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SPACE ASTRONOMY
OF THE
STEWART OBSERVATORY
THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

A SYSTEM FOR THE STUDY OF THE
DETECTION OF FAINT ASTRONOMICAL SIGNALS

Supported Under NGR 03-002-032

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INTRODUCTION

Two fundamental problems in astronomical observations are the optical detection of images, especially faint images, and the optimal retrieval of data from an image once detected. This report is concerned with the description of a system which has been fabricated to investigate the first problem by using an artificial star and sky pattern formed under widely variable controlled conditions. These conditions include a variety of controls on the detector environment as well as image parameters. The system shown in Figure 1 is known as the Signal Detection system and was the first major in-house project undertaken by Space Astronomy of the Steward Observatory. As such, it contributed heavily to our initial operational and organizational experience and, consequently, suffered slightly from our inexperience and required a longer than expected time to place into efficient operation.

The original design was based primarily upon photographic materials as the detectors to be studied, but the general nature of the images formed permits use of a wide variety of detectors of photoelectric type. Provision for individual control of the star and sky signals includes size, intensity and color of the sky spot, and size, intensity, color and bandwidth of the star spot. The original wavelength range is limited to the visible and near I.R. Consideration was not given to image polarization or off axis image properties and resolution. Control provisions at the detector included ambient air pressure to moderate vacuum levels (which automatically controls humidity as well), detector temperature down to dry ice level, and exposure control by either time or total light signal as seen by a photoelectric monitor operating continuously. Capabilities which were not included originally but which can or will be added include: systematic extension of the short wavelength

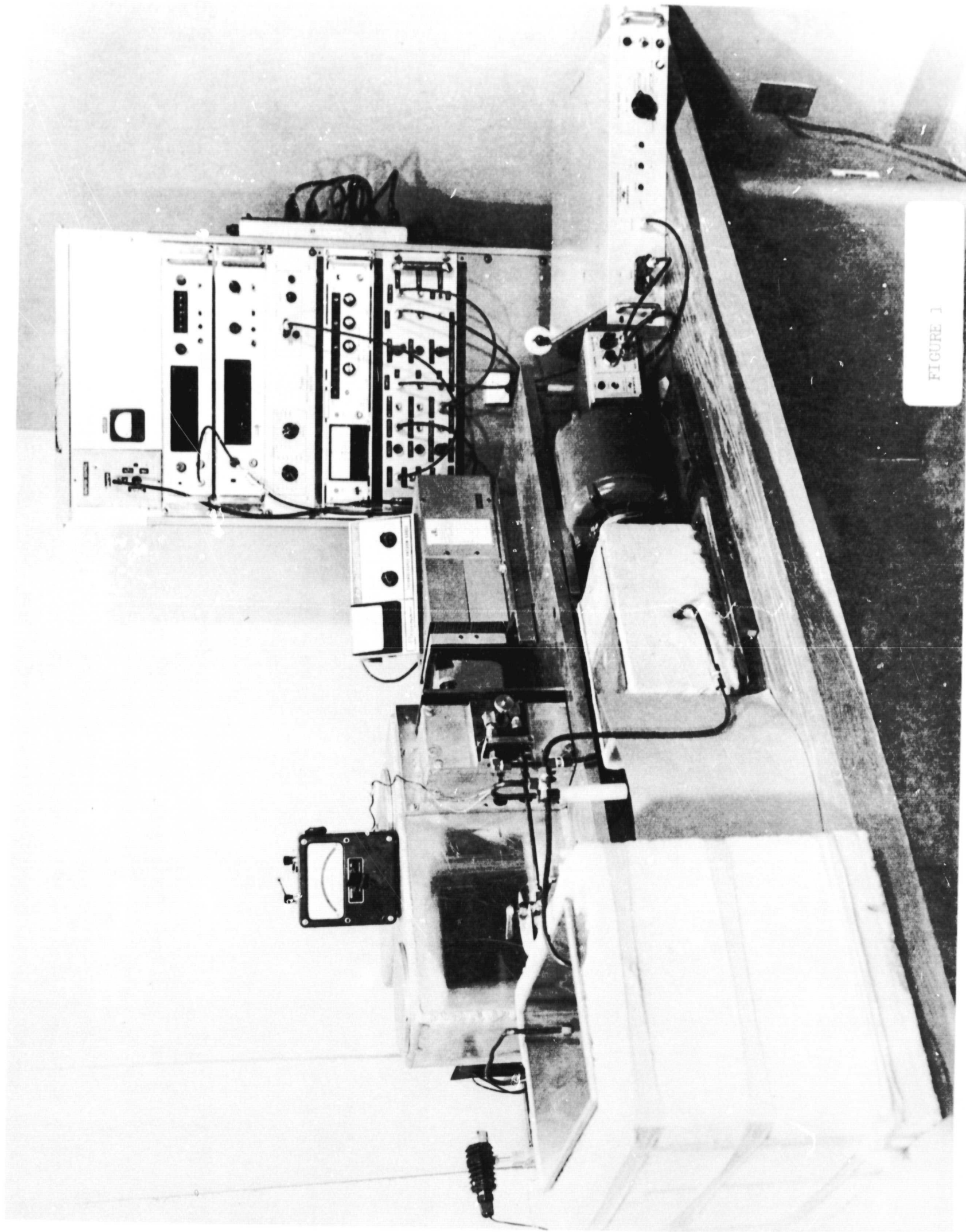


FIGURE 3

limit at least down to the fused silica transmission limit at 1600A and possibly further; addition of specific cryogenic temperature control capability below the dry ice point; inclusion of stroboscopic photographic pre- or post-flash capability; introduction of controlled amounts of radioactivity as background radiation sources; and addition of controlled magnetic field perturbations at the detector.

Programs which have been carried out with the system since it became operational have included studies of static electricity problems on film transport in a vacuum, studies of density and grain noise in film exposed to light at various temperatures, and testing of image dissector tubes as detectors for photometric and control functions in astronomical applications. Some of these results are briefly discussed in the SYSTEM APPLICATIONS section of this report. A great variety of possible future programs remains in studies of optimal ways of enhancing or detecting faint images and studying the effects of a wide variety of factors on detector performance.

GENERAL DESCRIPTION

The Signal Detection system divides into several subsystems which are discussed individually in following sections of the report.

A. The Main Chamber and Frame

The main chamber houses the optical system, provides access to two working focal planes, and provides a vacuum chamber for environmental control.

B. The Vacuum System

The vacuum system controls and monitors the pressure in the main chamber and any attached test detector compartment. Vacuum capability extends down to 20 microns.

C. The Optical System

The optical system produces an artificial star superimposed upon a uniform sky background. Star and sky are produced in separate channels and then combined and routed into MONITOR and DETECTOR focal planes. By interchanging or adjusting components, it is possible to individually control the size, brightness, effective wavelength, and, in the star channel, the bandwidth. Alternatively, the system can be used to image any general test pattern although no consideration has been given to precise resolution testing. Star spot size may be controlled from about 1-200 microns diameter and intensity over a range of 10^8 (20 magnitudes). The basic working wavelength range is from 3500A to 9000A.

D. The Electronic System

The electronic system consists of a photomultiplier light level monitor with its photocurrent detection circuits and the associated logic for controlling shutters and counter gates. Exposure may be automatically controlled by time (0.1 sec to many hours) or total integrated monitor signal level. A chopper system is available for the monitor to distinguish between star and background signals.

E. The Coolant System

The coolant system provides temperature control and monitoring for the detector under test. Temperature may be selected continuously from +100°F to -100°F.

F. The Test Detector Compartment

The test detector compartment houses the detector under test and interfaces to the main housing image plane and other subsystems as required by the detector.

MAIN CHAMBER

The main chamber is constructed of 3/8 inch aluminum plate and is attached

to a large base plate of 3/4 inch aluminum. Figures 2 and 3 present a general view of the chamber and base. The chamber is L shaped with the external portion of the optical system housed in the angle of the L. The base plate is supported on legs to allow clearance for the vacuum line connection and thermocouple vacuum gauge which attach to the underside of the base. All seams are aluminum welded to ensure vacuum seal. Early attempts to seal without welding were unsuccessful. Welding did produce some warping which complicates optical alignment. An improved design would utilize machining after welding.

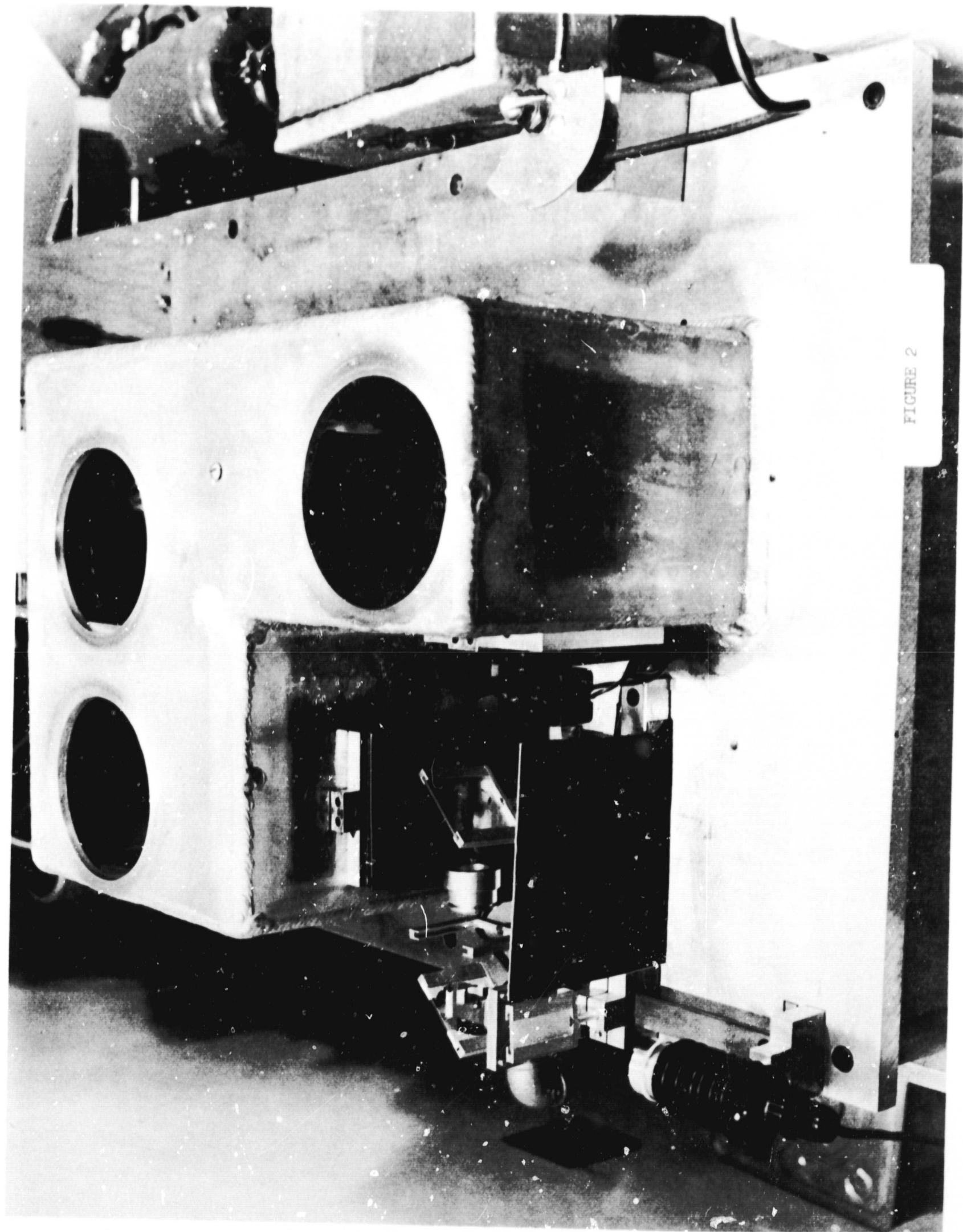
There are four optical openings in the walls of the main chamber: two round (2 inch diameter) entrance ports, one round (2 inch diameter) exit port, and a rectangular (4 x 6 inches) exit port. Vacuum seals at the round ports are accomplished with O-rings and thick fused silica windows. The two entrance windows are held in place by fixtures which serve also as mounts for electrically actuated shutters (Harvard #HU-159). The rectangular port is sealed by the detector compartment which has an O-ring set into its face plate.

In addition to the optical ports, there are three access ports (5 inch diameter) in the top of the main chamber. These openings permit access to internal components for adjustments or modifications. Vacuum seal of these ports is accomplished with O-rings set into aluminum caps. A vacuum relief valve is provided by a machine screw clamping against a small O-ring in the top of the chamber.

VACUUM SYSTEM

The vacuum system consists of a two stage floor pump, Welch Model 1402B; a thermocouple vacuum gauge, Robinair Model 1301D; the main chamber; the detector compartment; and 1 inch pipe fittings.

The pump connects to the main chamber at a threaded hole in the base



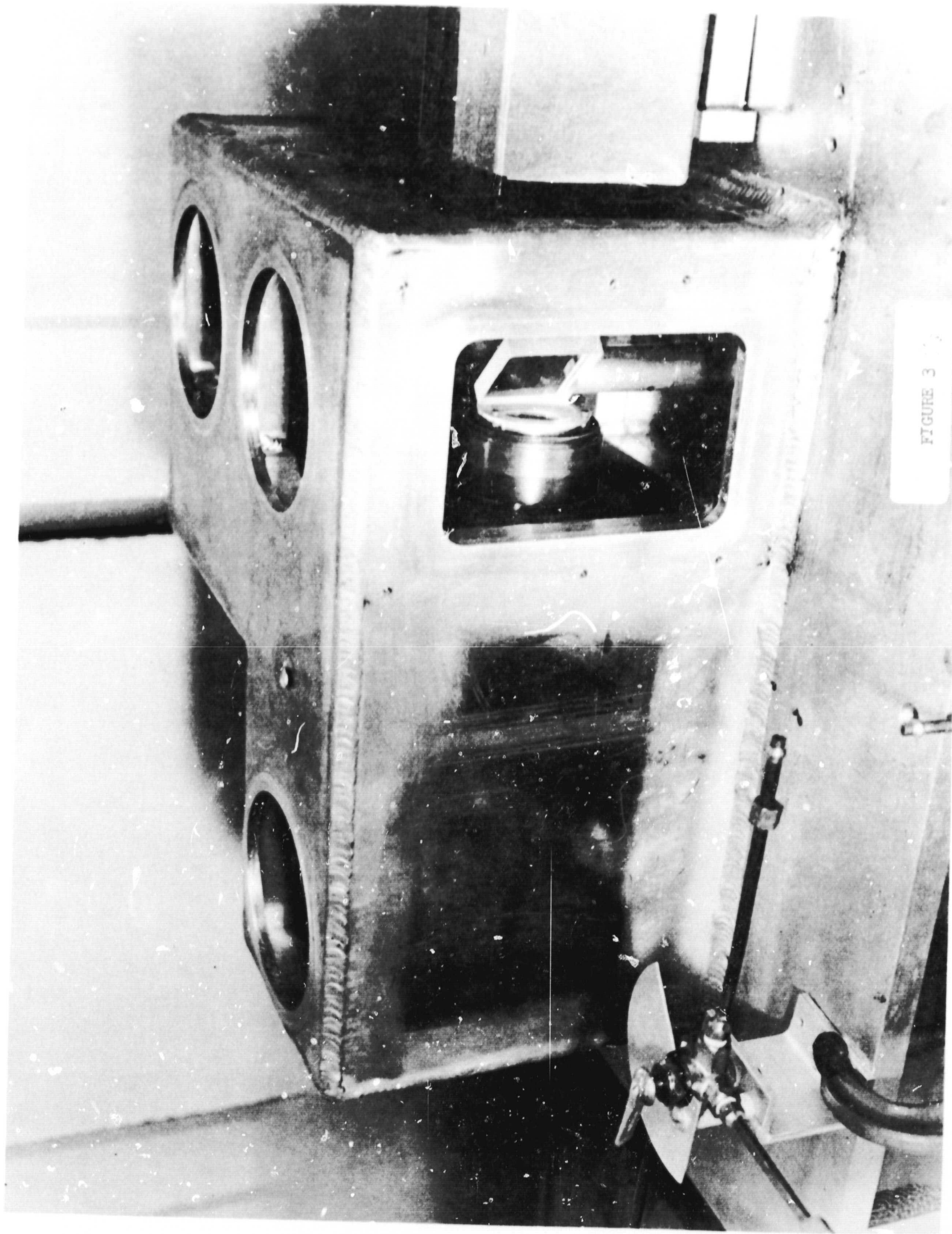


plate. The pipe is connected to the base plate and vacuum sealed using glyptal on the threads. The other end of the line is fitted to the pump throat by a piece of rubber tubing (to reduce mechanical vibration) and water-hose clamps. The detector compartment, being open to the main chamber, is evacuated simultaneously. Because of certain critical areas the detector compartment for film studies could not be sealed with a continuous weld. The compartment was spot welded at non-critical points and a liner of Varian Assoc. "Torr-Seal" applied to all seams.

A vacuum of 50 microns is achieved in about 1-1/2 hours; one of 20 microns requires about 8 hours. The pump runs continuously and pressures above the system limit (~ 15 microns) are maintained by a bleeder valve that introduces a controlled "leak" into the system.

OPTICAL SYSTEM

The optical system, Figure 4, produces images at two places--the test DETECTOR focal plane and the MONITOR focal plane. These sky and star images are developed in separate channels and can be used simultaneously or independently as experiments require.

In the sky background channel the source, S1 (American Optical Microscope Illuminator #651), which is utilized for both channels by means of a beam-splitter (BS1), illuminates an aperture (A1) positioned far enough away from the source to be uniformly illuminated and located a focal length away from the collimating lens which follows it. A diffuser (D1) directly in front of the aperture assures that all points in the aperture illuminate all points of the entrance pupil. The final sky background spot is the image of A1, hence, the spot image size varies with the size of A1. If the sky channel is used to image a test pattern instead of a sky spot, A1 is replaced by the test pattern. Light from A1 is deflected 90° by the front surface mirror (M1);

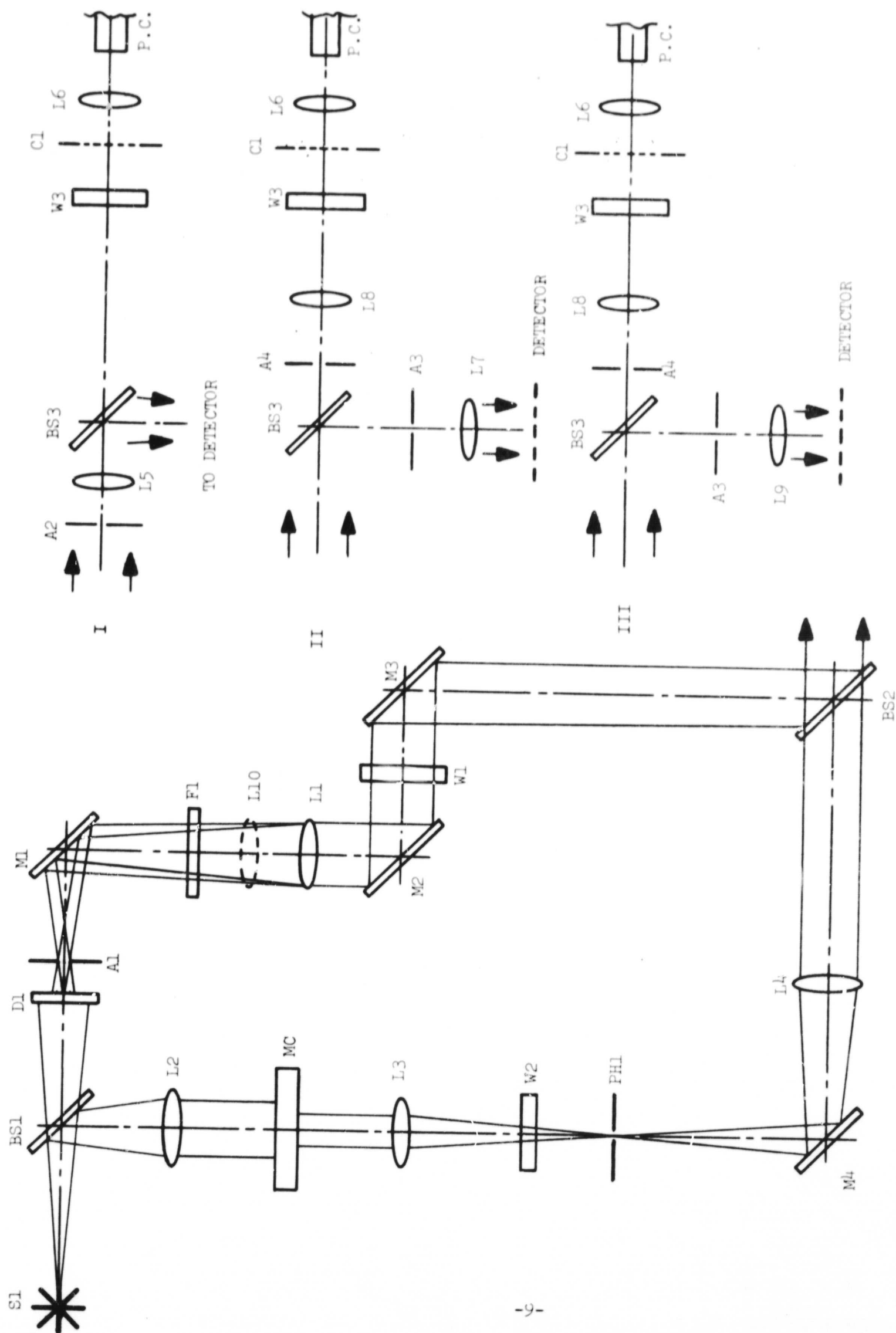


FIGURE 4 -- OPTICAL SYSTEM

LENSES

L1 = Achromat D = 26mm, f = 125.5mm

L2 = Achromat D = 37.5mm, f = 132mm

L3 = Achromat D = 18mm, f = 32mm

L4 = Achromat D = 44mm, f = 154mm

L5 = Achromat D = 36.8mm, f = 157mm

L6 = Achromat D = 17.5mm, f = 29mm

S1 = 50-100 watt incandescent (AO microscope illuminator #31-33-69)

L7 = 15X Beck Reflecting Microscope Objective

L9 = 36X Beck Reflecting Microscope Objective

W1, W2, W3 = Fused Silica, 3" dia. x 1/2"

M1-M4 = 2" x 2" front surface mirrors, Special Optics

Monochromator, M1 = Orion Optics #F-11-10

the diverging beam then falls on a collimating lens (L1) which also serves as the entrance pupil for the sky background channel. The collimated beam is deflected 90° at another front surface mirror (M2) and enters the chamber normal to the entrance window (W1). Between M1 and L1 there is provision (F1) for attenuating or filtering the beam. Inside the chamber the collimated beam is again deflected 90° at M3 and routed to a thin plate of glass (BS2) serving as a recombination beamsplitter. This beamsplitter lies in the path of both channels and it is here that the sky and star beams are combined.

In the star channel, light from the source is collimated by a simple lens (L2) and enters a monochromator (MC) (Orion Optics #F-11-10) where the desired wavelength and bandwidth is selected. The collimated monochromator output beam is focused on a pinhole (PH1), Ealing A22-67 series, by a condenser lens (L3). The star spot is an image of this pinhole and is variable within the range of 1 to 200 microns by interchanging pinholes and final imaging objectives. Star image size is fixed by the ratio of the focal lengths of the collimating (L4) and final imaging lenses (L5, 7, 8, or 9) following the pinhole. For example, if the pinhole PH1 is 10.0 microns in diameter, L4 has a focal length of 154mm and L5 a focal length of 157mm, the star image size is $(PH1)(L5)/(L4) = (10)(157/154) = 10.2$ microns. Light diverging from the pinhole is deflected by 90° at (M4) and recollimated by (L4). The collimated beam is combined with the sky background beam at the beamsplitter (BS2). Beyond this point the light travels as a combined beam and optical elements, common to both, determine the images formed at the monitor and test detectors. Three cases are distinguished according to image properties desired.

Case I

For star spot sizes larger than 30 microns the beam, after leaving the combining beamsplitter BS1, encounters a stop (A2). This stop serves as the

exit pupil and its size determines the beam area, hence, image brightness--larger stops giving brighter images but otherwise not affecting them. Passing through the stop, the beam encounters a simple lens (L5) located one focal length from the detector so as to place the image at the detector. Prior to reaching the detector, however, the beam is divided by a thick beamsplitter (BS3) that sends about 92% of the light to the monitor detector and 8% to the test detector. A thick plate is used to clearly separate the images from the two surfaces of the beamsplitter; each image contains about 4% of the light.

That part of the beam which proceeds to the monitor passes through the exit window (W3), a mechanical chopper (C1) that is used, if desired, to separate the light into sky + star and sky components and through a Fabry lens (L6) which images the exit pupil (A2) onto the photocathode of the monitor photomultiplier.

Case II

For spots 10 to 30 microns in diameter the beam, after leaving the combining beamsplitter (BS2), passes directly to the thick beamsplitter (BS3) where again part continues toward the monitor and part is deflected toward the test detector. Before reaching the test detector, however, the light passes through an aperture (A3) located just in front of a 15X microscope objective (L7) Beck 15X. The size of this aperture as with A2 in Case I determines the brightness of the image. The part of the beam proceeding to the monitor passes through a similar 2.5X microscope objective (L8) and aperture (A4) arrangement and then continues to the photocathode as in Case I. This choice of objective can provide the same sky spot scale in the monitor image as achieved in Case I if L1 is exchanged for an alternate lens, L10. The Fabry lens (L6) must also be relocated slightly.

Case III

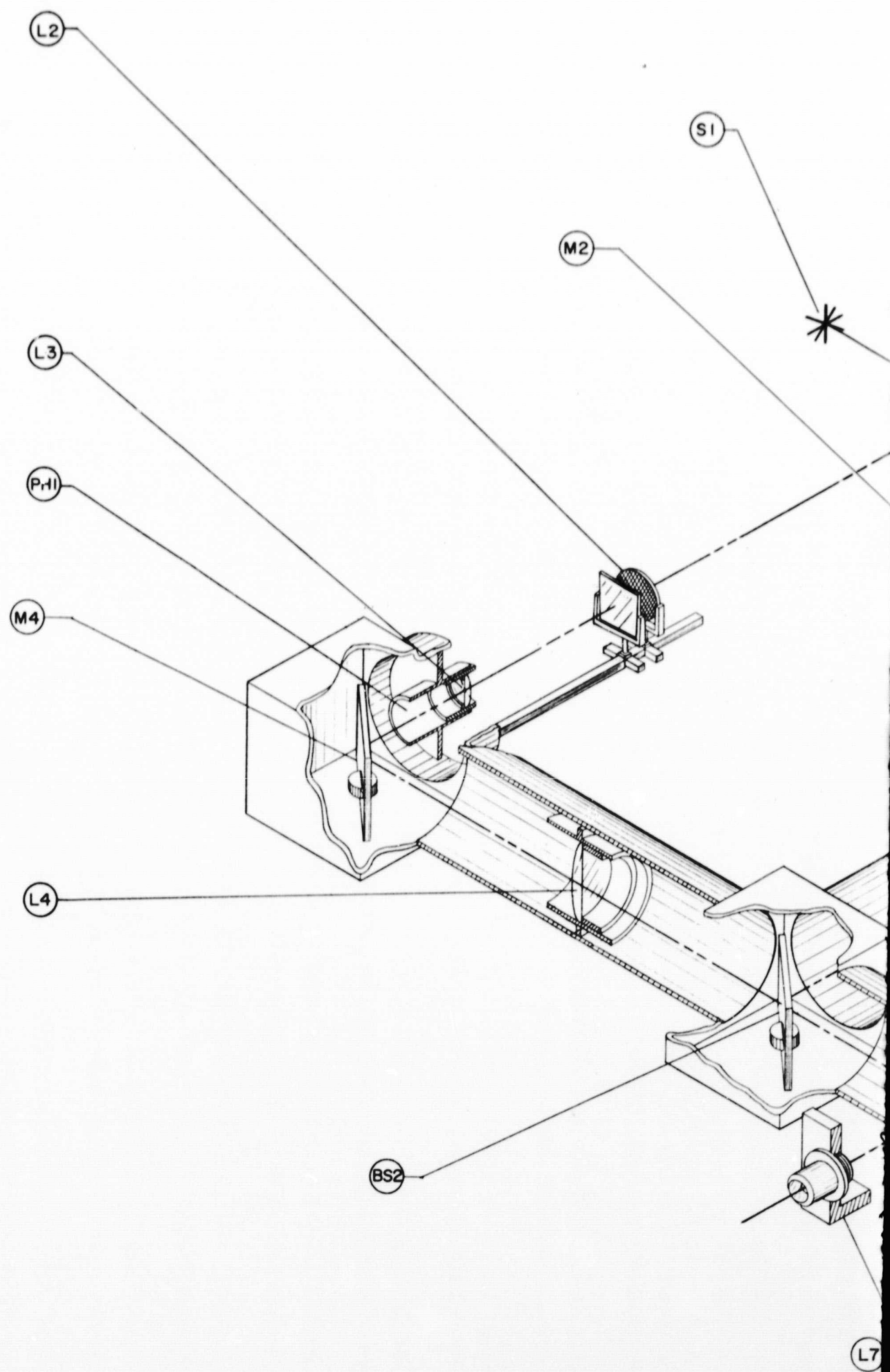
For spot sizes less than 10 microns the same arrangement as in Case II is used except that in place of the 15X microscope objective forming the image at the test detector, a 36X microscope objective (L9), Beck 36X reflecting, is used. The monitor channel is left unchanged.

Inside the main chamber the optical elements, except the thick beam-splitter and the microscope objectives, are enclosed in optical modules produced by Instruments Unlimited, Inc., Tarrytown, New York. Thin-walled tubes (2-3/4 inch ID, 3 inch OD) with inside threads on one end, outside threads on the other, are joined at junction boxes by threaded rings which fasten over circular openings in the junction boxes and allow secure fastening of the tubes. The junction boxes have mounting shafts on the base which seat in mounts fastened to the base plate. Figure 5 illustrates the optical assembly with the enclosing optical modules.

Lenses are mounted inside the tubes using annular adapters. The adapter and lens is inserted into one end of a tube and is held fast when the mating piece of tubing is screwed on.

Front surface mirrors and the recombination beamsplitter are mounted in frames inside the junction boxes. The mounting stem of each frame is a shaft which slip-fits the hollow mounting shaft of the box. Mirror adjustment is made by rotating the shaft which extends through the top of the box.

Outside the main chamber optical elements are mounted on machined tool-steel bars. The bars define optical axes independent of the base plate and provide a reference for the rest of the optical system. Optical mounts are notched to clamp to the rails. A hole in the top adapts to shafts of individual element holders which are standardized to a 2 inch x 2 inch size.



Foldout Frame

FIG. 5

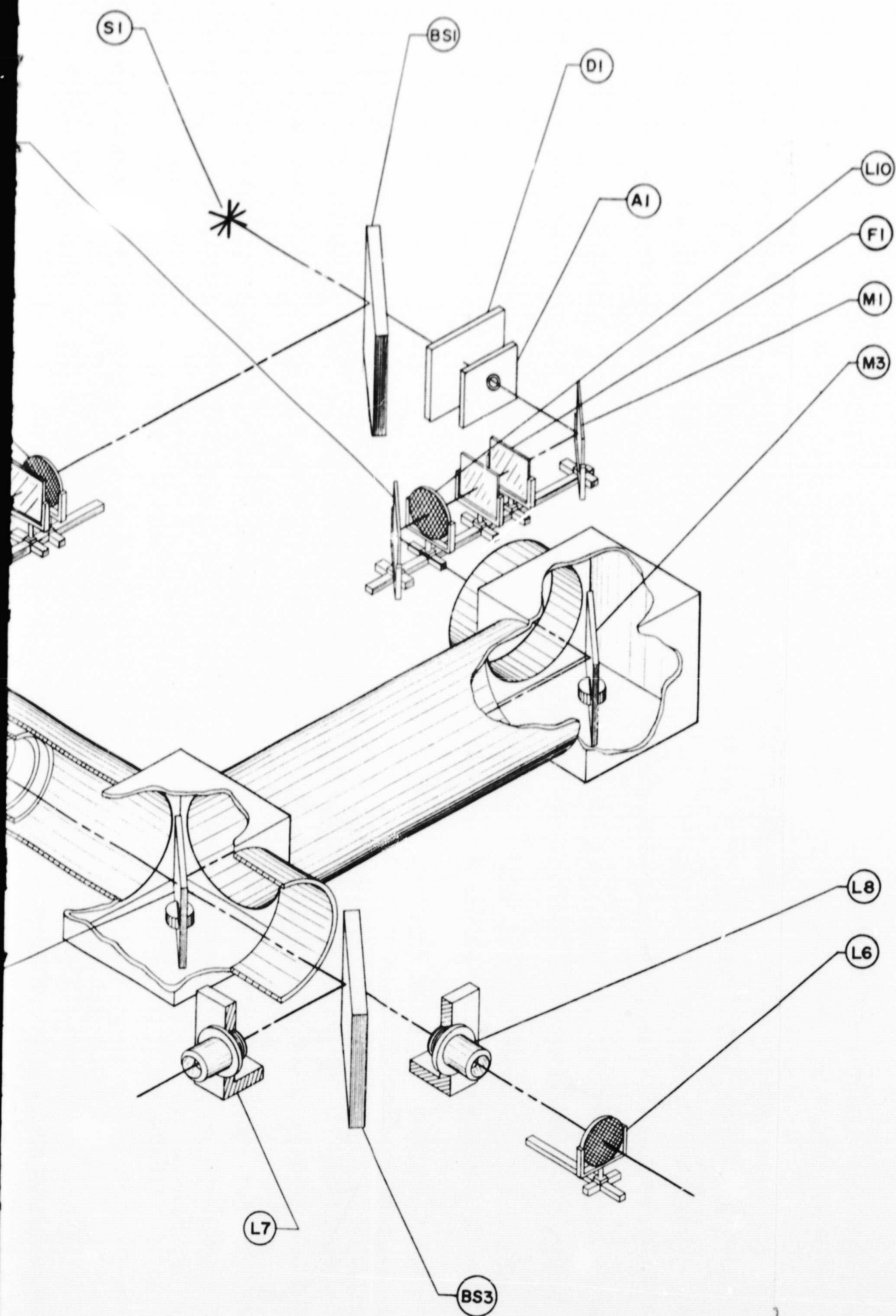


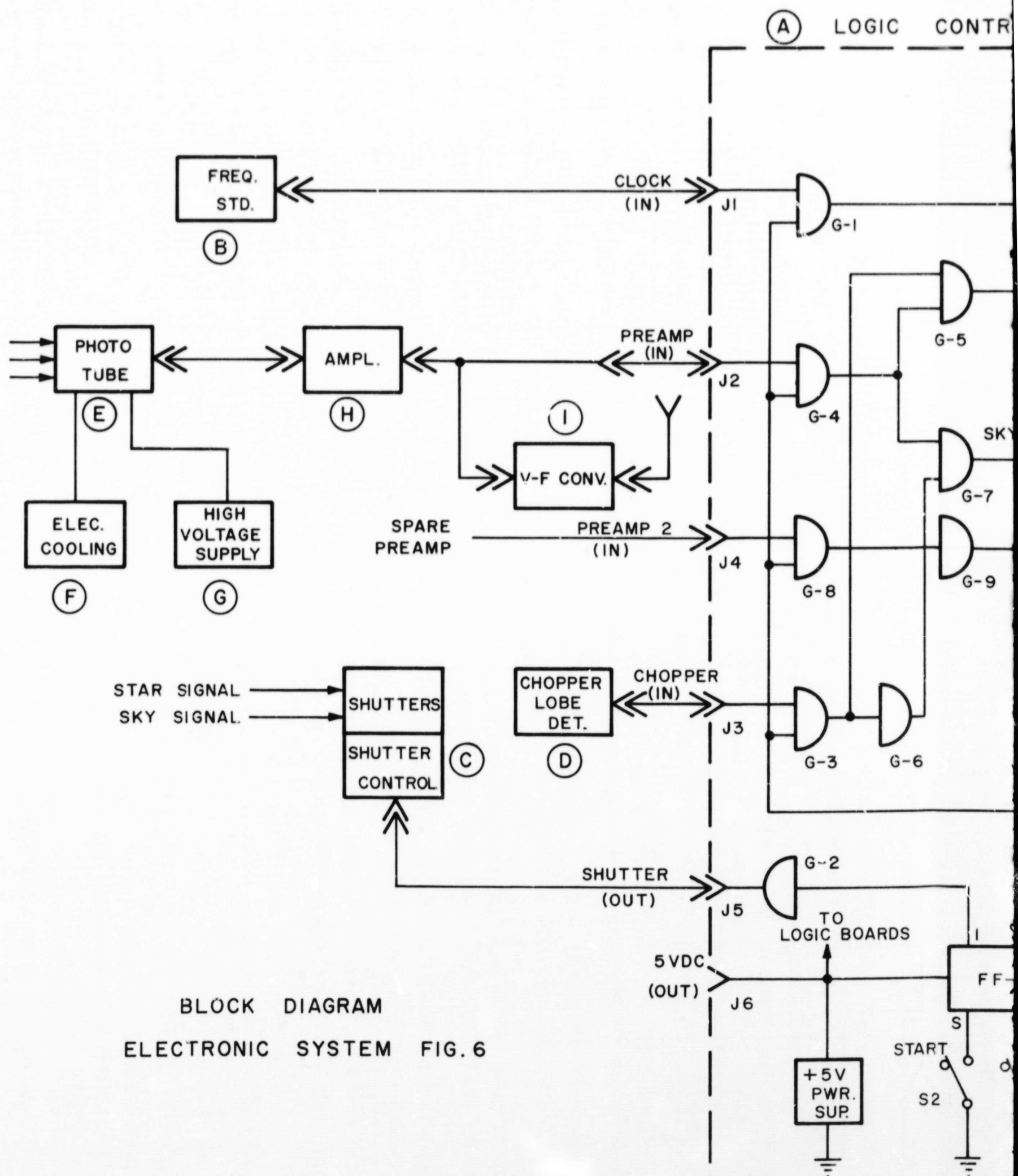
FIG. 5

Foldout Frame

ELECTRONIC SYSTEM

The Electronic System, shown in the block diagram of Figure 6 and photograph Figure 7, controls the mode of signal detection. The system consists of the following units. (The letter designations are the same as those used in the figures.)

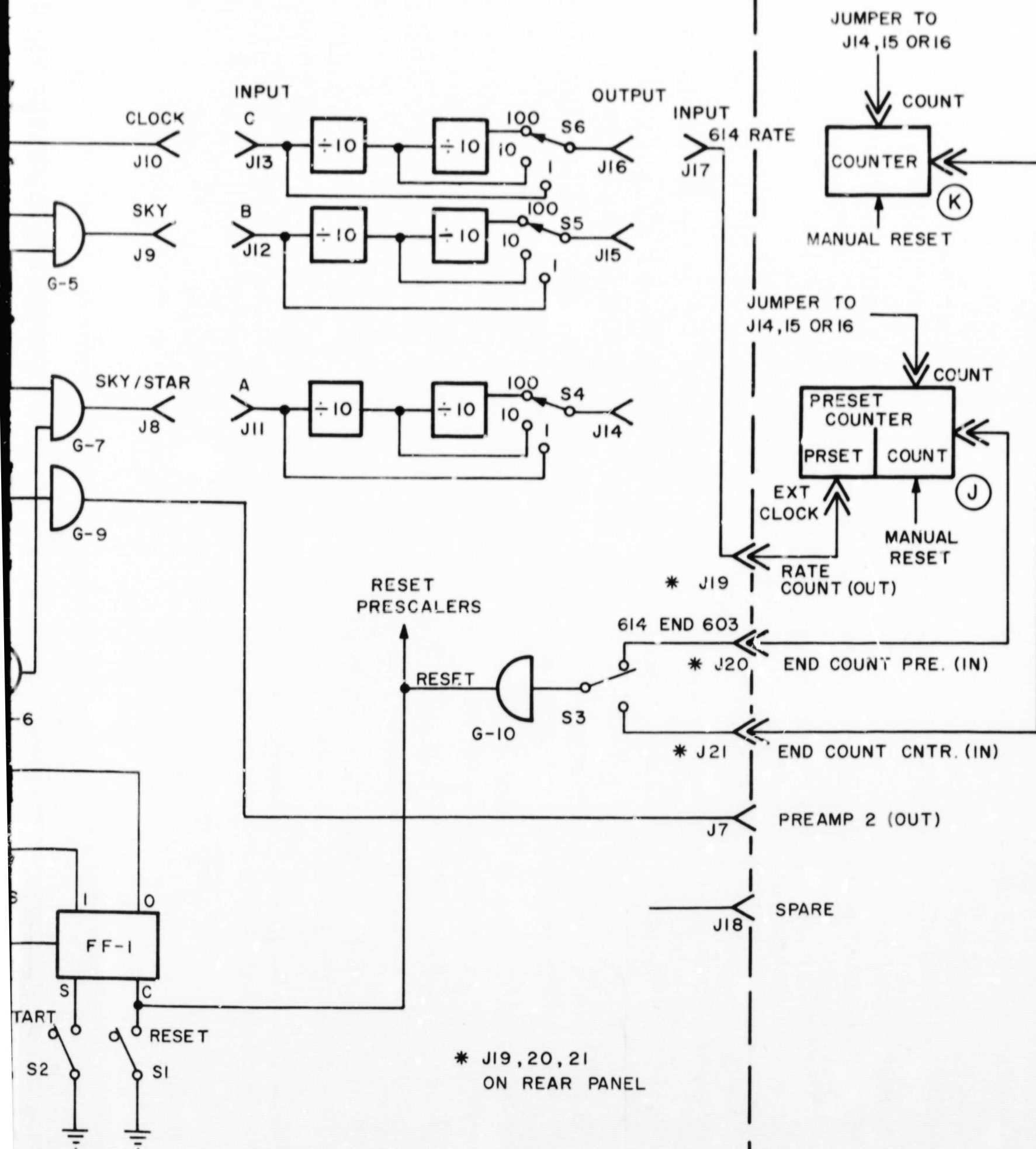
- A. Logic Control Unit--Generates the control signals to control the operation of the system.
- B. Multiple Frequency Standard (Anadex Model CU-2R)--Serves as the master clock to synchronize and time the system.
- C. Shutter Control and Shutter (Harvard 2-inch)--Shutter control opens or closes the shutter manually or as commanded by the output of the Logic Control Unit.
- D. Chopper Lobe Detector--Separates sky and star signals.
- E. Monitor Photomultiplier (EMI Model 6256S)--Detects the amount of light in the monitor channel.
- F. Thermoelectric Enclosure and Control (Products for Research Model TE-102TS)--Cools the photomultiplier for dark current control, down to about -10°C .
- G. High Voltage Power Supply (Calibration Standards Corporation Model 120B)
--Provides high voltage for the photomultiplier.
- H. Amplifier (Dymec Model 2460A)--Amplifies the output of the photomultiplier tube for either pulse-count or V - F modes. This unit is not well suited for high frequency pulse amplification and has been utilized primarily to drive the V-F converter (unit I).
- I. Voltage-to-Frequency Converter (Dymec Model 2211BR)--Converts the voltage output of the amplifier to standard pulses at a frequency proportional to the voltage. The accumulation of the output pulses is thus proportional



BLOCK DIAGRAM
ELECTRONIC SYSTEM FIG. 6

foldout, FRAME

CONTROL PANEL



Foldout FRAME

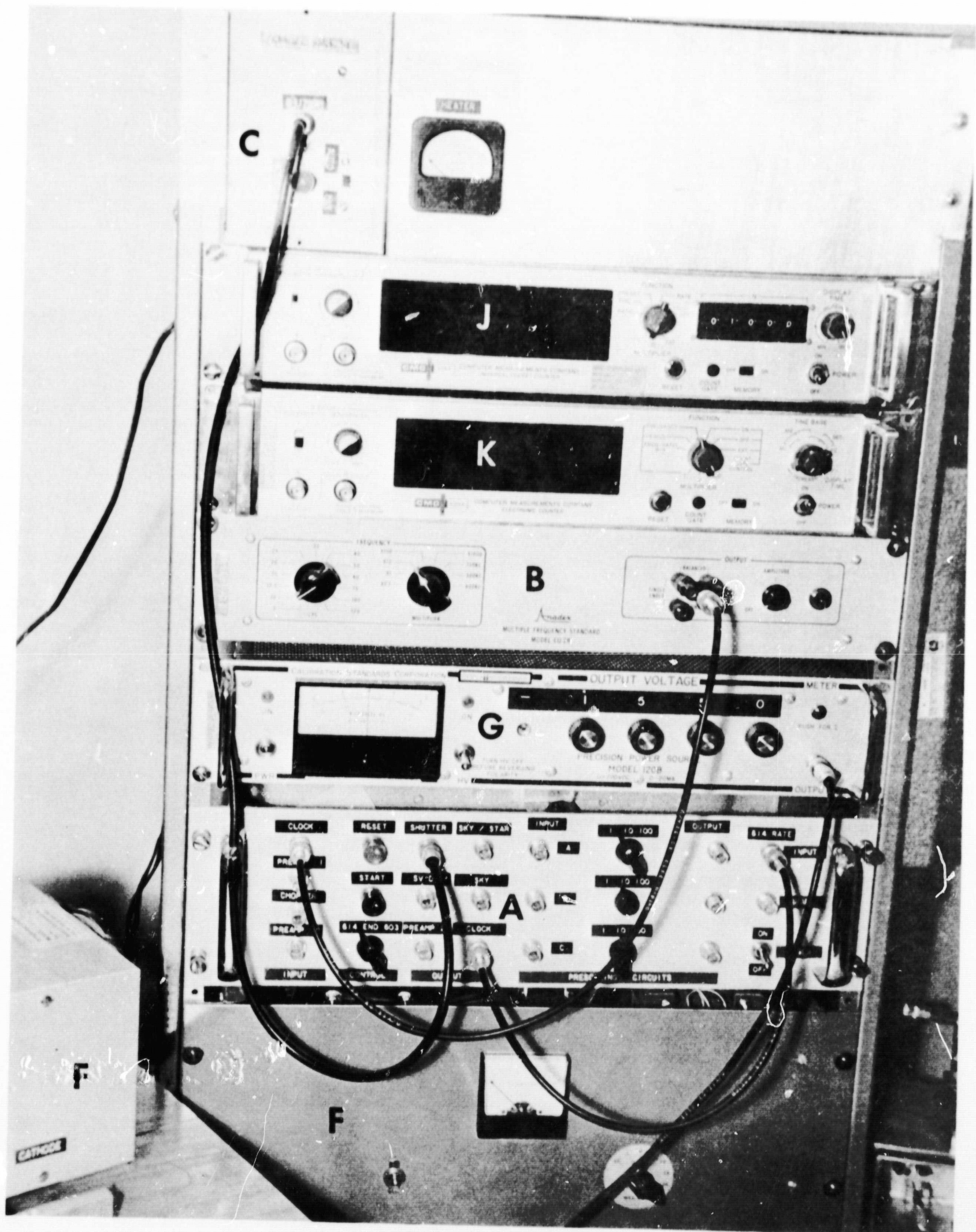


FIG. 7

to the integral of the signal during the measurement period.

- J. Universal Preset Counter (Computer Measurements Company Model 614A)-- Counts clock or signal pulses to control shutter timing.
- K. Electronic Counter (Computer Measurements Company Model 603A)-- Counts clock or signal pulses for data records in conjunction with the CMC 614A counter.

Not shown on the Figure 6 block diagram are a Sola Constant-Voltage Transformer (Model 23-25-210) and a C.E.A. Isolation Transformer (Model OE-A73) used to provide stable, noise-free line voltage to the various units of the system.

The Signal Detection system has several basic modes of operation. Two or three basic quantities are available for recording: The exposure time as obtained from counting of gated clock pulses; the gated photocell light monitor signal as derived from either a pulse amplifier system or V-F conversion system connected to the monitor photocell; and if a photoelectric device is used at the "detector" focus, its output may also be gated and recorded if desired.

The light monitor signal, if desired, may be split into two parts by the chopper assembly so that for a signal consisting of a star superimposed upon sky the star plus sky and sky signal alone are available for recording; each signal is available one-half of the time. If the switching and chopper system is not used the total monitor signal is continuously available.

Three quantities may be conveniently recorded at any one time, one of which may be used to control the shutters or otherwise provide gating signals. Two of the quantities are routed directly to the two counter displays while the remaining quantity is utilized to drive the preset switch counter in the 614A counter or to control the ratio mode of the 603A counter.

In order to achieve maximum operational flexibility the logic control has been fabricated in the form of a patch panel where signal gating, pre-scaling, and control signal routing is utilized as required by interconnecting with external coaxial cables terminated in BNC connectors. Figure 8 is a picture of the logic control panel; the panel is electrically diagrammed in Figure 6. The function of individual connections and switches as labeled in the figures is as follows:

Input

Clock (J1)--input is gated through to the J10 output connector. This gate circuit is normally connected to the multiple frequency standard output to give a gated time base for timing control or interval determination.

Preamp 1 (J2)--input is gated through to J8 or J9 according to the chopper control signal applied to J3. This gate circuit is normally connected to the V-F or pulse output from the monitor photoelectric detector.

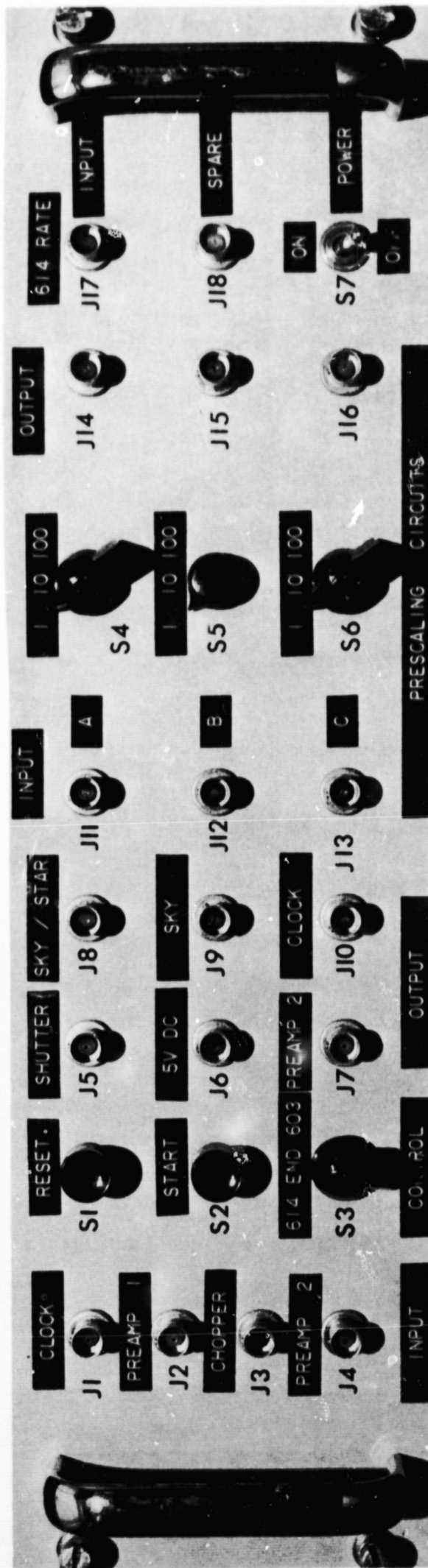
Chopper (J3)--input for the control signal which switches the preamp 1 signal between output points J8 and J9. This is normally connected to the output of the chopper lobe detector if that system is in use.

Preamp 2 (J4)--input is gated through to J7. This gate circuit is available for any signal desired, such as a photocell in the "detector" position.

Control

Reset (S1)--this button manually initializes the logic control to assure that all shutters and gate circuits are closed and the prescalers are reset. Reset normally occurs automatically at

FIG. 8



the end of a cycle if appropriately wired; however, S1 provides general interrupt capability and manual gating. The switch operates by resetting FF-1 in the logic.

Start (S2)--this button operates FF-1 to open the gate circuits and shutters.

614 End 603 (S3)--this switch determines the origin of the automatic reset signal when timing control is provided by preset counts on the 614A or 603A counters. In the 614 position the signal is derived from J20 on the rear of the logic unit. In the 603 position the signal comes from J21 on the rear of the logic unit.

Output

Shutter (J5)--this terminal provides a signal synchronized with the gate circuits which is used to control the S.D. shutters. It is normally connected to the Shutter Control unit.

5VDC (J6)--provides panel access to the Data Technology Model PS-5V logic power supply.

Preamplifier 2 (J7)--gated output of the signal applied at J4.

Sky/Star (J8)--gated output of the signal applied at J2 subject to the switching control of the chopper input at J3. If the chopper is not used, J8 always provides the output for the signal at J2.

Sky (J9)--alternate gated output of the signal applied at J2 when the input at J3 is activated. See the previous (J8) description.

Clock (J10)--gated output of the signal applied at J1. This is normally used to carry time information derived from the frequency standard.

Prescaling Circuits

Three individual two decade prescaling circuits are available for individual or ganged use. Inputs at J11, 12, or 13 have output

at J14, 15, and 16 respectively. Switches S4, 5, and 6 determine the scaling in each channel (divide by 1, 10, or 100). Data Technology 13305 units have been used with a frequency response of 2 MHZ.

Extreme Right Edge

614 Rate Input (J17)--this is a direct line to the rear panel connector J19 and is normally utilized to route gated clock pulses to the external clock terminal on the rear of the 614A counter when used in RATE mode as described in the OPERATIONS section.

Spare (J18)--no connection, available for additional control functions.

Power (S7)--power switch to the logic unit.

Rear Panel

Rate Mode (J19)--output of signal applied to front panel connector J17.

See the J17 description.

End Count Pre (J20)--input point for the automatic logic reset and gating signal selected when S3 on the front panel is set at 614. Normally this is connected to the End Count point on the rear of the 614A counter.

End Count Cntr (J21)--input point for the automatic logic reset and gating signal selected when S3 on the front panel is set to 603. Normally this is connected to the End Count point on the rear of the 603A counter.

The operation of the logic control unit proceeds as follows, with reference to the circuit diagram in Figure 6: pressing the START button S2 causes the control flip-flop FF-1 to change to the "1" state. This change is detected at G1-G4 (and G8 when utilized). G1 to G10 have the following functions.

- G1: Gates the J1 CLOCK input directly to the J10 CLOCK output.
- G2 (inverter/driver): Driver to the J5 SHUTTER output utilized to actuate the S.D. shutters.
- G3: Switches the signal derived from the J2 input between the output points J8 and J9 by operation of the G5 and G7 gates and G6 inverter/driver.
- G4: Gates the input signal at J2 through to G5 and G7 which, depending upon the state of the G3, route the signal pulses to either J8 or J9.
- G8: Gates any signal applied at J4 through the inverter/driver G9 to the output point J7.
- G10 (inverter/driver): Drives the reset of FF-1 and prescaling circuits from the end-of-count signal selected by S3. The change of state of FF-1 resets all the logic control gates.

For separate monitoring of the contributions to the total count made by the star and sky portions of a composite simulated star plus sky signal, the signal is split into (1) sky and (2) star + sky alternately. The separation is accomplished by a rotating mechanical slotted chopper and three fixed focal plane apertures as shown in Figure 9. The middle of the fixed apertures contains the star image, the others exclude it. The outer set of slots alternately transmit the star and sky or sky alone. The inner set of slots provides a control switching signal by permitting a TI 980709-800 photo diode to see or not see a lamp mounted behind the chopper blade. The chopper blade is driven by a Globe 138A100-2 synchronous motor (3600 rpm). The photo diode and logic amplifier generate the control signal which is fed to the CHOPPER J3 input on the logic control panel. When not used the chopper assembly is

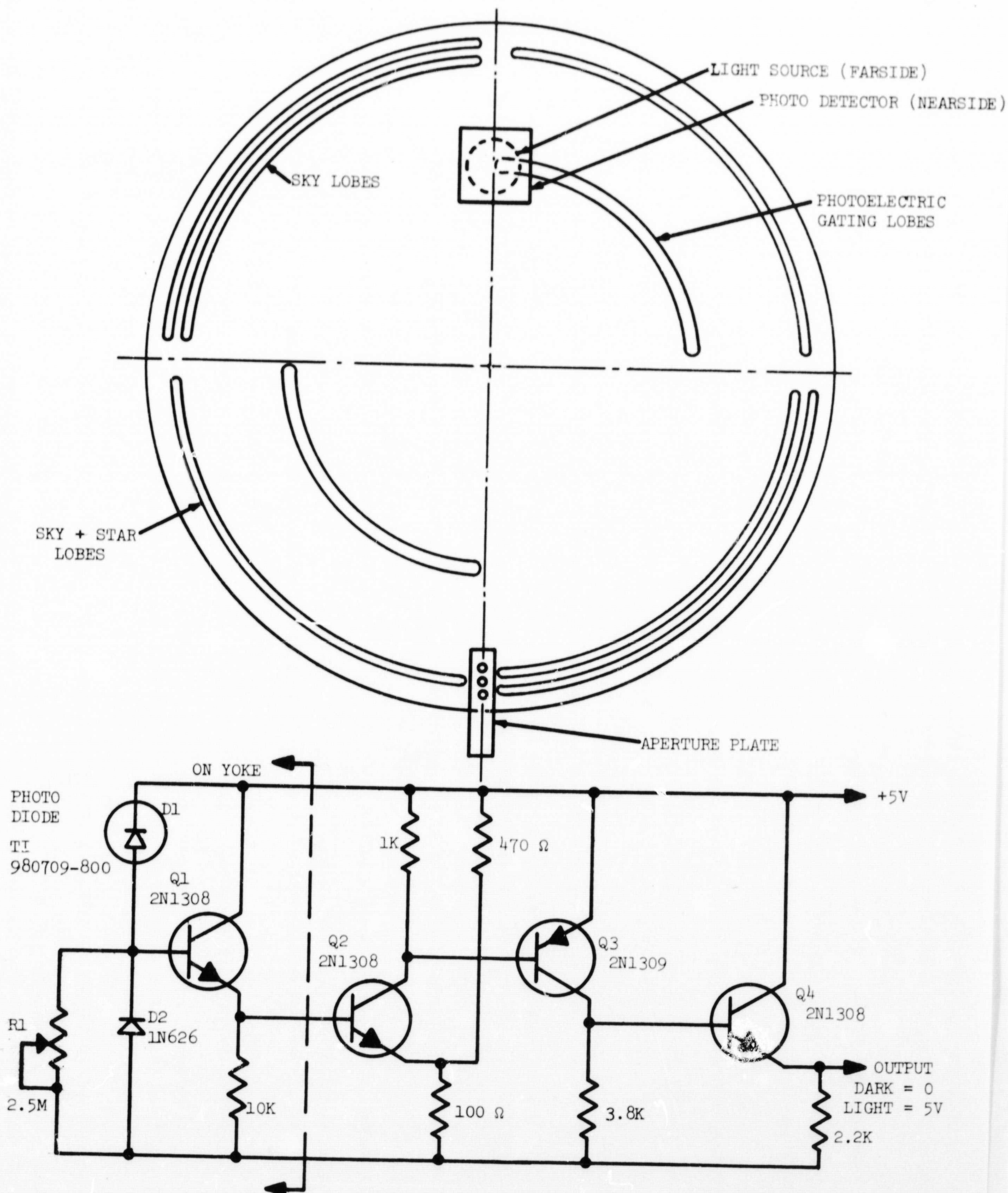


FIGURE 9 -- CHOPPER LOBE DETECTOR AND CIRCUIT

completely removed and a single fixed field aperture substituted to define the output beam.

The schematic for the shutter control system is shown in Figure 10. A transistor amplifier (Q5 and Q6) amplifies the Shutter Control Signal (from J5 of the Logic Control Panel). When the control switch is in the AUTO position, the signal operates the relay K-1 which applies 115 volts AC power to the two Harvard shutters. When the control switch is in the MANUAL position, the shutters are operated continuously. In the AUTO position, the shutters may be momentarily operated by pressing the MOMENTARY switch. The "sky" and "star" shutters are operated in parallel. If it is desired that one of the shutters remain closed, the shutter coil may be unplugged.

COOLANT SYSTEM

The coolant system provides temperature control for detectors by circulation of a heat exchange fluid. The system which is well shown in Figure 1 contains a motor driven pump (Dayton 1/4 HP; Oberdorfer Centrifugal Pump #1P-588), two heat exchanging baths, 1/4 inch copper tubing coolant lines, and a mixing valve (Imperial #108HD). Dry ice in methanol in an insulated stainless steel tank and a 550 watt AC heater (Regan Heater 1-3/8 inch diameter, 5 inches long) controlled from a variac (Staco #500B) provide the heat sink and source. Any detector compartment utilizing cooling must have an internal subassembly to interface with the cooling system supply lines. The detector compartment must also provide temperature monitoring at the detector if desired.

The coolant system was designed as a closed-loop system using methanol as the circulating fluid. It has generally been operated open-loop directly in the methanol cold sink supply since pressure leaks are troublesome in

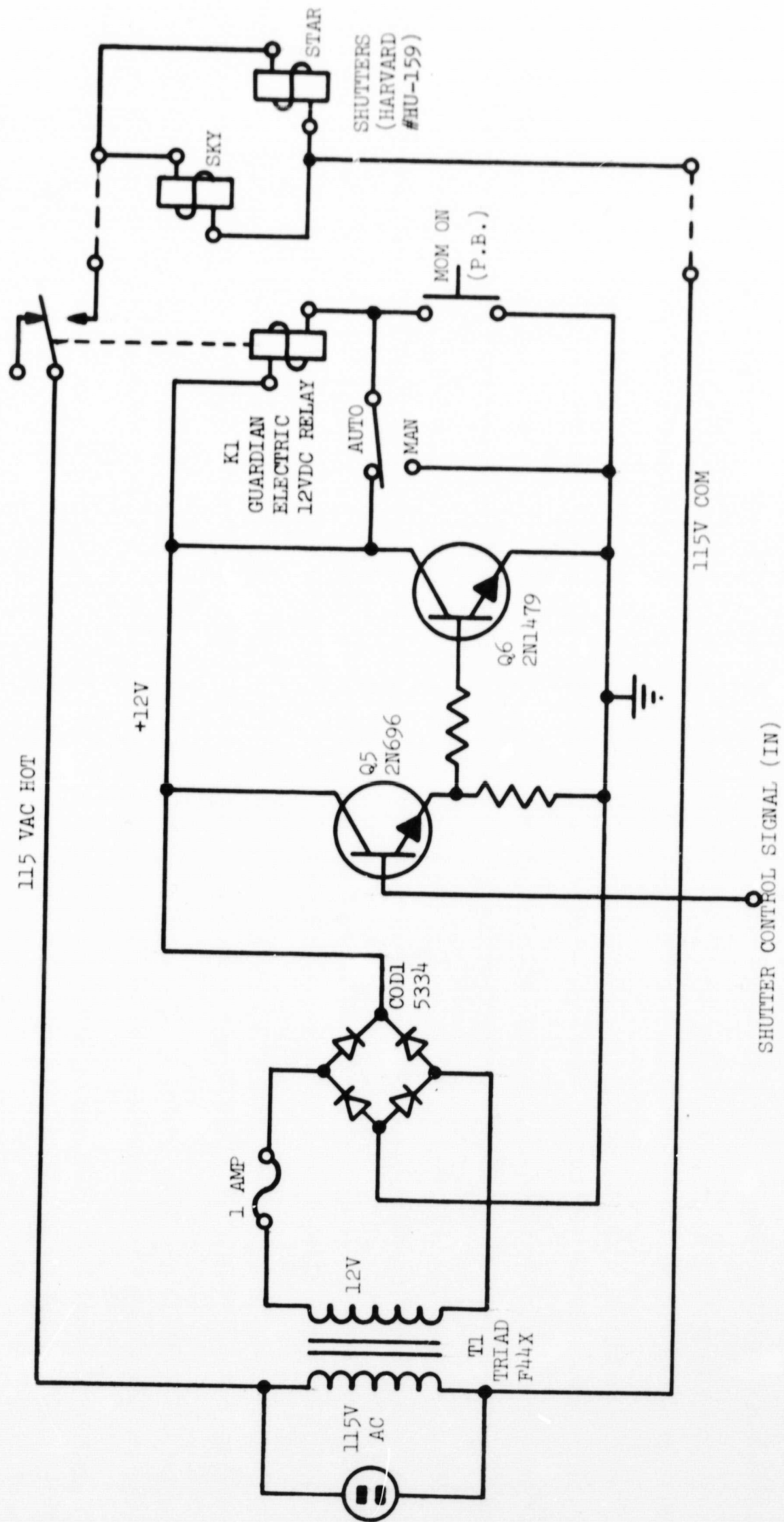


FIGURE 10 -- SHUTTER CONTROL

closed-loop operations. The pump has been potted in plastic foam to reduce frosting and eliminate the large thermal losses at the massive fixture. As the fluid is pumped through the lines, heat is exchanged in the heat sink' and source by conduction. (The temperature of the cold bath presents no problem since the freezing point of methanol is well below that of dry ice, but the temperature of the hot bath must be kept below 64°C to prevent boiling the methanol.)

The heat sink consists of a stainless steel tank encased in a polystyrene liner and filled with methanol. Dry ice is added to chill the methanol to dry ice temperature (-78°C) where the temperature is maintained constant by keeping some dry ice in the tank at all times. The copper coolant line winds in a multiple-turn cylindrical coil and rests below the surface of the liquid. The temperature of the bath is simply monitored with a thermometer immersed in the liquid. For some purposes an intermediate temperature is provided directly in the heat sink by mixing limited amounts of dry ice with methanol. Although the coolant lines have not been insulated, this would be desirable to reduce external frost formation.

The hot source consists of a cannister filled with a heat-transferring medium (Thermal-Mastic, Virginia Chemical and Smelting Company) encasing the 550 watt cylindrical heater which is located at the center of two flat spirals of the coolant line. The temperature of the bath is thermometer-monitored and is set by adjusting a heater control variac which is monitored by a meter at the top of the electronics rack. An equilibrium calibration for bath temperature as a function of meter reading has been obtained.

The temperature of the supply to the detector compartment is controlled by a mixing valve which determines the relative flow to the cold and hot baths. The mixing valve is a regular two-way valve that was modified so two outputs

could be obtained. One output serves as a return line to the heat sink and the other to the heat source. At the "zero" indicator position of the mixing valve, all the fluid is routed to the heat sink, thereby dropping the carrier fluid temperature to its minimum value. At the other extreme indicator position all the fluid is passed into the heat source giving maximum carrier fluid temperature. Intermediate temperatures are obtained by intermediate settings of the mixing valve.

Figure 11 shows a schematic diagram of the coolant system. From the out side of the heat sink the fluid passes to a junction which connects to the out side of the heat source. The fluid then goes to the pump. From the pump the fluid goes to the detector compartment, circulates, and exits. The fluid then goes to the in side of the mixing valve with the out side proportions to the heat sink and source as determined by the valve position.

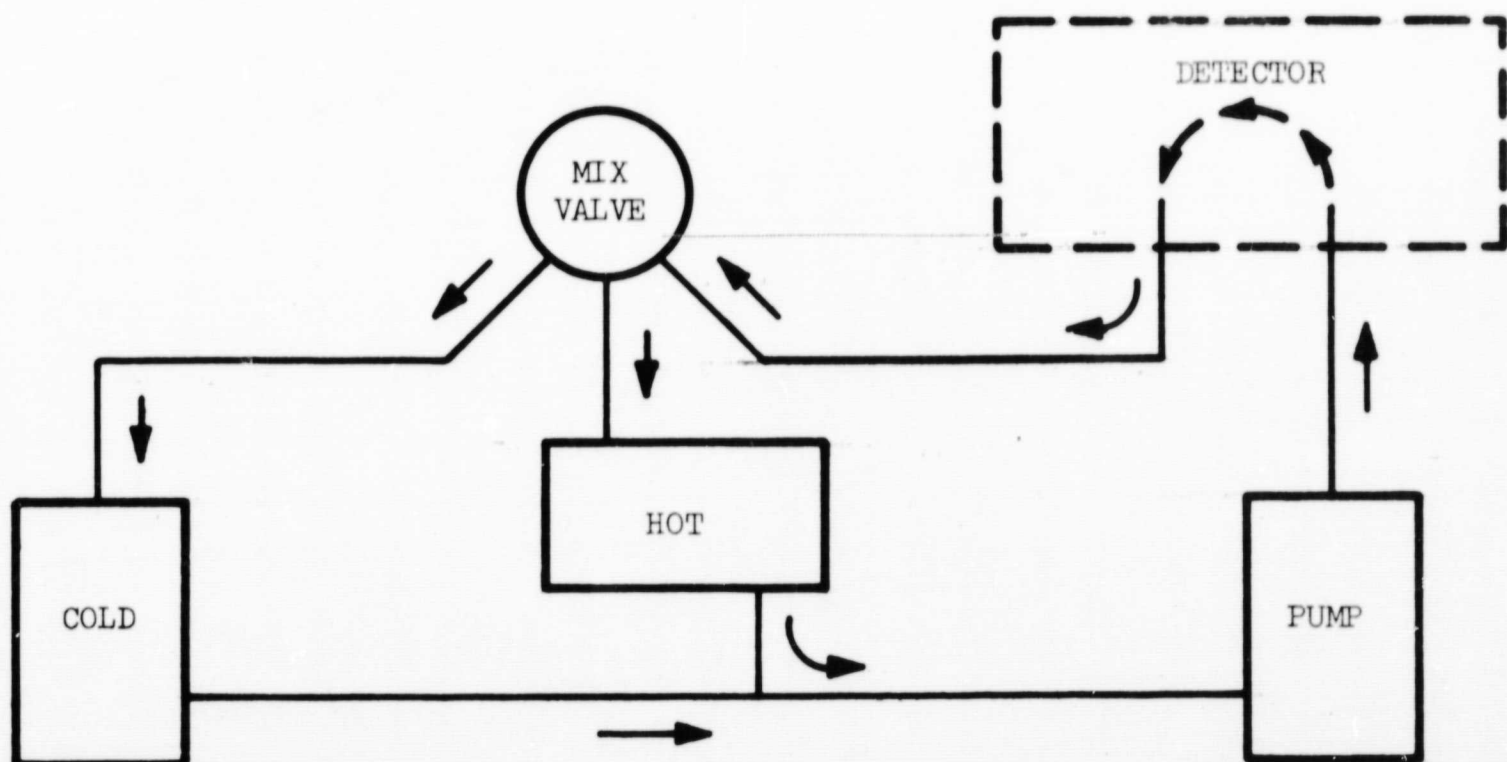


FIGURE 11 -- COOLANT SYSTEM DIAGRAM

TEST DETECTOR COMPARTMENT

35mm Film Compartment

The 35mm film transport compartment is a rectangular box constructed of 1/2 inch aluminum plate with a removable side for film access. Figure 12 is a view of the chamber. The box is attached to an aluminum face plate and seams are welded where possible to ensure vacuum seal. At the removable side, the vacuum seal is accomplished with an O-ring set into the box edges. The face plate has an O-ring to seal against the main chamber and a 3/4 inch circular opening through which light enters the film compartment from the main chamber.

Inside the film compartment is a 35mm film transport system and a coolant system which is utilized when film temperature is to be controlled. The film transport system consists of supply and takeup cassette mounting shafts, two 35mm film sprockets, a mechanical counter, and a manual film advance mechanism. One end of the cassette mount is attached to the inside wall of the film compartment; the other end is attached to the removable side of the compartment so that, when the side is in place, the cassettes are held by in-line mounts. The cassette mounts have free-running shafts which connect with the cassette spools and turn with the spools during film advance. The shaft of the upper (takeup) cassette holder extends through the removable wall and serves as the manual film advance control. Vacuum seal on the rotating shaft is accomplished by an O-ring set into the wall around the shaft and a cap which, when tightened forces the O-ring onto the shaft. The 35mm sprockets, which act as guides for the film, are mounted on the inside of the face plate above and below the signal entrance port. A mechanical counter attached to the lower 35mm sprocket monitors the passage of film. The counter is on the outside of the removable side. The rotating shaft

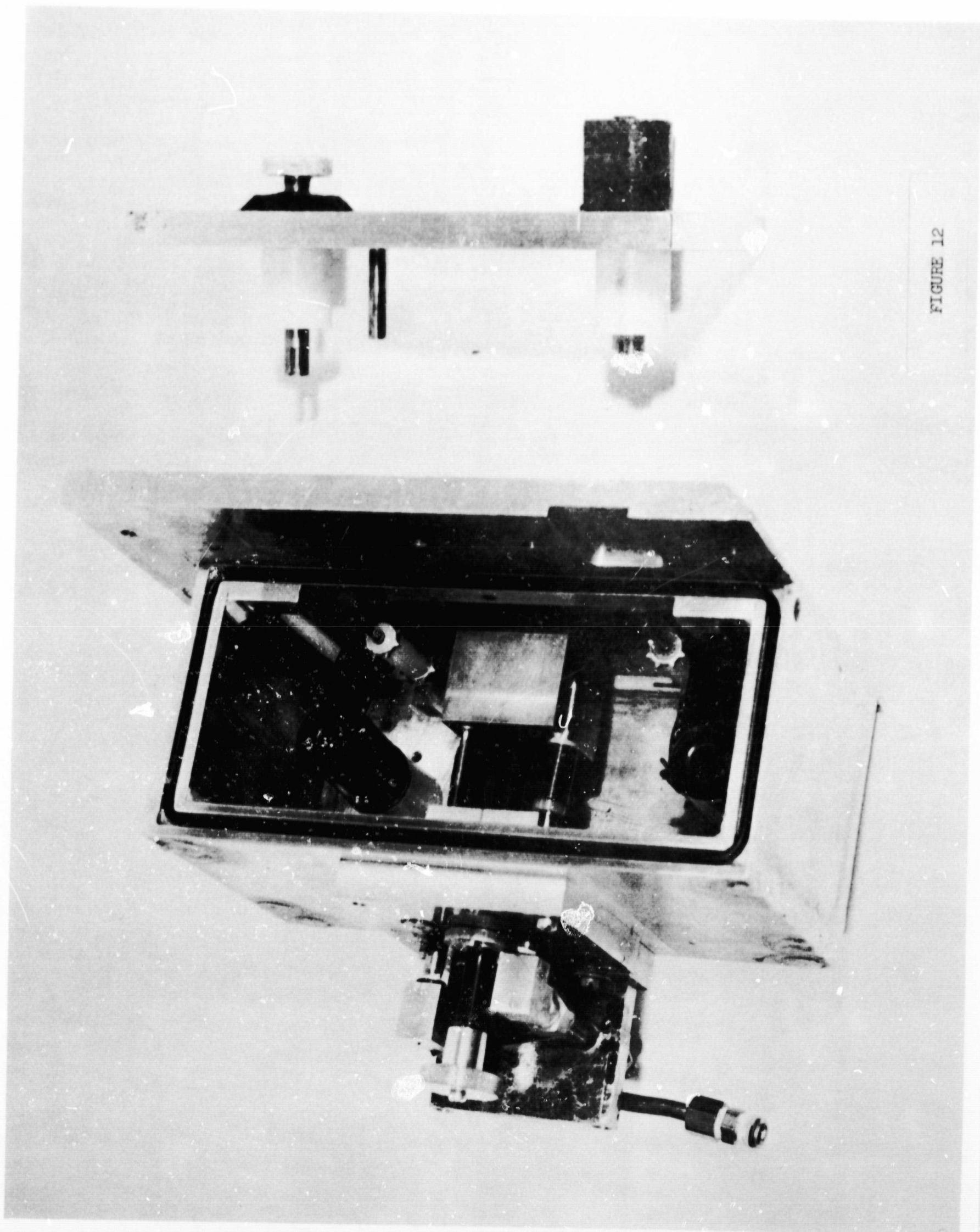


FIGURE 12

which passes through the side is vacuum sealed by the same means as the film advance shaft.

The coolant system inside the film compartment is detailed in Figure 13 and consists of a hollow platen, stainless steel tubing, and a pair of thin-walled flexible stainless steel metallic bellows (Servometer Corporation, 0.250 inch O.D., 0.0012 inch wall, and 1 inch long). The platen is a cube of stainless steel with a machined cylindrical cavity. A copper plate seals the open end of the platen and has a home-made Iron-Constantan thermocouple junction embedded in it for temperature monitoring. The thermocouple leads exit the compartment by feed-throughs in the side of the film compartment opposite the removable side and connect to an external meter (Weston Micro Ammeter # 931) which has been calibrated to indicate temperature vs thermocouple output by submerging the junction in a series of baths of known temperature.

Two stainless steel tubes go from one end of the bellows through the back wall of the film compartment to external coolant line connections. Vacuum seal at the back wall is by O-rings on the inner and outer faces with Sylastic between. The other end of the bellows connects to the platen cavity with short stainless steel tubes. All stainless steel joints are silver-soldered for coolant fluid sealing. Where the coolant lines pass through the walls they are thermally isolated by virtue of the O-ring/Sylastic seal. The platen, which presses the film against a plastic thermal insulation panel set into the face plate, is retracted for film advance by an attached opaque insulated rod that extends through the back wall of the compartment. The difference in coolant line length between the two positions of the platen is accommodated by the compression or extension of the metal bellows. Two pins pressed into the platen back and sliding in holes in the

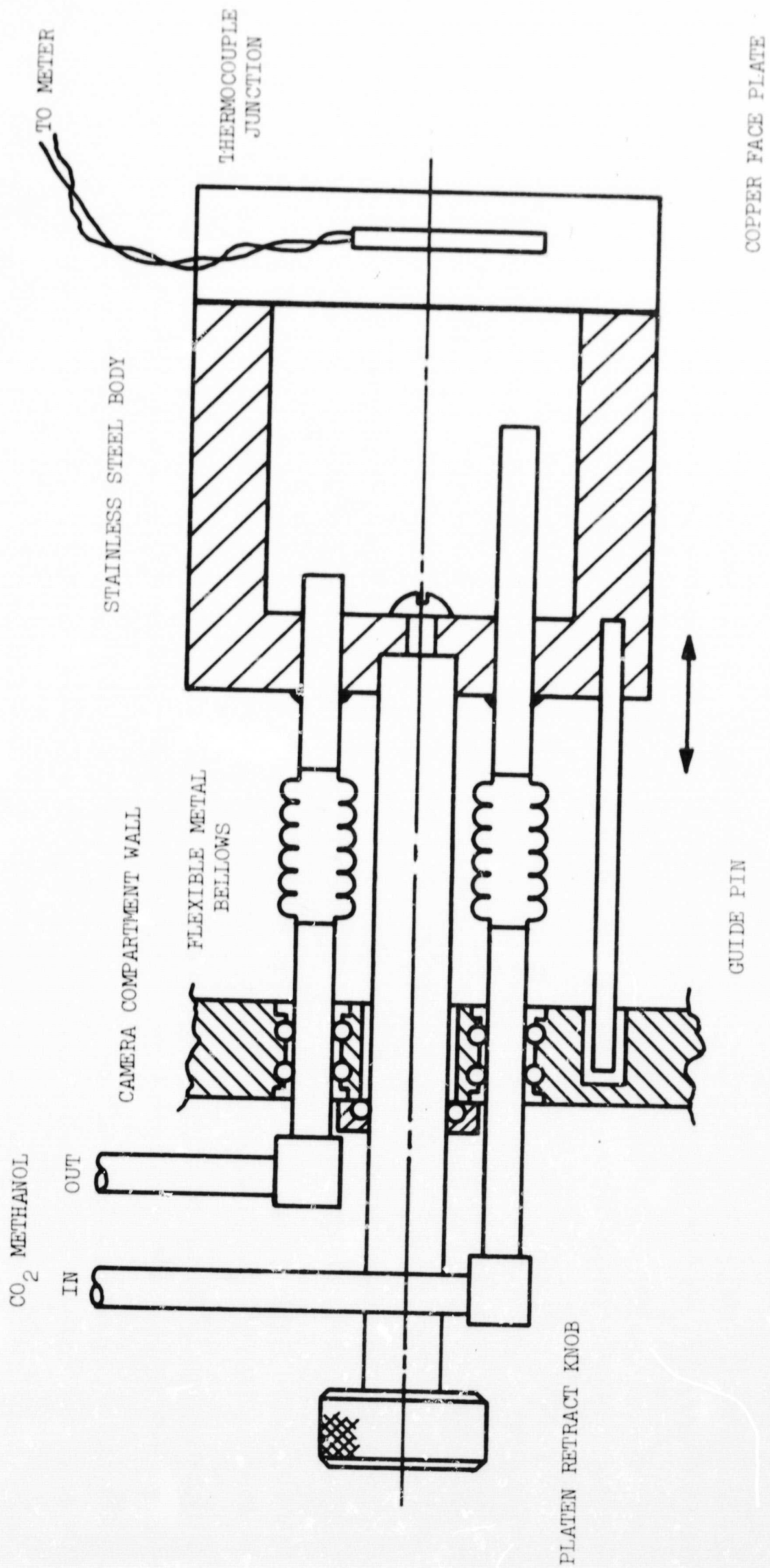
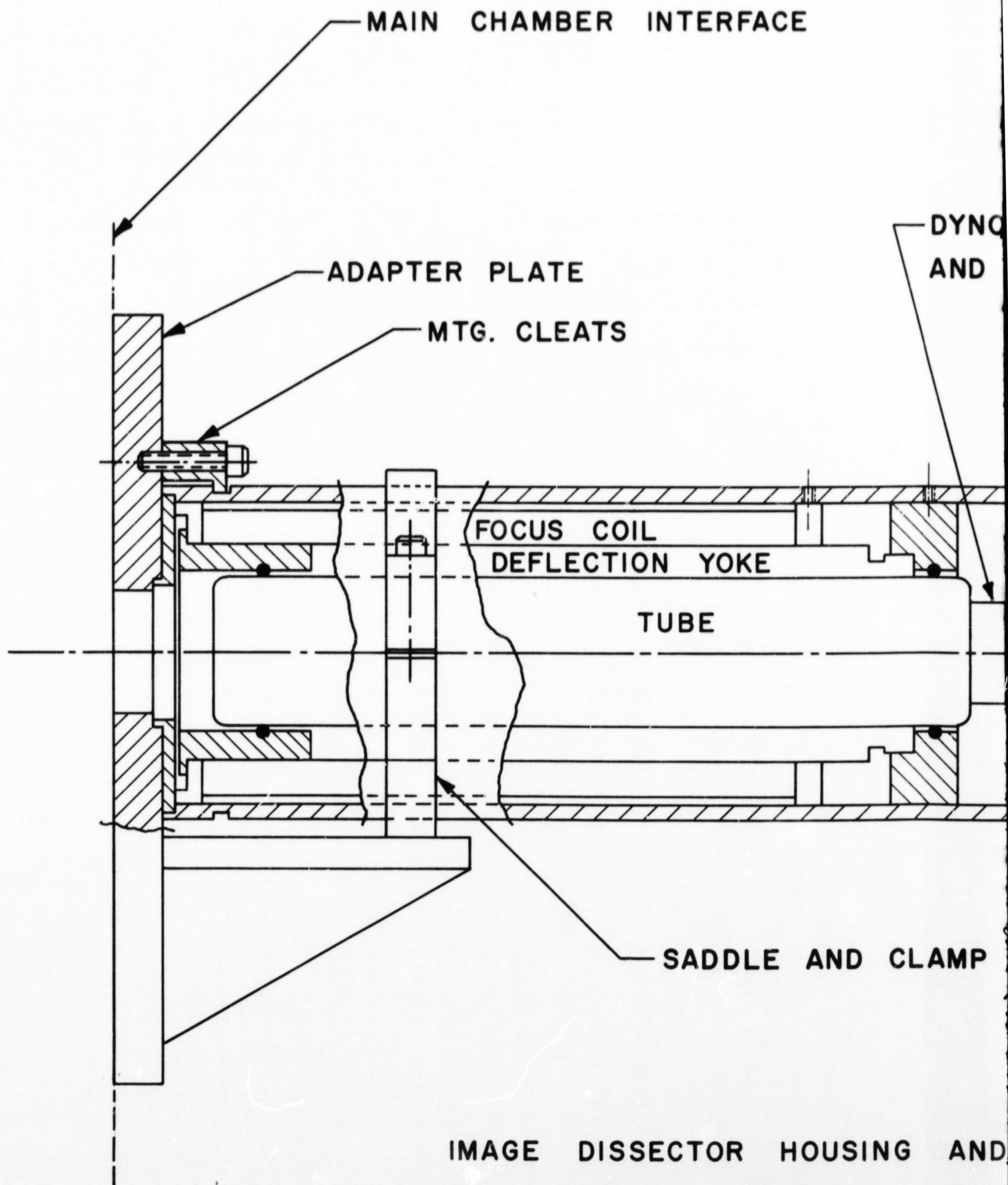


FIGURE 13 -- COOLANT SYSTEM INSIDE FILM COMPARTMENT

rear mounting block of the chamber serve as stops to prevent exceeding the mechanical limits of the bellows and as guides to prevent the platen from rotating.

IMAGE DISSECTOR COMPARTMENT

For testing ITT 4011 image dissector tubes, a housing shown in Figure 14 has been constructed. No provision for vacuum operation has been made with this unit. Two phenolic discs, each containing an O-ring, support and center the tube in the housing. The deflection coil is held and centered around the tube by locating on machined surfaces of the phenolic discs. The focusing coil is centered and held in the outer housing by accurately machining the inside diameter of the housing to allow a close fit. Three set screws lock the focusing coil in place. The housing is machined from aluminum alloy tubing to approximately 11 inches long and 3-1/2 inches in diameter. Saddle blocks with clamps are provided to support the entire assembly. The supports allow a small lateral adjustment for focus and allow the rotation of the entire assembly to align the deflection coil in a specific direction. The housing, when assembled to its adapter plate, is made light tight by means of accurately machined steps in the adapter plate and projections in the housing which mate for a close fit. The housing is held on the adapter plate by means of cleats. The adapter plate has a right angle bracket at the forward saddle and clamp to add rigidity. The focal plane in the S.D. chamber is accurately known and the adapter plate is mounted so that there is very little focus adjustment required. Three connectors are mounted on the rear plate of the housing through which all electronic connections are accomplished. The dynode resistor chain is mounted within the housing at the tube socket. Some of the early test results in image dissector scans of test star images is contained in the SYSTEM APPLICATIONS section.

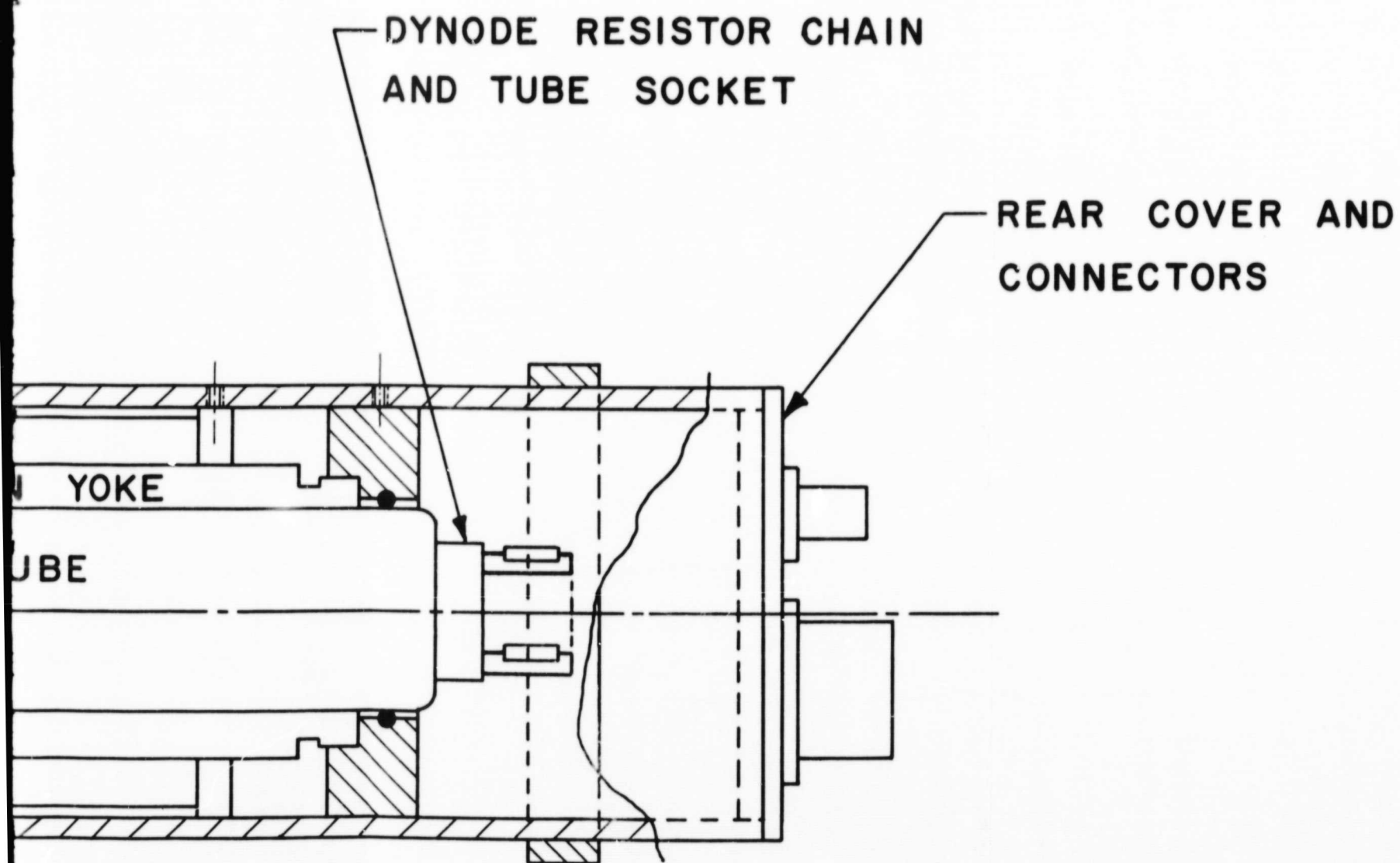


Foldout Frame

IMAGE DISSECTOR HOUSING AND
ADAPTER ASSEMBLY

FIG. 14

INTERFACE



SADDLE AND CLAMP

CTOR HOUSING AND
R ASSEMBLY

FIG. 14

Foldout FRAME
2

OPERATIONS

As indicated in the previous portions of this report, the S.D. system is capable of very versatile operation. Several of the most common modes of operation are described here for convenience to users of the system. The basic operational modes of the two counters are briefly given here for convenience. Each counter has five modes of operation set by the "function" switch on the counter. Each counter has two input channels denoted A and B and may utilize an internal time base or be connected to an external time base at the rear. This external time base input will be denoted as C. The setting of the "multiplier" switch on each counter will be denoted M and may be 1, 10, or 100. The preset switch on the 614A counter will be denoted N. The only remaining switch, the time base switch T on the 603A counter, is used to select the internal frequency used in period or frequency measurement and provides automatic decimal point control on the counter.

603A

1. Frequency: registers input on A during a standard time set by T.
2. Period: registers time as set by T for M counts into A.
3. Ratio: registers input on B for M counts into A.
4. External: registers input on A between gate signals applied at rear connectors.
5. On: registers A count continuously.

614A

1. Ratio: registers input on B for $N \times M$ counts into A.
2. Time: registers time for $(N+1)$ counts into A.
3. Preset: registers A count with stop when count reaches $(N+1) \times M$.
4. Rate: registers input on A for $N \times M$ time pulses (10 μ s internal or any external)

5. On: registers A/NxM continuously.

The first four modes of either counter provide gate signals at the rear of the counter (Digital Output Connector) upon completion of the operation.

For any mode of operation when the monitor photocell is in use and time is being recorded or used for interval control the following interconnections are standard:

1. Monitor Photomultiplier output (anode) to HP 2460A amplifier input.
2. Monitor Photomultiplier input (cathode) to CSC high voltage output.
Set high voltage at -1500 volts typical.
3. HP 2460A amplifier output to the Dymec 2211B V-F converter input if used.
4. Anadex frequency standard to logic control CLOCK input J1. Set the Anadex output to 10 volts.
5. Logic control SHUTTER output J5 to the shutter control SHUTTER input.
6. If the chopper lobe detector is used to separate star from sky connect the lobe detector output to the logic control CHOPPER input J3. In this mode the monitor signal output from the V-F converter or pulse amplifier must be connected to logic control PREAMP 1 input J2.
7. Connect the Digital Output connector at the rear of either the 614A or 603A counter (whichever is being used to control the end of cycle) to J20 or J21 respectively on the rear of the logic control to provide the end-of-cycle reset control. Set S3 to 614 or 603 on the front of the logic control.
8. Set the 603A and 614A rear panel "oscillator" switches to internal or external according to the source of time signals. If external

connect the gated CLOCK output J10 on the logic control to the "100KC" terminal on the 603A rear panel or to the "CLOCK" terminal on the 614A rear panel. This connection is most easily made by wiring from J10 to J17 on the logic control and then from J19 on the logic control rear panel to the counter. If desired a pre-scaler circuit may be wired in between J10 and J17. Note that when external gated clock control is used on the counters and the counter is manually reset on the front panel the counters are on and ready to count, thus, no "start" signal is required at the counters. When the logic control is initiated, timing information begins to arrive at the counters and they provide the end-of-cycle control pulse.

There is an important distinction to be drawn between investigations using integrating detectors (such as photographic films) and photoelectric detectors which are non-integrating. For the former, total exposure is set by the mechanical shutters on the S.D. system. If total exposure is being recorded the monitor signal should not be gated but should be connected to a counter directly with the counter simply set to ON and manually reset just before beginning an exposure. The result will automatically include the effects of shutter actuation time which is quite significant at short exposures. Normally one would use the 614A counter in RATE, TIME or PRESET mode to "time" control or "total signal" control the exposure and use the 603A to monitor the actual total signal including all shutter actuation time effects. Since the 603A gate is continuously open, care must be taken to determine any dark current or V-F offset count added to the signal.

In using non-integrating detectors, all data and time signals will normally be gated through the CLOCK, PREAMP 1, and PREAMP 2 gate circuits.

The shutter control will be set to "manual" so the shutters are locked open and no shutter actuation time affects the data. Any combination of counter control and data recording may now be used. Data or time is fed into A, B, or C inputs of either counter as desired and any of the available functional modes may be used.

The following specific modes of operation have been found particularly useful. Connections 1-5 previously described are assumed to have been made.

A. Photographic sky "spot density" exposures controlled by time with record of total exposure intensity.

1. Logic control CLOCK output J10 to 614 RATE J17.
2. Logic control RATE MODE output J19 to CMC 614A CLOCK input.
3. CMC 614A OSCILLATOR switch to EXT.
4. CMC 614A function switch to RATE.
5. CMC DIGITAL OUTPUT to logic control END COUNT PRE J20.
6. Logic control END switch S3 to 614.
7. CMC 603A function to ON.
8. Monitor output at V-F or pulse amplifier split with one branch direct to CMC 603A input A and the other branch to PREAMP 1 input J2 with SKY/STAR output J8 to CMC 614A input A.
9. STAR channel shutter plug disconnected.

Exposure is initiated by manual RESET of both counters, RESET S1 on the logic control, and then START S2 on the logic control. The SKY spot shutter opens at START and closes after NxM clock pulses derived from the Anadex frequency source have been entered into the 614A C input. The 614A counter shows the exposure amount including some shutter clipping while the 603A counter contains the full exposure count including all shutter effects.

B. Photographic sky "spot density" exposure controlled by total exposure (approximate) with record of time and actual total exposure.

1.-3. Same as A operation above.

4. CMC 614A function switch to TIME.

5.-9. Same as A operation above.

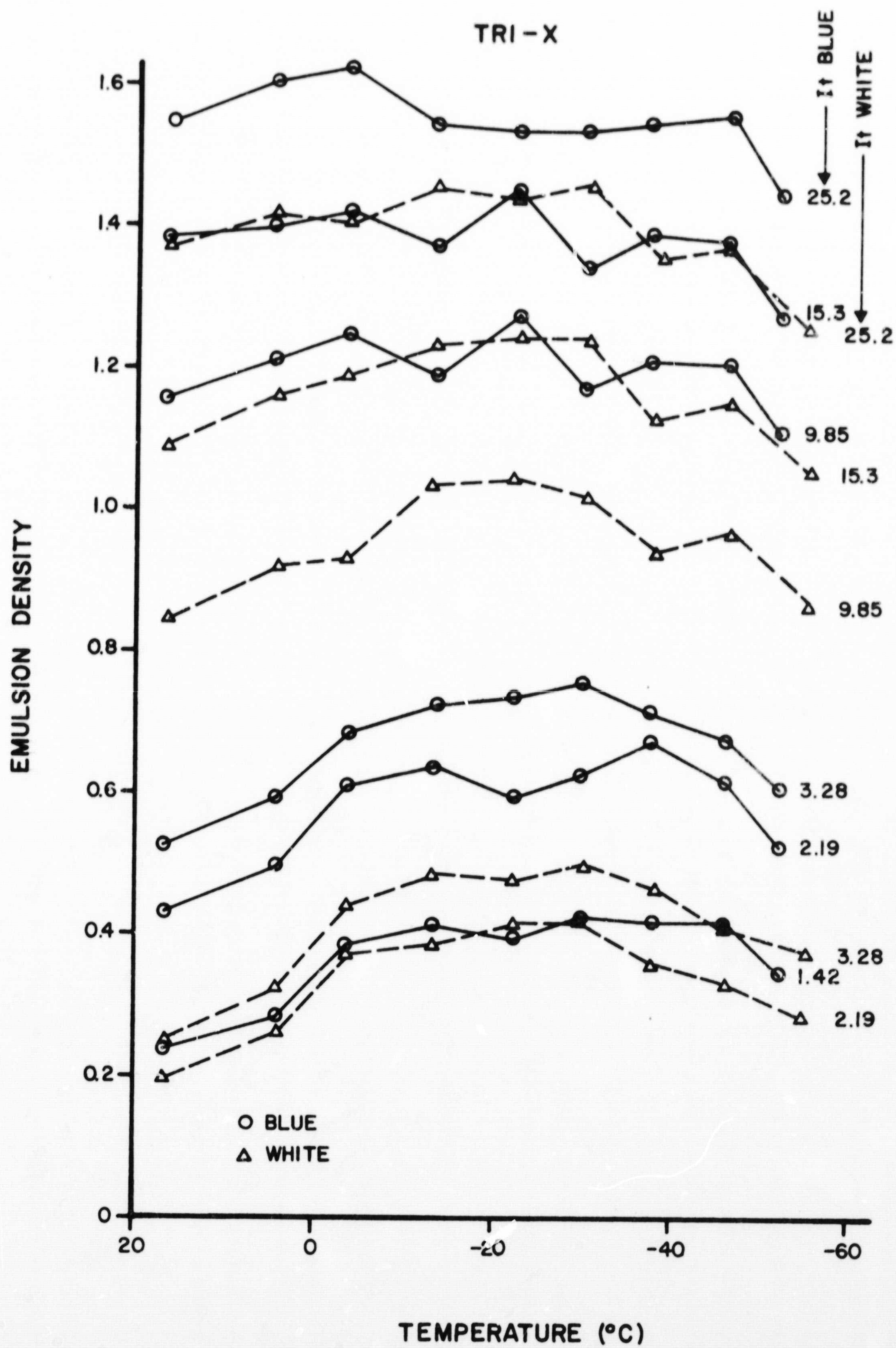
Exposure is initiated as in the A operation above. The CMC 614A counter registers the exposure time for (N+1) counts (exposure amount) into the A channel input. The 603A counter operates exactly as in the A mode. Note if either the time or exposure including shutter effects is not required the 614A PRESET mode can be used with the 614A counter and NxM both giving the exposure amount and the 603A either recording time or shutter-compensated exposure.

C. Photoelectric Signal Recording

The shutters are set to manual open and all gating is done through the logic control gates and counter gates. So many obvious modes of operation are available that they are not detailed here. Refer to the basic counter operational mode description at the start of the OPERATION section and to the 603A and 614A operation manuals.

SYSTEM APPLICATIONS

A variety of investigations have been carried out with the S.D. system. Three brief examples are given here. Using the sky spot alone as a calibration source, various photographic films were exposed to known amounts of light (It product) as a function of temperature and the variation of density with temperature determined. Figure 15 shows typical curves of density vs temperature for Tri-X film. For any given film there is an optimum temperature at which response a particular intensity level is best. Much more data of the

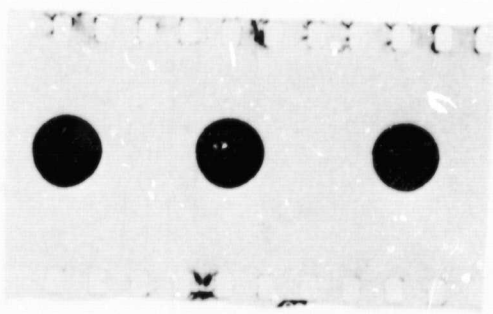
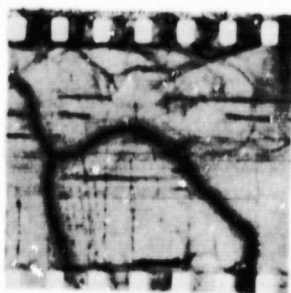
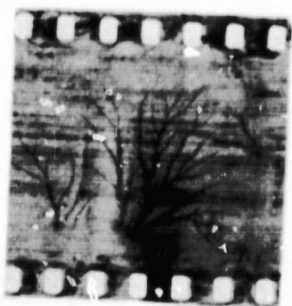
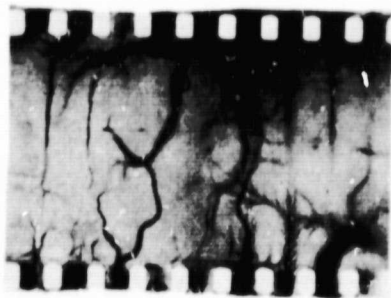
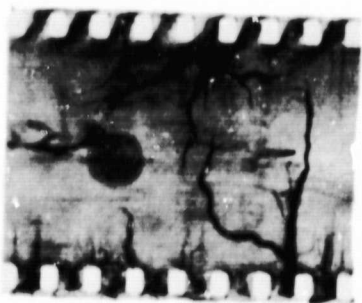


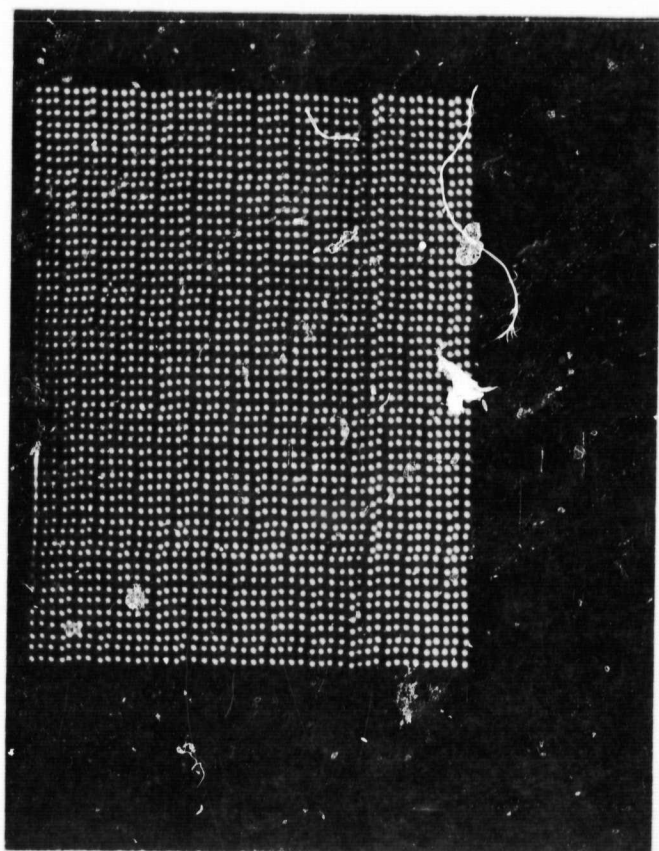
type shown is being obtained and the effect of temperature on grain noise is also being examined.

Early work with film transport in a vacuum chamber led to a serious problem with static electrical discharge on film. Figure 16 shows samples of film obtained before and after a program was insitituted to minimize static electrical problems. Technical report T 68-11 has been issued describing this work.

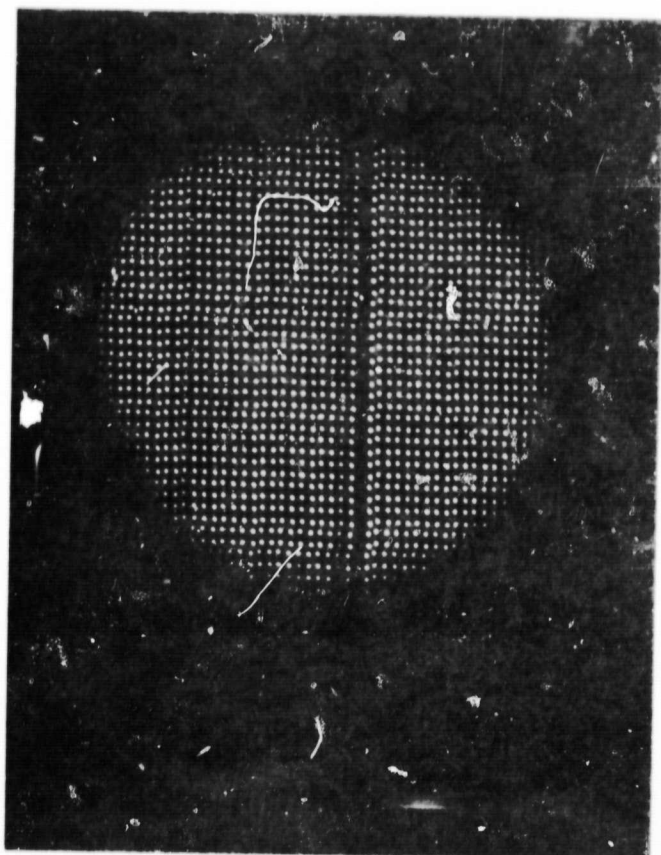
To illustrate applications of the S.D. system to non-photographic problems, Figure 17 shows scans of the artificial star and sky spots as done with an ITT 4011 image dissector tube. Grid point spacing is 0.001 inch on the I.D. cathode in these pictures. The star spot was 0.006 inch in diameter and the I.D. aperture was 0.006. Pictures were obtained by using the I.D. output signal to control intensity modulation of a storage oscilloscope scanned in the same pattern which is selectable in any size from 1 x 1 to 1000 x 1000. Figure 17b shows the sky spot alone within the scan pattern. The scope intensity is modulated by the signal and the background suppressed. In Figure 17c the star is added to the sky signal and in Figure 17d the sky is suppressed to enhance the star. All scans are taken with a few seconds integration on the oscilloscope storage phosphor and adjustment of intensity discrimination level and integration time.

These brief examples are intended only to convey the sense of the wide possible applications of the S.D. system. Individual studies are reported in separate technical reports with full details as they are completed.

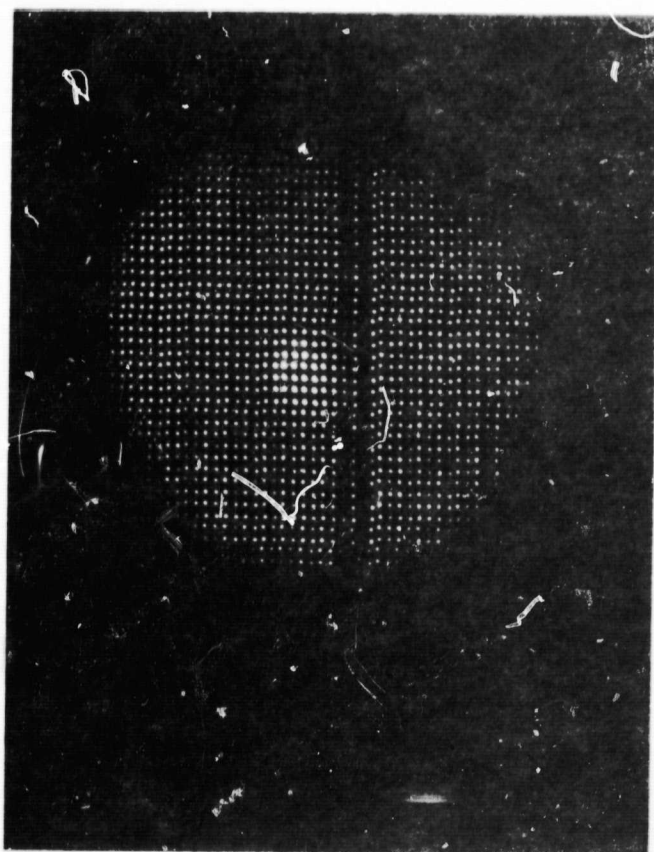




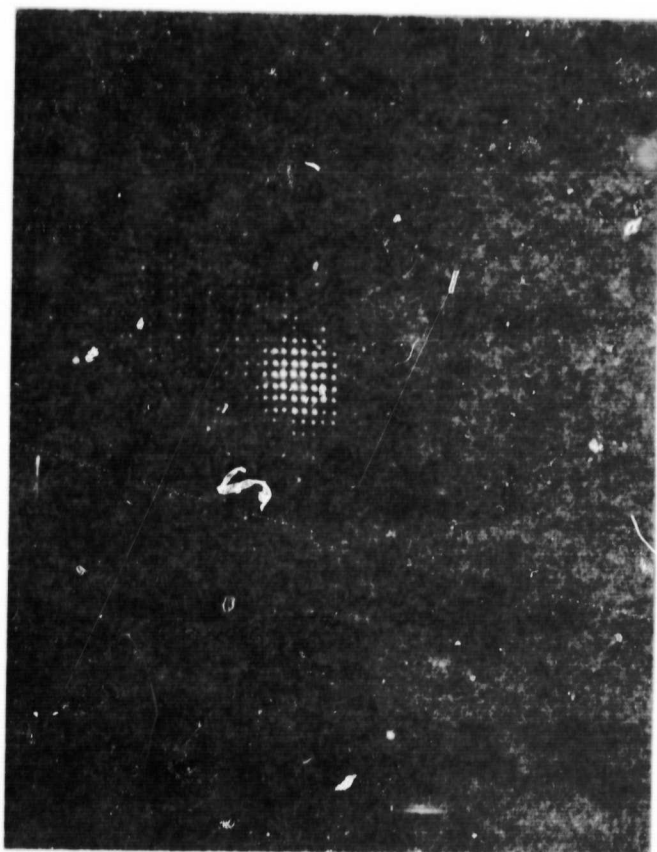
A



B



C



D

FIGURE 17