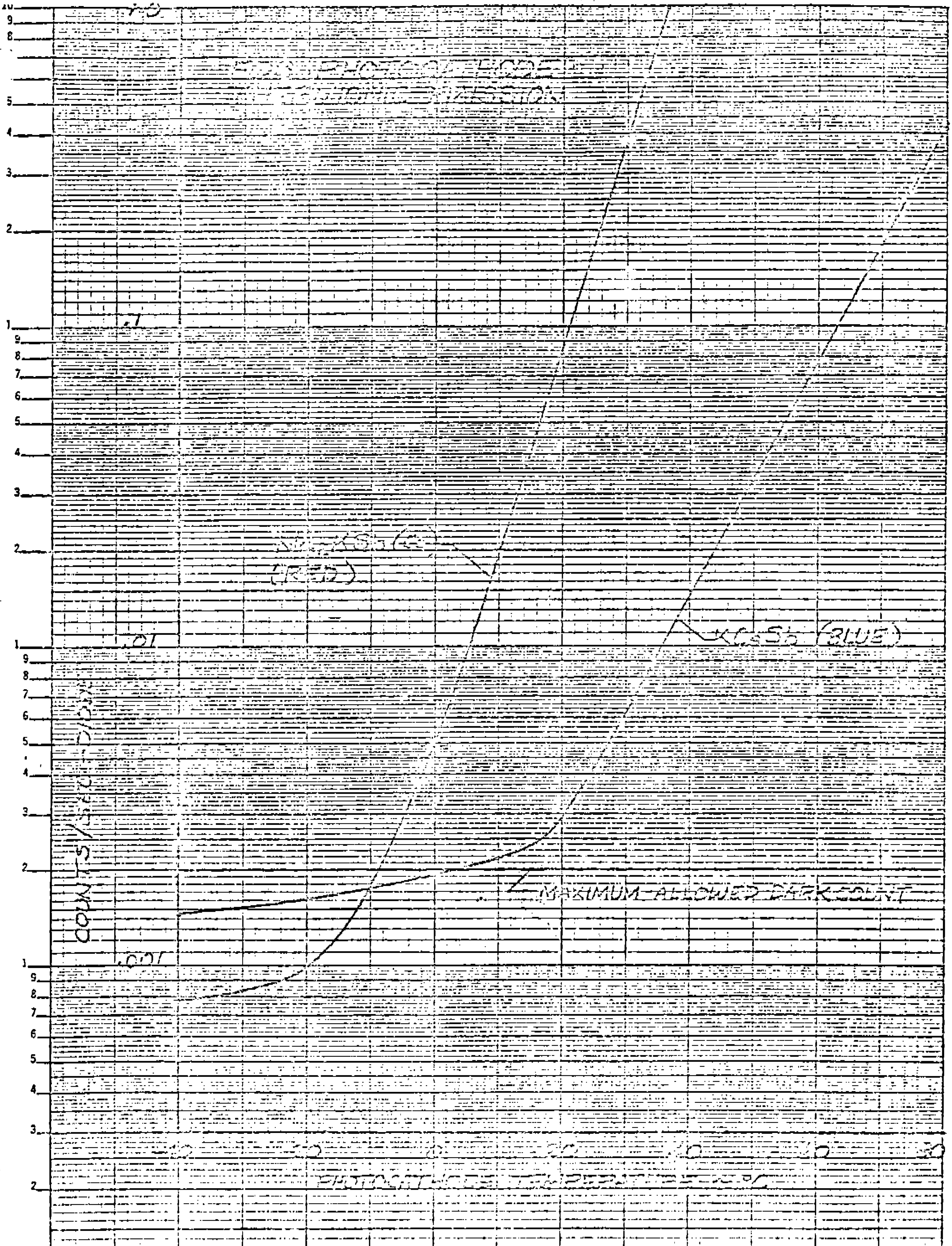


FIGURE 4.4-3

The diode array is a monolithic silicon device approximately 1.2 inches long. The width is chosen to keep wire lengths about 0.100 or less. The device has 512 diode elements in a single row. Each element is 40 by 200 microns and has a 50 micron center-to-center spacing with adjacent elements. The silicon from which the device is made has a bulk resistivity of about 10 ohm-cm and is normally biased to produce a depletion width of about five microns. The device is to be bonded onto the header using a gold-silicon eutectic. One mil aluminum wirebonds are installed using a thermosonic bonder. One hundred percent prestress screening will be employed to weed out weak bonds.

A digicon schematic is shown in Figure 4.4-4.

Deflection Coils - Around the digicon is mounted a pair of orthogonal deflection coils. The rotational orientation of these coils is such that the resulting photoelectron deflections are either in the dispersion direction or orthogonal to it. These coils are completely encapsulated.

Permanent Magnet Focus Assembly - The major structure of the detector subsystem is part of the PMFA. This assembly includes the permanent magent rings (2), the reluctor rings, the flux return cannister, the magnetic shield, and the trim focus coil.

Charge Amplifier Assembly - Figure 4.4-1 also shows the charge amplifier circuit boards physically mounted in their operating location although these components are considered to be part of the electrical subsystem.

The detector subsystem also contains temperature sensors and provides for conductive cooling of the charge amplifier assembly and the photocathode.

4.5 Electronics

The electronics subsystem consists of two (2) Analog Signal Processors (ASP), two (2) Central Electronics Assemblies (CEA), two (2) Central Power Supplies (CPS), two (2) High Voltage Power Supplies (HVPS), one (1) Calibration Lamp Power Supply (CLPS), two (2) Remote Interface Units (RIU), one (1) Expander Unit (EU) and the Cable Harness Assembly. The physical location of these components is shown in Figure 3-1. Figure 4.5-1 is a block diagram of the system.

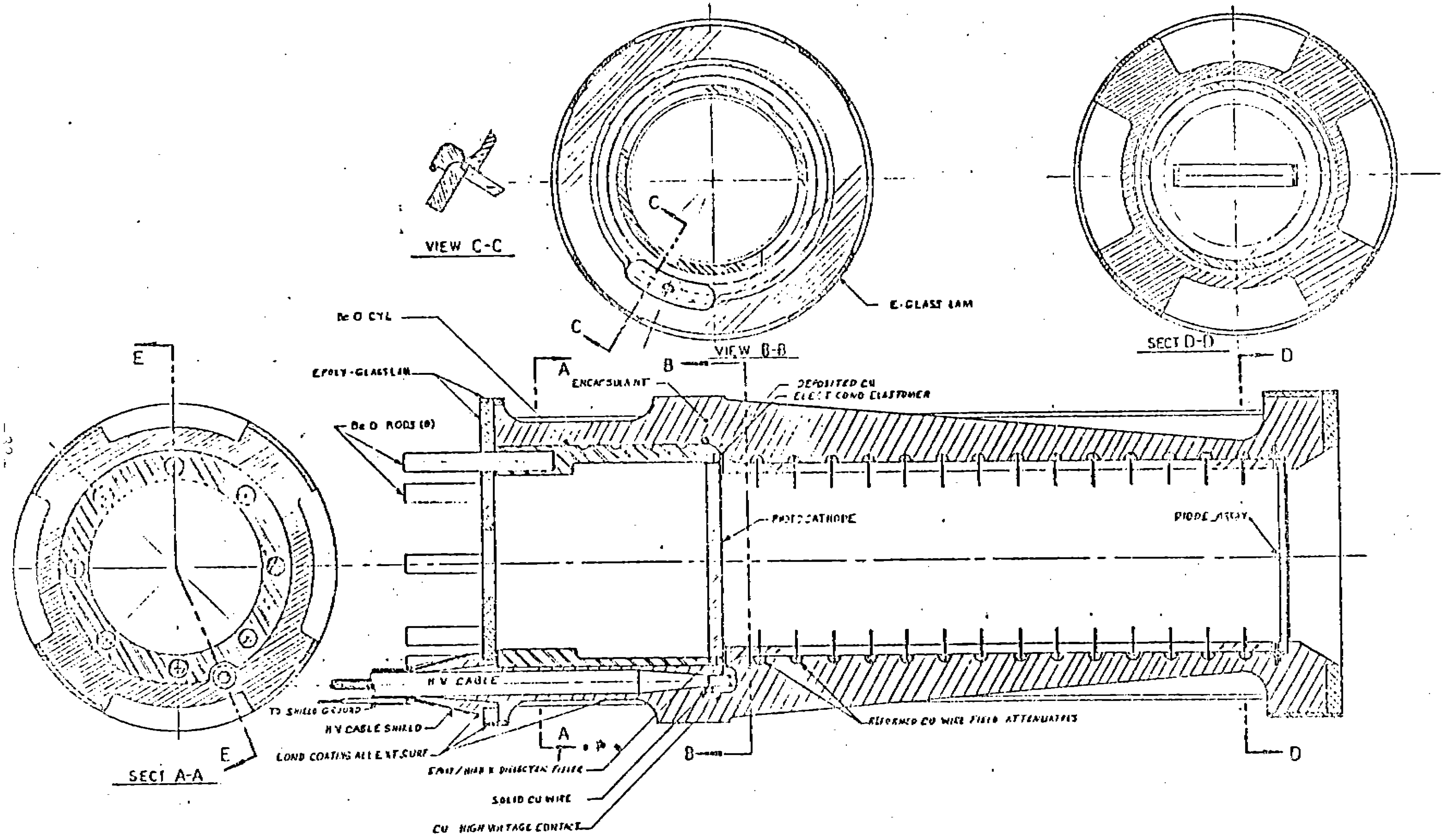
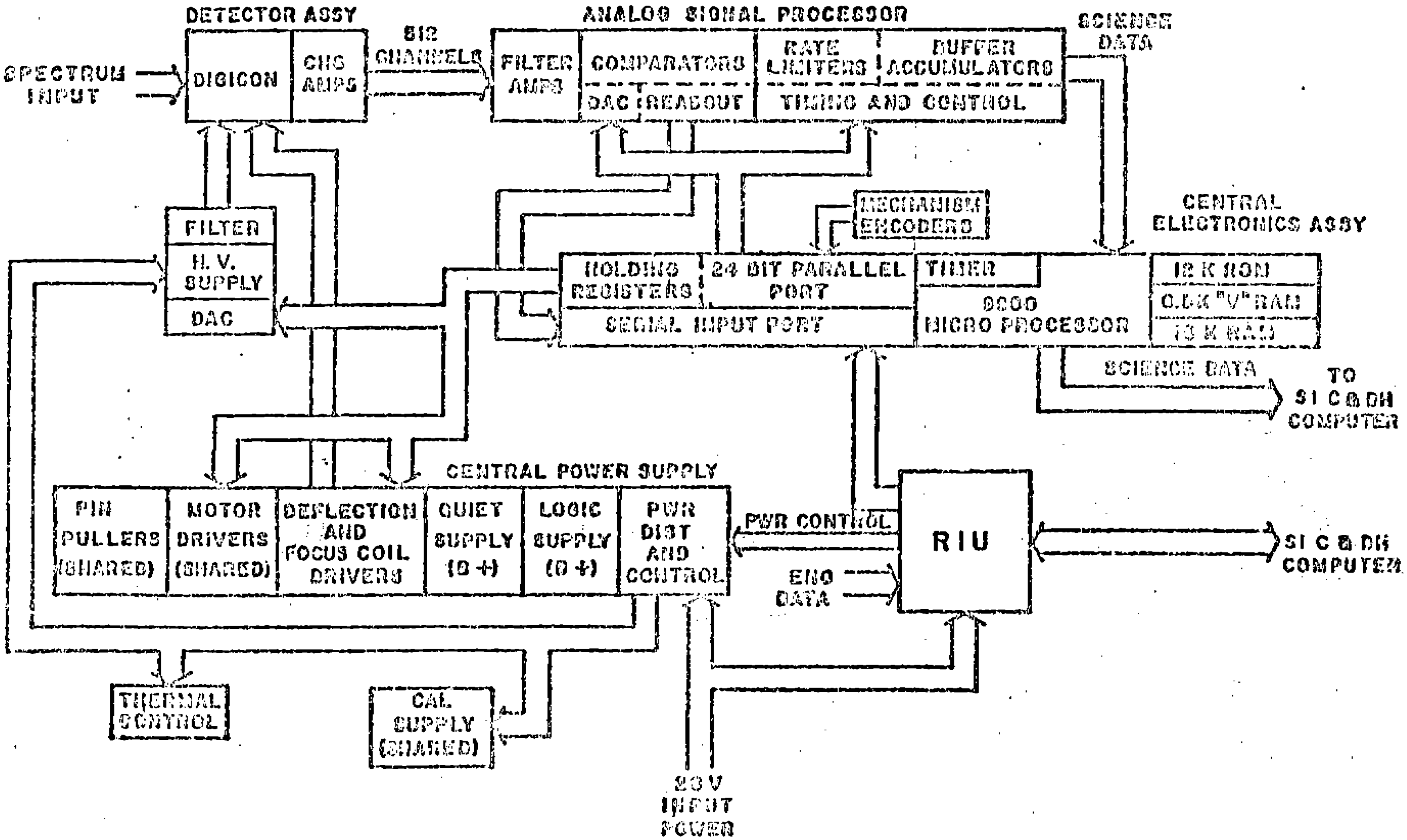


FIGURE 4.4-4 FOS DIGICON CONCEPT



F. O. S. ELECTRICAL
BLOCK DIAGRAM

FIGURE 4.5-1

Analog Signal Processing - Signals from the detector are processed into usable forms and transmitted to the CEA. The signal processing is performed by five types of circuits: 1) charge sensitive preamplifier, 2) filter amplifier, 3) comparator, 4) rate limiter/buffer accumulator, and 5) serial to parallel converter. The charge sensitive preamplifier circuits are located in the detector adjacent to the digicon header, and the other four (4) types are located in the ASP.

Charge Sensitive Preamplifier - The Charge Sensitive Preamplifier circuits are located adjacent to the digicon header and provide the electronic interface to the digicon tube. The anode of each diode in the digicon is connected to the input of a charge amplifier. Each amplifier converts the equivalent of 5250 electrons (8×10^{-16} coulombs) to an output pulse with a peak of 4.5 mv.

Filter Amplifier - The Filter Amplifier takes the output of the charge amplifier and amplifies and shapes it to an approximate gaussian-shaped pulse of about 250 mv amplitude.

Comparator - The Comparator circuit converts the analog signals, from the filter amplifier, into digital signals to be used by the Rate Limiter/Buffer Accumulator. The conversion is accomplished by feeding the analog signal into a comparator. The comparator threshold is obtained from a Digital to Analog Converter which is controlled from the Central Electronics Assembly. The programmable threshold is used to match the channels during instrument calibration.

Rate Limiter/Buffer Accumulator - The Rate Limiter is used to introduce a known dead time of 9.77 ± 1.0 microseconds into the ASP. The accumulator/buffer is designed for two modes of operation - count and time resolved. In the count mode, the output pulses from the rate limiter are counted for a selected period of time. In the time resolved mode, the elapsed time from the start of the sample period to the first pulse is measured in the accumulator. At the end of a sample period, the contents of the accumulators are transferred into the buffers and are then read sequentially by the Central Electronics Assembly. The mode and sample period are controlled from the Central Electronics Assembly.

Serial to Parallel Converter - The output of the selected accumulator channel is routed to the input of the serial to Parallel Converter where it is shifted serially into a 16-bit shift register. The output of the shift register is available to be read by the microprocessor.

Central Electronics Assembly - The Central Electronics Assembly (CEA) provides the primary interface between the FOS and the SI Control and Data Handling system of the ST. Commands are received by way of the RIU. Science data is transmitted from the CEA to the Science Data Formatter, and Engineering data is transmitted to the RIU.

The CEA consists of a microprocessor, memory, 24-bit output port Digital to Analog Converter (DAC) interface, mechanism and flat field calibration lamp control, accumulator control, and the SI C&DH Interfaces.

Microprocessor - The microprocessor used is a 16-bit monolithic central processing unit fabricated with Integrated Injection Logic (I^2L). The microprocessor has a 16-bit word length with the capability of directly addressing 32 K words. The microprocessor clock is 3 Mhz, but can be reduced to 1.5 Mhz if the microprocessor chip degrades with life or radiation.

Memory - The CEA includes 12 K words of Programmable Read-Only-Memory (PROM) which contains the instrument firmware and fixed operating parameters. There is also 16 K words of Read/Write Memoray (RAM) which is used for storing science and engineering data, variable operating parameters and scratch pad memory. The RAM is assigned addresss space locations in blocks of 2 K words. An additional block of 512 addresses is assigned to the virtual RAM (VRAM) which is a 16-bit register which may be loaded and read by the microprocessor. This allows the execution of up to 512 identical instructions without the use of memory.

24-Bit Output Port - This is an output port used for microprocessor communication with the DACs and for control of the flat-field calibration lamp and mechanism drivers. This port consists of ten address bits, 12 data bits and two control bits.

DAC Interface - The DAC interface provides a method of loading and reading the DAC control registers. The registers are loaded through the 24-bit port, and are read serially. The DACs include 512 Discriminator DACs - 8-bits each; the Focus Trim Coil DAC - 8-bits; X & Y Deflection DACs - 12-bits each; Discriminator Reference DAC - 8-bits; and High Voltage Control DAC - 10-bits.

Mechanism and Flat Field Calibration Lamp Control - The FOS mechanisms are controlled by the microprocessor through an 8-bit mechanism register. This register is loaded from the 24-bit port. Three of the bits are used to select the mechanism to be enabled, while 4-bits are the four phase signals to the motors. The eighth bit is not used. Position feedback from the mechanisms is read serially by the microprocessor.

The flat field calibration lamp is turned on and off by the microprocessor through the 24-bit port.

Accumulator Control - The accumulators in the ASP are controlled from the microprocessor throught the 24-bit port. The control signals clear, enable and inhibit the counter, select the operating mode and transfer data to the output buffers. In addiion, there is an Enable/Inhibit signal for each channel which is loaded through the 24-bit port to force the output of any malfunctioning channels to zero.

SI C&DH Interfaces - The CEA provides the interfaces to the SI C&DH for receiving serial commands, transmitting science data and transmitting serial engineering data. The command and engineering data interfaces are to the Remote Interface Units (RIU) of the SI C&DH system while the science data is transmitted to the Science Data Formatter (SDF). The RIUs are located in the FOS as shown in Figure 3-1 and the SDF is external to the FOS. The characteristics of these interfaces are in accordance with the SI to SI C&DH ICD, IMB No. 7936229.

Central Power Supply - The CPS contains the power distribution and control circuits for the FOS and the power conditioning circuits for the ASP and the CEA. In addition, the CPS contains the control and monitoring circuits for the pin pullers, motor drivers, deflection and focus coils and thermal controllers.

Power Conditioning for ASP and CEA - There are two power supplies in the CPS, each electrically isolated from input power and from each other. The logic supply furnishes the necessary power for all the logic elements in the CEA and the ASP. The quiet supply furnishes power to all the sensitive analog circuits in the ASP and also to the deflection and focus coil driver circuits.

Power Distribution and Control - Figure 4.5-2 shows the FOS power distriubtion. The switching is performed by magnetically latching relays controlled from the RIU using discrete commands.

Pin Puller - Each CPS contains circuits which perform the pin puller functions. Two discrete commands are required to fire any pin puller. The ARM command enables power to the actual pin puller electronics through a latching relay. A FIRE command then causes a current pulse of sufficient magnitude and duration to flow through the selected pin puller. The latching relay is normally in the SAFE position which prohibits the FIRE command from activating the current pulse.

Motor Drivers - The four mechanisms are operated by DC stepper motors containing four motor coils each. The control for the motors originates in the CEA and is transfered to the CPS as CMOS level signals. Each motor receives an individual enable command, and the four phase control signals are common to all motors. The control signals are optically isolated from the power switching circuits in the CPS.

Deflection and Focus Coil Drivers - There are three coil driver circuits in each CPS for driving the X and Y deflection coils and the trim focus coil. Each driver circuit is a programmable current source controlled from the CEA.

Thermal Controllers - Circuits are provided in the CPS to control the heaters in the optics compartment and on the bulkhead. These circuits monitor the temperature at the heater locations and turn the corresponding heater on or off by way of solid state switching components. The turn on and turn off times are controlled to prevent electromagnetic interference.

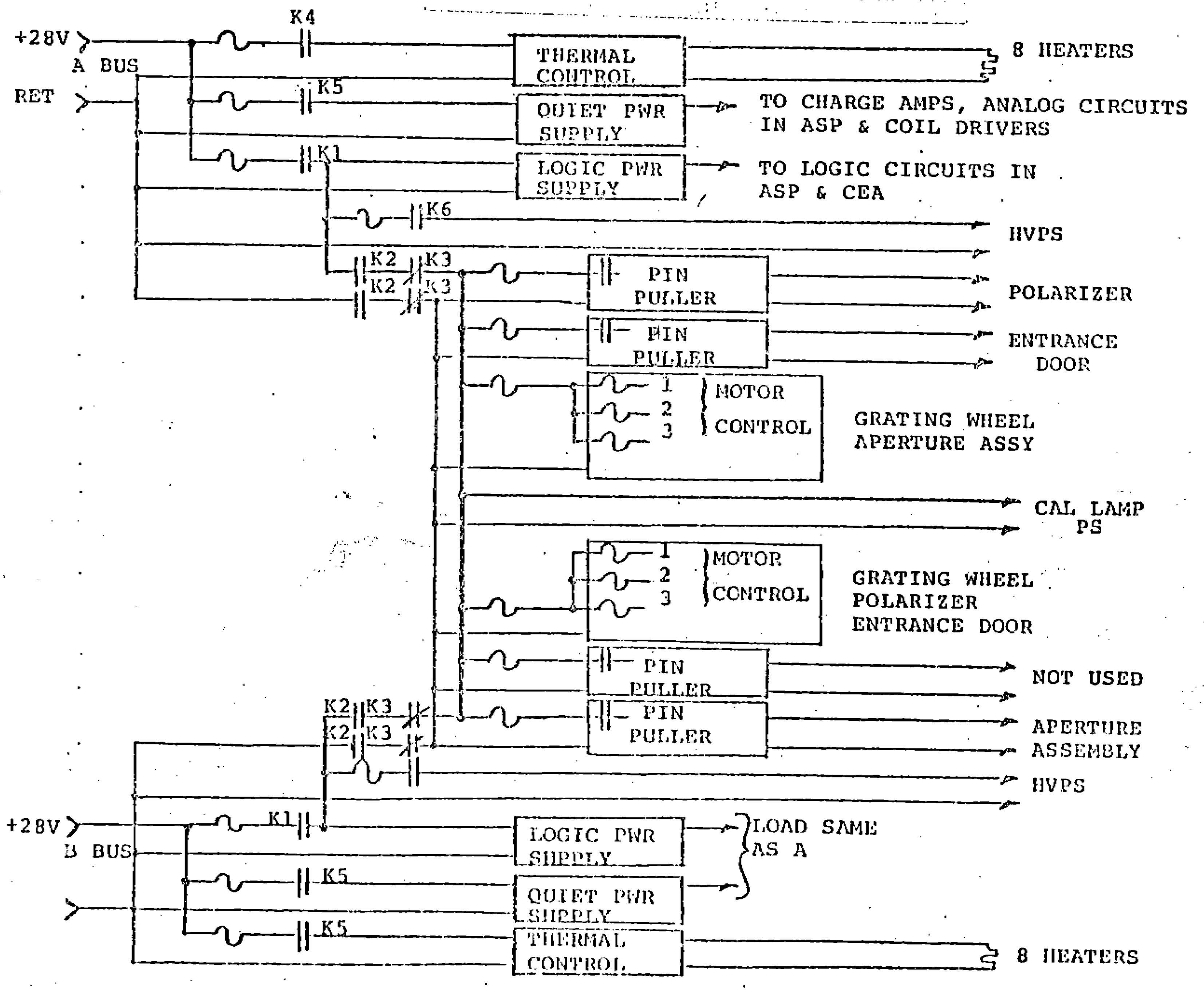


FIGURE 4.5-2 FOS [illegible]ER SWITCHING/DISTRIBUTION

High Voltage Power Supply - The High Voltage Power Supply (HVPS) converts power from the input power bus to a regulated, filtered voltage output for the Detector Subsystem. The HVPS output is controlled from the CEA by way of a 10-bit digital command. The output voltage is programmable from 0 to -25,100 volts in 24.4 volt increments. The HVPS provides engineering data monitoring of its output voltage, output current and temperature.

Calibration Lamp Power Supply - The Calibration Lamp Power Supply (CLPS) converts power from the FOS common bus to a current-stabilized DC output suitable for starting and operating the calibration lamp. The CLSP is capable of greater than 400 volts DC for starting the lamp and then regulates the current at 10 ma ± 20%. The CLPS provides engineering data monitoring of its output voltage, output current and temperature.

Remote Modules - The FOS command and engineering data interfaces are supplied by two Remote Modules (RM). Each RM consists of one RIU and half of the EU. The characteristics of the RM are described in the SI to SI C&DH ICD IBM No. 7936229.

4.6 Thermal

The thermal control subsystem uses a passive design augmented with heat pipes and electric heaters to maintain the instrument components within the required temperature limits. The design is cold-biased to permit temperature control within the desired range by a combination of radiators and electric heaters. The concept is illustrated in Figures 4.6-1 and 4.6-2.

The FOS instrument has been divided into optics and electronics compartments which are thermally isolated to the maximum extent feasible.

Optics Compartment - The optics compartment contains the optical bench, the optical elements, the two detector assemblies with the charge amplifiers, the optics mechanisms, and the calibration sources with their power supply.

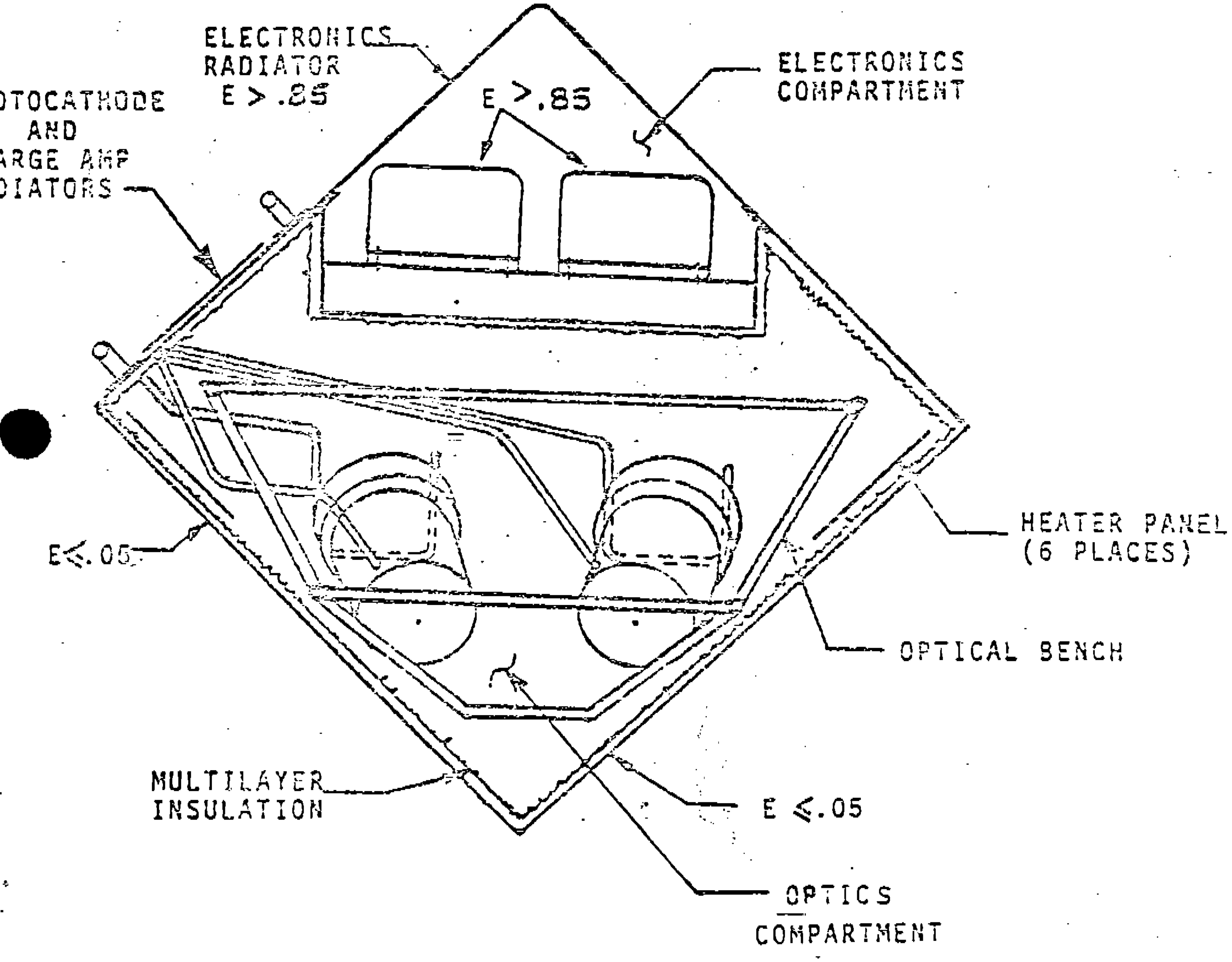
The interior of the compartment is insulated with multilayer insulation blankets. The blankets are formed by ten layers of perforated double aluminized mylar, 1/4-mil thick, alternated with dacron net spacers. A polyester screen cloth is used as a filter to prevent any particle trapped within the insulation from escaping during ascent venting. Aluminized kapton sheet, 2-mil thick, forms the insulation covers. For stray light control, the insulation side facing the interior of the compartment is painted black.

The compartment optical bench and components are maintained at $16^oC \pm 4^oC$ with a redundant electric heater system. Film heaters are attached to six aluminum panels located at the inboard sides of the FOS facing the optical bench structure, three panels per side. Each panel is approximately 24 by 9 inches, and is temperature controlled by a sensor located on the panel. The heater power requirements are approximately 38 watts for the cold operating conditions.

The detectors' photocathodes are maintained at low temperature ($\leq -8^oC$) to satisfy the detector dark count requirements. This is accomplished with heat pipes that transfer thermal energy from the detector assemblies to radiators located on the FOS sides facing the SSM walls.

FIGURE 4.6-1

THERMAL CONTROL SUBSYSTEM



VIEW LOOKING AFT

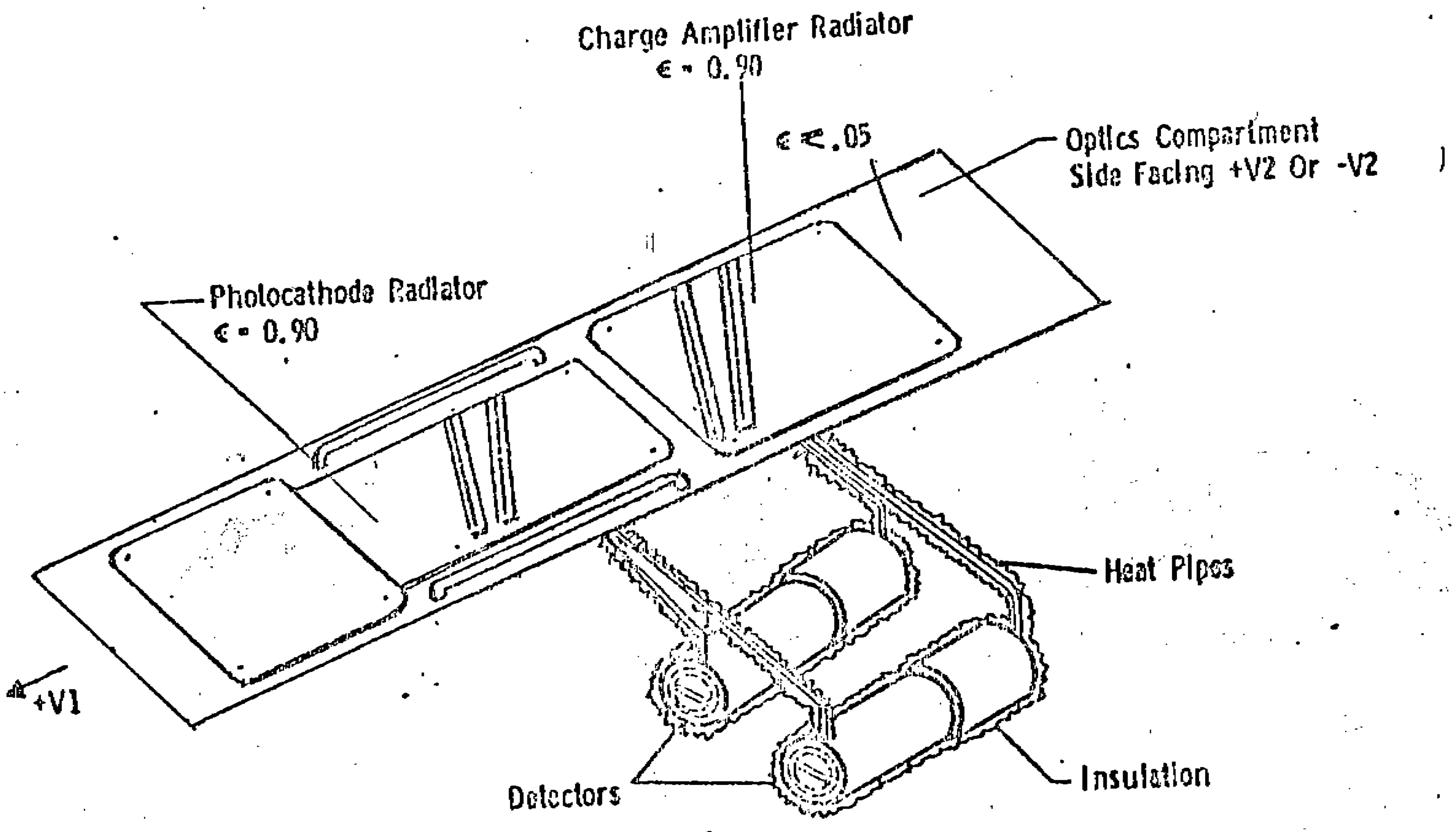


Figure 4.6-2 DETECTOR THERMAL CONTROL

A schematic of the design configuration is presented in Figure 4.6-2. The two detectors are coupled with four heat pipes to two separate radiators: the photocathode end of the detectors to one radiator and the charge amplifier end to the other. This arrangement, with a separate path for the charge amplifier heat dissipation (approximately eight watts), minimizes the impact of the digicon/charge amplifier configuration constraints upon the photocathode temperatures. The charge amplifiers, housed within the detector magnetic shields, are mounted as close as feasible to the diode array side of the digicons and are thermally coupled through 520 electric wires to the diode array.

At the photocathode end of the digicon, eight beryllium oxide rods and a beryllium oxide cylinder connect the digicon ceramic body to a flange external to the pole piece. A ring-shaped saddle, to which the evaporator zone of the heat pipe is permanently attached, is bolted to the flange and forms a nonpermanent joint between the heat pipe and the detector.

At the charge amplifier side, the coupling to the heat pipe evaporator zone is through two rectangular saddles attached to the hybrids board supports extended through the detector aft cover. This joint, as in the case of the photocathode end, is also of nonpermanent type.

The heat pipes are made of internally-grooved aluminum tubing 5/16 inches in diameter, with ammonia as the working fluid. They extend from the detectors (evaporator side of the heat pipe) to the radiators (condenser side) with lengths in the 40-70 inch range. Bends along the pipe length permit the contraction of the pipes without applying undesirable loads to the detectors. The bends along the pipe length are all contained in one plan to permit the verification of the zero-g heat pipe performance.

For ground testing, boiler reflux operation of the heat pipes is obtained within the FOS +P1 axis inclined 9.75 degrees from the veritical, in the P1 - P2 plane.

The radiators, one 2.6 ft^2 for the charge amplifier and the other 4 ft^2 for the photocathode temperature control, are located on the FOS P3 side facing the +V2 SSM wall. The radiators are thermally isolated from the FOS structure with multilayer insulation and standoffs. The thermal standoffs also provide the electrical isolation of the radiators from the FOS main structure required to satisfy the single point ground requirement.

The temperature of the detector assembly components, (digicon, permanent magnets, deflection coils, and charge amplifier) during the FOS operating modes are within the specified range; therefore, no heater power is required for these modes.

For monitoring of the thermal performance of the compartment components, sensors are located at the main mechanical interfaces with the OTA, at the optical bench attach links, and on some critical optics components. In addition, sensors will monitor the temperature near the photocathode, diode array, coil assemblies, and charge amplifiers.

Electronics Compartment - The electronics compartment contains all the support electronics required for the operation of the FOS including the SI C&DH Remote Interface Units.

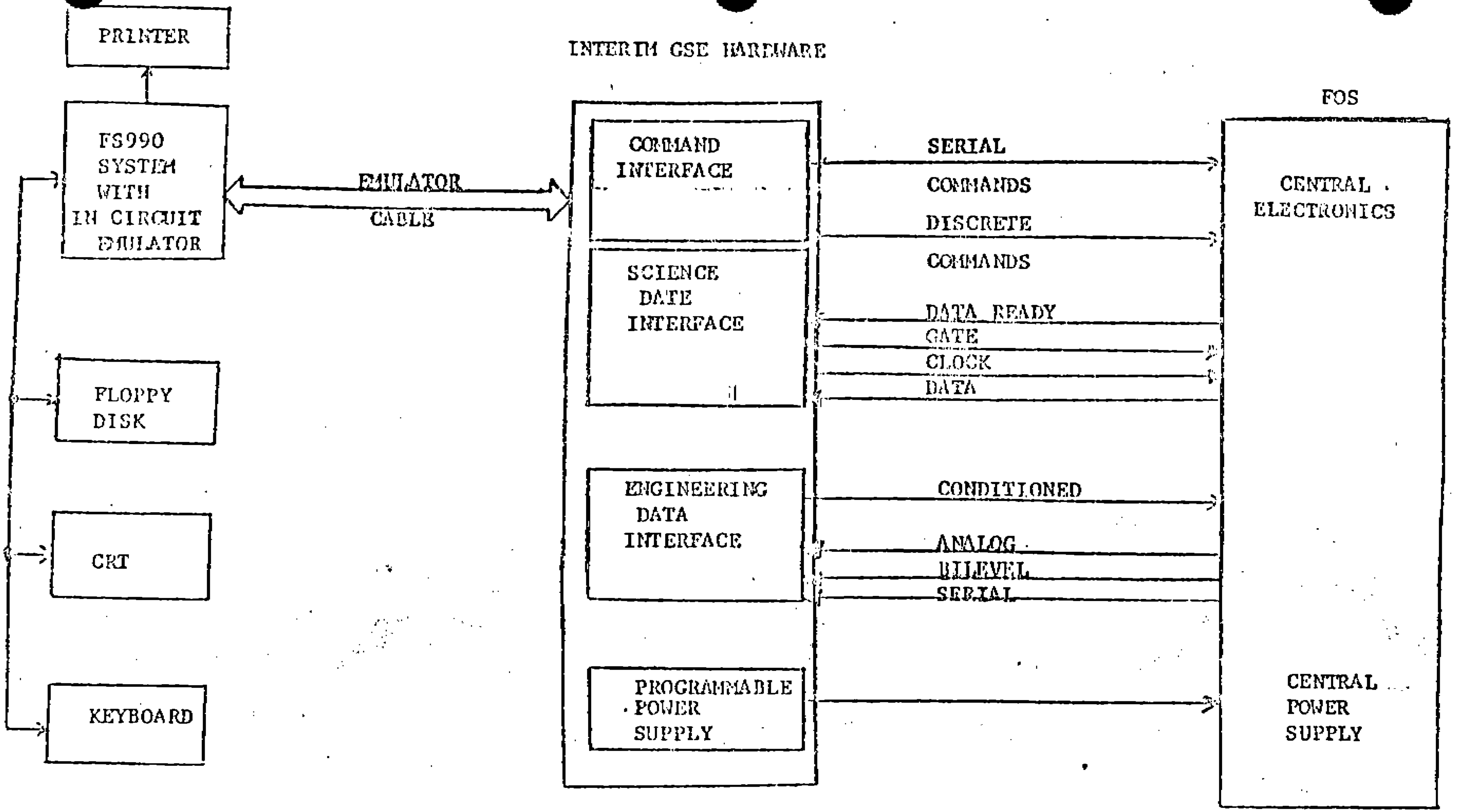
The electronic boxes are attached to an aluminum structural shelf and radiate the internally generated heat through the covers to the compartment radiators. The compartment dissipation is approximately 100 watts. No additional heater power is required while the electronics is operated during hot or cold operating modes.

4.7 Ground Support and Test Equipment

The Ground Support Equipment (GSE) for the FOS consists of the Interim Electrical GSE (IGSE) and mechanical GSE.

IGSE - The FOS IGSE is capable of exercising the FOS via the command interfaces and verifying the correct instrument performance via the science data interface and the engineering data interface. Figure 4.7-1 shows a block diagram of the IGSE. The heart of the IGSE is the Texas Instruments FS990 Microprocessor Development system which is mounted in a desk type console along with the floppy disk, CRT, keyboard and printer.

The IGSE hardware simulates the command, Engineering Data and Science Data interfaces of the SI C&DH as defined in the SI to SI C&DH IBM No. 7936229. The Programmable Power Supply is programmable from the FS990 and can be programmed from 0 to 32 volts dc.



Interim GSE Block Diagram

FIGURE 4.7-1

The IGSE Software will provide two capabilities for the check-out of FOS equipment. The first capability will concentrate on the checkout of individual electronics boxes. This will give the ability to test all modes of operation or logic paths the device inherently contains. The second capability will provide the means to drive FOS at the assembly and systems levels. This will allow simulation of modes of operation similar to those which will be encountered in actual use.

Mechanical GSE - The mechnical GSE shown in Figure 4.7-2 for FOS consists of a pallet with casters to function as a dolly, a shipping container, a spreader bar with slings and a lifting adapter that mounts to the GSE interface pads on the FOS enclosure. For delivery, the FOS will be purged with dry nitrogen and bagged.

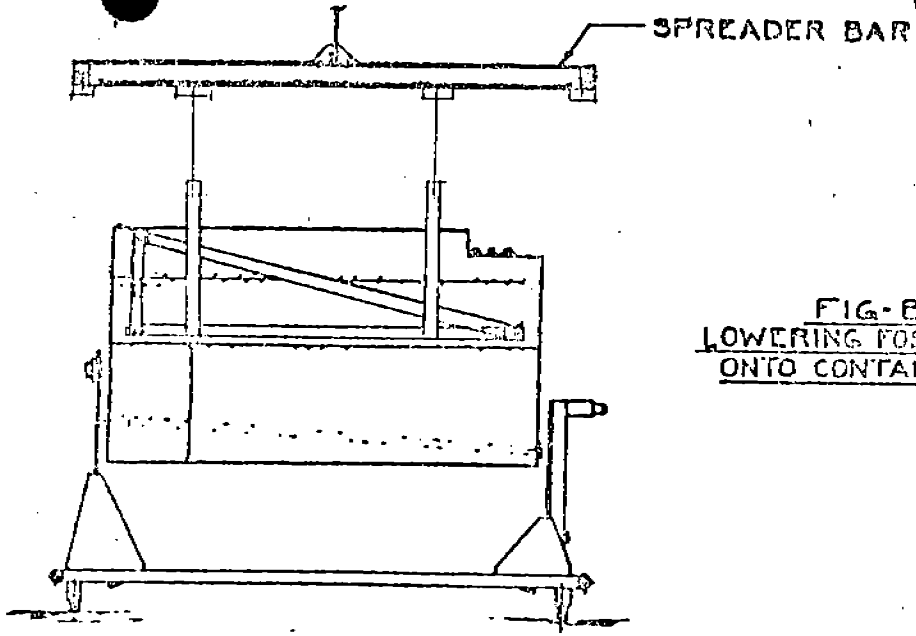


FIG-A LOWERING FOS ONTO SUPPORT PALLET

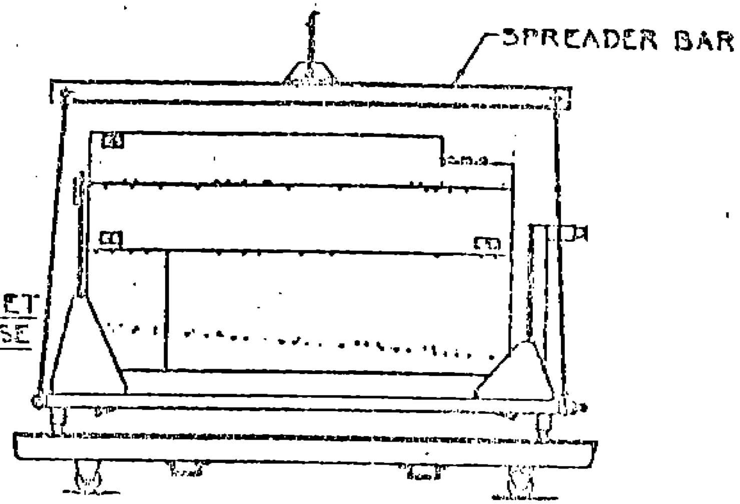


FIG-B
LOWERING FOS & PALLET
ONTO CONTAINER BASE

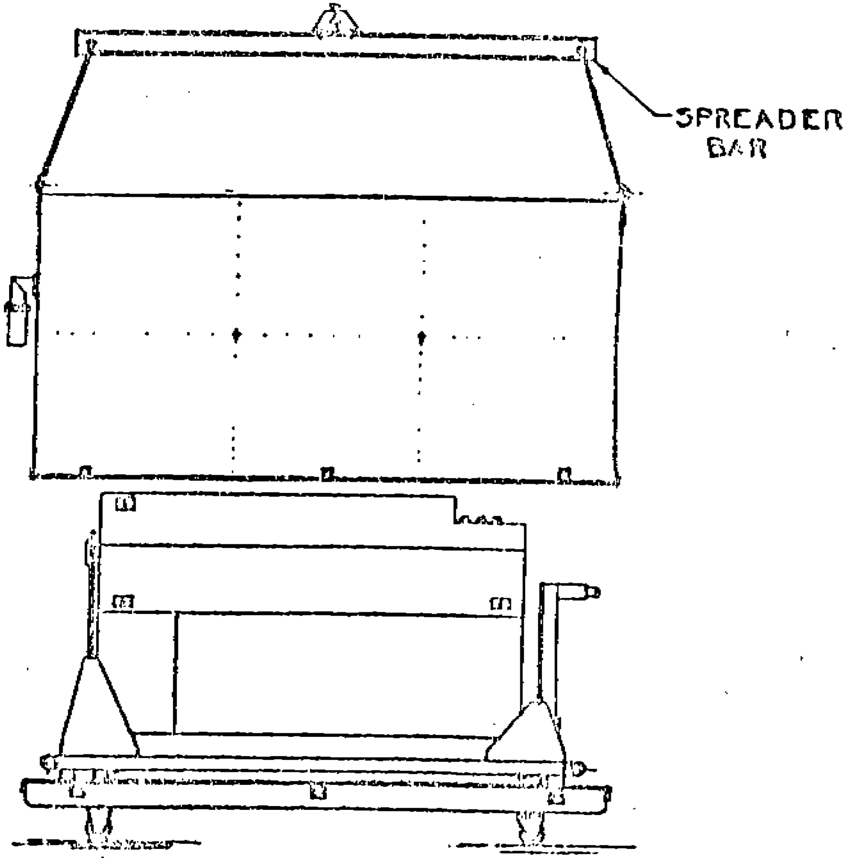


FIG-C LOWERING CONTAINER COVER
ONTO CONTAINER BASE

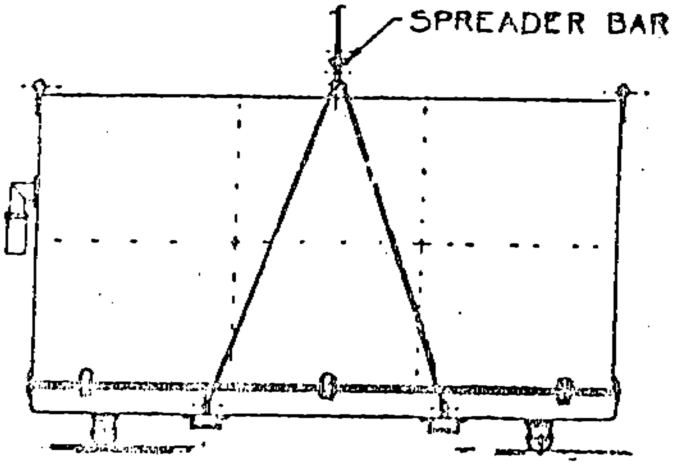


FIG-D SHIPPING CONTAINER

FOS MECHANICAL GSE

5.0 SYSTEMS OPERATION

5.1 General Requirements and Constraints

According to the present baseline, the FOS will be operated in two basic modes: hold mode and data-taking mode. The latter mode consists of five basic configurations for obtaining scientific information. An extensive series of observations is necessary at the beginning of ST operations to exercise all modes of instrument hardware and software operations. A set of commands are necessary to configure the FOS for each scientific observation, standard star observation, or calibration. These include selection of the one of two detectors to be used, powering up the detector if needed, selecting the grating/prism/filter set, polarizer, and aperture desired, etc. These functions should normally be executed during slews to new targets to save observing time. Many targets will, however, require observation in many different FOS configurations necessitating changes while locked on target.

5.2 Hold Mode

The present baseline configuration calls for a Hold mode to maintain the optical bench at 16°C when the instrument is not in use. This requires up to 56 watts of power to supply the heaters. Two orbits prior to a scheduled observation, all power supplies of the selected side (red or blue) will be turned on consuming 115 watts in the warm configuration or 135 watts in the cold case when heater power is also needed. This two orbit transition period allows the instrument to reach an operational level.

5.3 Data-Taking Mode

The first step required for data-taking is acquisition of the target using the direct imaging optics. Reconfiguration of the mechanisms follows to permit a high resolution, low resolution, or spectropolarimetry condition in the optics. Calibrations, which also require some reconfiguration, may be performed prior to and/or following an observation. A special data-taking mode to permit observation of targets of rapidly varying luminosity is also available.

5.3.1 Acquisition Mode

The FOS acquisition mode is used to obtain and center the target in the aperture. A large entrance aperture, a 4.3 sec square, is dedicated to acquisition. The acquisition aperture is used in conjunction with the direct imaging camera mirror on the grating wheel. Direct imaging of the target concentrates the light allowing a quicker response than with a spectrally dispersed image.

Many FOS acquisitions will rely on "peaking up" on either the target star or a nearby reference star prior to a blind offset. This involves a series of digicon deflections and small telescope repointings to locate the region of maximum signal on the sensor. The length of observation required for this peak-up activity depends upon the brightness of the target star, the spectral shape of the target star, and which of the two sensors is employed.

5.3.2 Calibration Mode

An internal FOS calibration mode is available for periodic standardized calibration of the optical-detector system. There will be two wavelength calibration lamps and two flatfield sources. Many different FOS configurations (grating position, etc.) may need to be calibrated during the course of observation of one target.

In addition to the use of the internal calibration sources, spectrophotometric standard stars will be observed periodically to provide an end-to-end calibration of ST/FOS sensitivity. Only extended operational experience will determine how often these observations are necessary. The maximum projected frequency of standard star observation is once per target; the minimum is once per day, but could conceivably be even lower frequency if the FOS exhibits excellent stability.

5.3.3 Low Resolution Mode

The low resolution mode is designed to have a resolving power of R=100 $\pm$ 50 for wavelengths λ = .11 um to .22 um and λ = .4 um to .8 um using two individual low resolution gratings. An order blocking filter is used in conjunction with the longer wavelength grating. The filter and gratings are part of the grating wheel and may be rotated into position for data-taking with either the blue or red digicon. A sapphire, thin prism covering the wavelength range from λ = .16 um to λ = .8 um is available for "quick-look" observations at low resolution.

5.3.4 High Resolution Mode

The high resolution mode (R=1000 + 500, -0) ranges from λ = .11 um to λ = .8 um. A total of six gratings with overlapping ranges are used to achieve this wavelength spread. Blocking filters are provided for the four higher wavelength gratings. The high resolution filters and gratings are also located on the grating wheel and may be rotated into the light path of either the red or blue digicons.

5.3.5 Spectropolarimetry

The FOS has the capability to analyze the incoming light to permit spectropolarimetric observations. The polarizer, located downstream from the entrance aperture, has the capability to move into the light path to polarize light or remain out of the light path for normal observation. The polarizer allows measurement of any angle of polarization. Spectropolarimetry is possible in both the low resolution and high resolution modes.

5.3.6 High Time Resolution

For observing rapidly-variable objects of unknown or variable period, a high rate integration mode is available in the software to send all data to the Science Data Formatter as quickly as possible. Approximately 5% of all FOS data will be taken at this maximum rate of 1Mbs.

5.4 Data Description

Electron charges received in each channel at the digicon pass through the charge amplifier, filter amplifier, comparator and the buffer/accumulator. Functions such as noise rejection, co-addition of the 512 accumulations, substep control and time-resolved spectrophotometry are all controlled in the FOS hardware. All 512 channels combine in the serial to parallel converter. The 16-bit data word enters the microprocessor and memory in the Central Electronics of the FOS at a maximum rate of 1.024 Mbps. The actual integration of scientific data is controlled by the microprocessor without the need of C&DH intervention.

A low rate, non-time resolved integration mode of FOS data-taking will be employed most of the time. A typical one minute integration period in the FOS microprocessor before transferring the data to the Science Data Formatter (SDF) results in a data rate of approximately 750 bits per second. At this rate, only 200 feet of magnetic tape per hour of FOS operation are needed for ground storage.

APPENDIX A

FOS PERFORMANCE PARAMETERS

FOS PERFORMANCE PARAMETERS

A. Detectors

The instrument shall contain two independently operable 512-channel digicon detectors with associated electronics.

B. Image Format

Each detector diode array shall be a linear array of 512 elements on 50 μm nominal centers. Each array element shall have a geometric height of 200 $\pm$ 10 μm and a geometric width of 40 $\pm$ 2 μm.

C. Image Scale

The spectrograph optics shall reimage the entrance aperture focal plane such that the image scale at either detector is 140 $\pm$ 10 μm/arcsecond when illuminated by the OTA or its optical equivalent.

D. Fields of View

There shall be 12 apertures with dimensions corresponding to fields of view from 0.1 arcsec to 4.3 arsec in scale. The size, configuration and relative locations of the apertures is defined in Table 1. Apertures not selected for a given observation shall not allow stray light contamination. One aperture position shall be opaque. A failsafe position shall be provided with 0.5 sec and 4.3 sec square apertures.

E. Spectral Resolving Power

When observing a point source, the instrumental profile full spectral width at one-half peak response, divided into the source wavelength at the center of each spectral subrange, shall be 10^3 +500, -0 for the high resolution modes, and shall be $10^2 \pm 50$ for the low resolution modes.

F. Instrument Profile

When observing a point source, the instrument profile (defined as the detector response to a monochromatic source from within a solid angular distribution simulating the OTA focal ratio, central obscuration, and aastigmatism) for every resolution mode and spectral range, when normalized to peak response = 1.0 shall lie on or below the curve depicted in Figure A-1 and A-2 for every detector diode.

TABLE A1

APERTURES AND RELATIVE POSITIONS

GROUP	NO.	SIZE(WxL)* (ARC SEC)	NUMBER	SHAPE	PURPOSE
B	1	0.5	Single	Round	Science-Polarization
	2	0.3	Single	Round	Science-Polarization
	3	1.0	Single	Round	Science-Polarization
	4	Blank	--	--	Background
A	1	4.3	Single	Square	Acquisition
	2	0.5	Paired	Square	Science-Beam Switching
	3	0.25	Paired	Square	Science-Beam Switching
	4	0.10	Paired	Square	Science-Beam Switching
C	1	1.0	Paired	Square	Science-Beam Switching
	2	0.25x2.0	Single	Rectangular	Science-Nebular
	3	2.0	Single	Square	Science-Wide Occulter (0.3 arcsec bar)
	4	0.7x2.0	Single	Rectangular	Science-Narrow Occulter (0.3 arsec bar)

*W(width) in-dispersion
L(length) cross-dispersion

G. Spectral Ranges

The FOS optical geometry shall permit observations with a spectral resolving power of 10^3 as defined above over a wavelength range from 114 to 900 nm. The optical geometry shall permit observations with a spectral resolving power of 10^2 as defined above over the range from 114 to 800 nm. The optical geometry shall permit spectropolarimetric observations over a wavelength range from 120 to 320 nm, and a non-dispersive train for direct imaging from 114 to 900 nm.

H. Efficiency

For both the resolution = 10^3 and 10^2 modes as described above, FOS efficiency shall exceed 1.0 percent over the entire range from 120 nm to H α (656.3 nm), shall exceed 2.0 percent from 120 to 200 nm, shall exceed 7.0 percent from 200 to 400 nm, and shall have a peak efficiency exceeding 10.0 percent.

I. Instrument Noise

The FOS background noise from all sources during inflight operating conditions outside the SAA shall not exceed 2×10^{-3} counts/sec/diode at $-10^{\circ}C$ photocathode temperature.

J. In-Flight Calibration

The FOS shall have on-board spectral calibration sources to allow determination of any astronomical source apparent wavelength to a relative accuracy of 20 percent of the spectral resolution at that wavelength, and it shall have a flat-field source.

K. Exposure Intervals

The FOS shall be capable of exposure times of 50 microseconds minimum duration, shall be capable of meeting performance requirements with minimum intervals of one millisecond between exposures and shall be capable of maximum continuous exposure rates up to 100 512-channel exposures/second.

L. Instrument Stability and Repeatability

The FOS radiometric response (total counts per photon for a monchromatic input to the instrument) derived from repeated measurements shall be constant within the following limits for 99 percent of the operating diodes.

a) The response shall be stable to within 1.0 percent over periods up to 4 hours with the opto-mechanical configuration held constant.

b) The response shall repeat within 3.0 percent for opto-mechanical reconfigurations (returning to starting configurations) during a 4 hour observing period.

c) After achieving thermal equilibrium, response shall repeat within 5.0 percent for measurements made up to 24 hours apart (with the opto-mechanical configuration returned to that of the first measurement, with the instrument recalibrated with the internal wavelength calibration system and with the target recentered with the ST).

M. Pulse Saturation Error Correction

For input count rates randomly distributed in time up to 10^5 counts/sec/diode, the measured rate shall be correctable to the true input rate to an accuracy better than 4.0 percent. For input rates (also random in time) between 1 and 10^4 counts/sec/diode, the measured rate shall be correctable to the true input rate to an accuracy better than 1.0 percent.

N. System Switching Time

The time required for the FOS to switch from operation with one detector to operation with the other detector shall not exceed 5 minutes.

O. Acquisition

When provided with an input image of a point light source with position stability better than 0.01 arsec, the FOS shall be able to locate its centroid to within $\pm$0.03 arsec for use in target acquisition.

P. The photocathode operating temperature shall be maintained between $-32^{\circ}C$ and $-8^{\circ}C$ for the cold and hot interface sink temperature extremes defined in ICD-02, Axial SI to OTA/SSM.

Q. Polarimeter Optics

The FOS shall be equipped with a polarizer module which shall modulate the light irradiance on the detector in a way related to the state of polarization of the incident light. In particular the modulation of the irradiance shall exceed seventy percent (70%) for 100% linearly polarized input light of any position angle for wavelengths from 0.1216 to 0.300 μm. The polarizer module shall have a transmission of unpolarized light exceeding 0.1 at 0.1216 μm when both output beams are summed. The polarizer module shall have a setting so that both FOS beams are clear simultaneously. In the event of failure of the polarimeter, it shall be possible to remove it from the light paths permanently.

R. Derived Limiting Magnitude (Informational Purpose Only - Not an Additional Requirement.)

From the FOS efficiency and noise performance stated in 3.2.1.H and 3.2.1.I, and assuming an OTA collecting area of 4.5×10^2 cm^2 with 63% OTA throughput, the FOS will achieve S/N>7 per diode at 400 nm in the $\lambda/\Delta\lambda = 1000$ mode for a 3 hours integration of an unreddened A0V stellar flux distribution of magnitude V = 23.

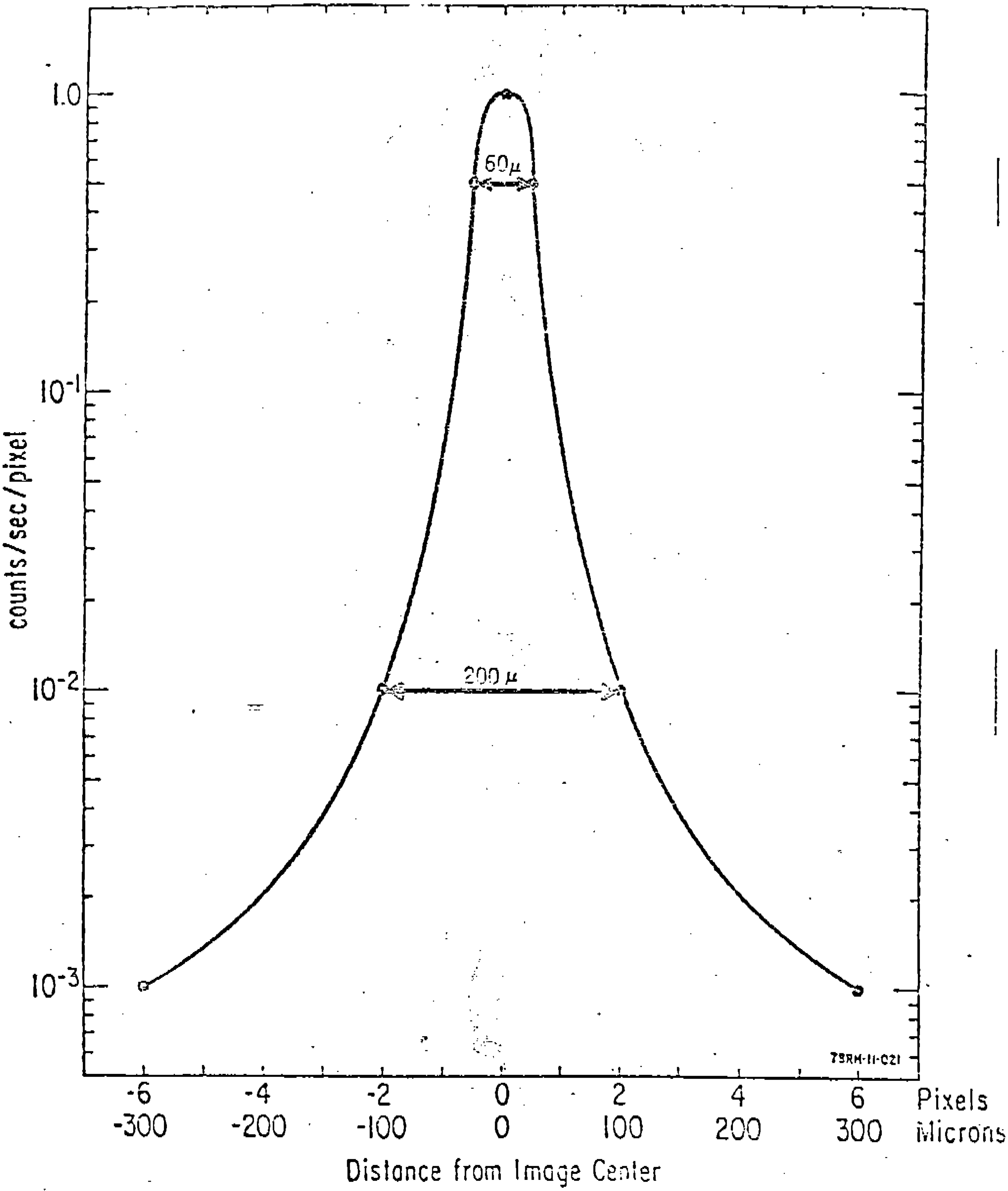


Figure A-1
FOS Instrument Profile
Distance from central image point ≤ 6 pixels

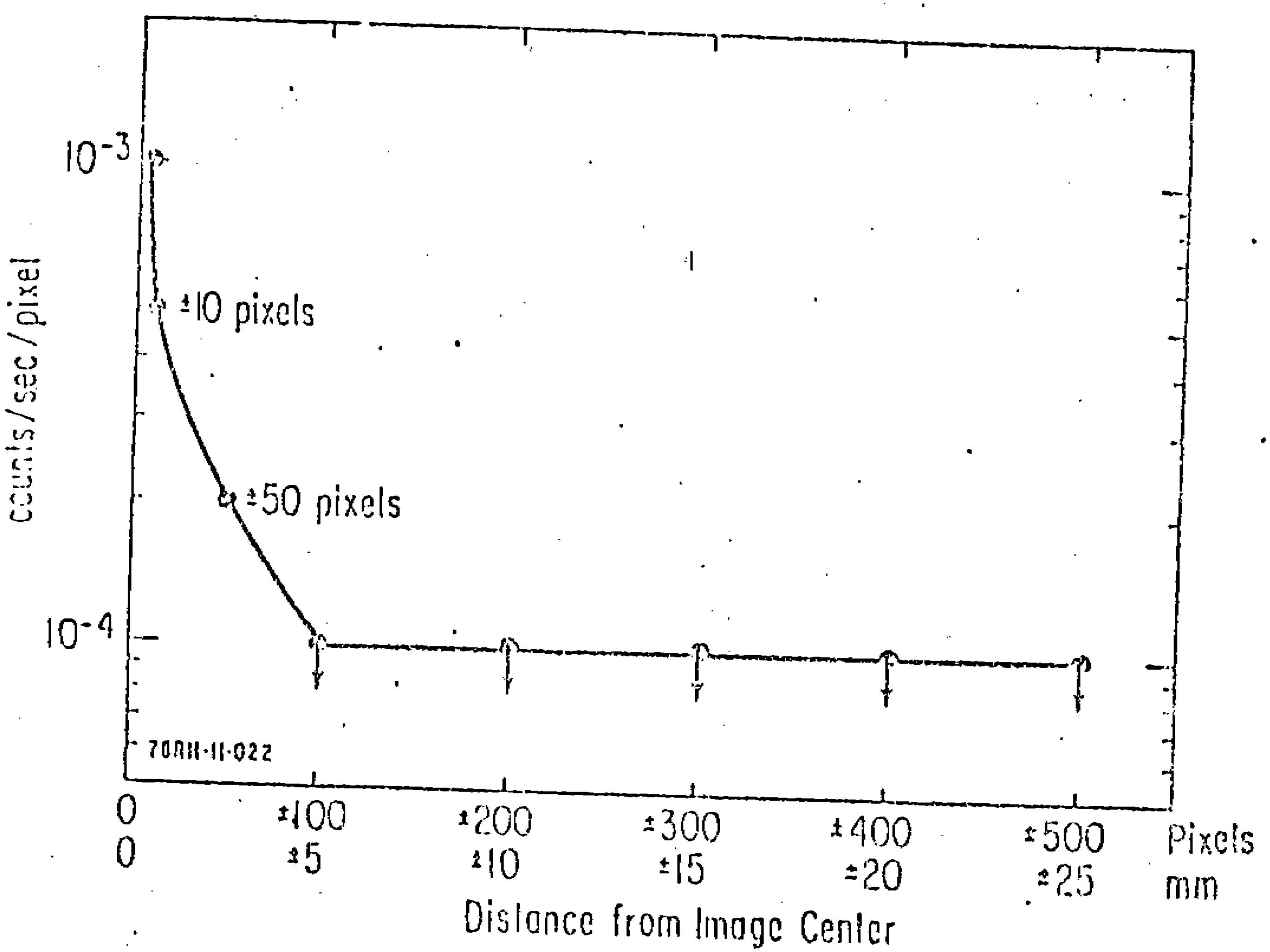


Figure A-2
FOS Instrument Profile
Distance from central image point = 6-511 pixels