NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

VLBA TECHNICAL REPORT NO. 1

LOW-NOISE, 8.4 GHz, CRYOGENIC GASFET FRONT-END

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August 29, 1984

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Section 1. SYSTEM DESCRIPTION

1.1 Brief Block Diagram Description

This report describes a dual-channel, low-noise amplifier system intended for use as a radio astronomy or space communications receiver front-end. A frequency range of 8.0 to 8.8 GHz is covered with optimum performance at 8.4 GHz where a receiver noise temperature of < 36K (noise figure < 0.51 dB) is achieved. The dual-channels allow both left and right circularly-polarized (LCP and RCP) signals to be received.

A block diagram of the system is shown in Figure 1.1-1 and photographs are shown in Figure 1.1-2. A 2.5908 cm (1.020") diameter, circular waveguide, propagating both TE_{11} circular-polarized modes, provides the input to the system. An iris-matched window (see Section 2.2) in the waveguide supports a vacuum in a dewar which contains receiver components cooled to a temperature of ~ 15K (-258C) by a closed-cycle, cryogenic refrigerator. The thermal barrier separating the 300K and 18K portions of the input waveguide is achieved by a 0.4 mm (.016") gap in the waveguide wall; a radial choke prevents leakage from the gap. A compact polarizer (see Section 2.3) transduces the two circular waveguide modes to two SMA coaxial-line outputs which connect via directional couplers and isolators to the inputs of three-stage, ~ 30 dB gain, gallium-arsenide field-effect transistor (GASFET) amplifiers. The amplifier outputs connect to commercial coaxial-line, vacuum-seal, feed-thru connectors via 2.159 mm (.085") diameter coaxial

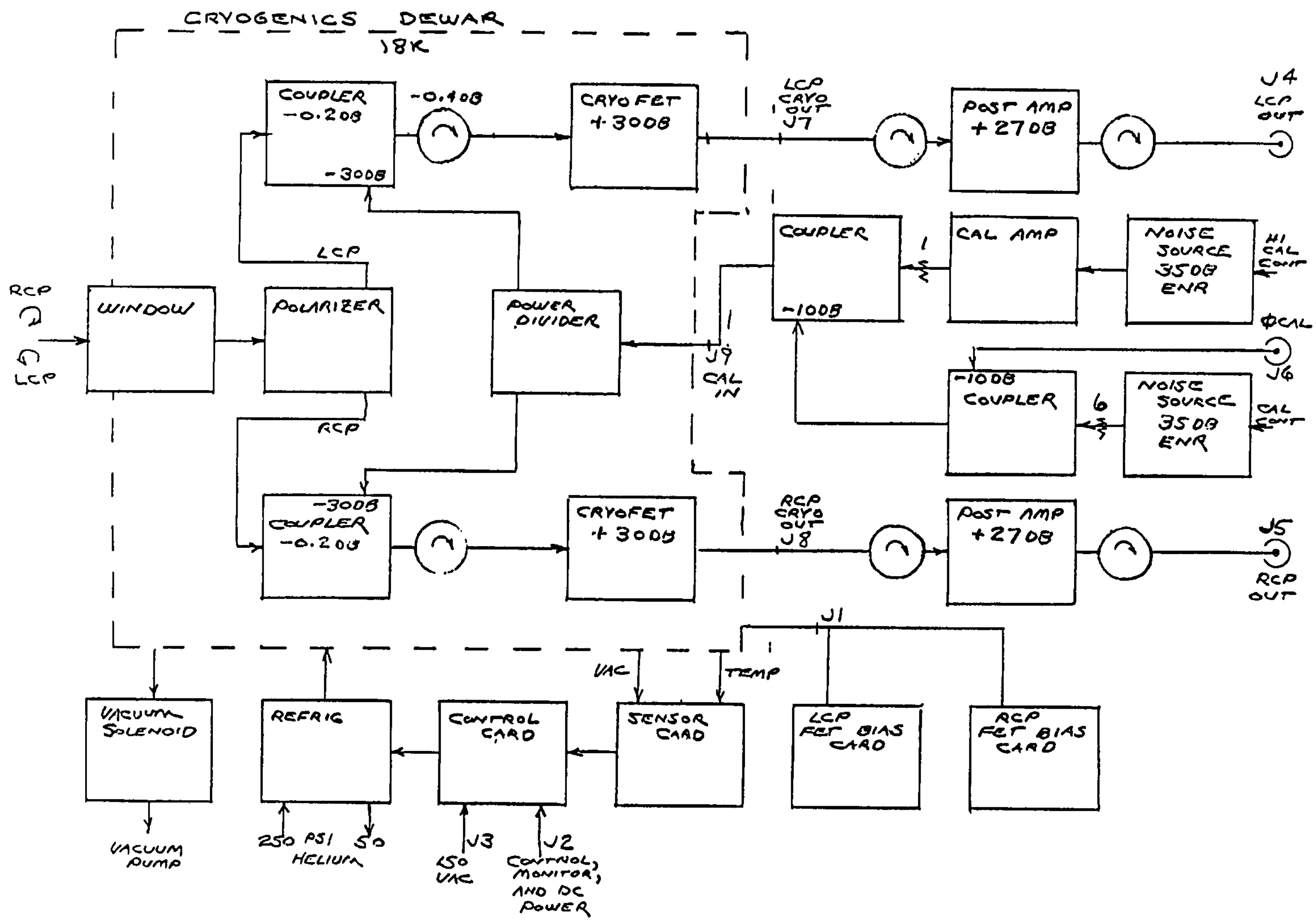

Fig. 1.1-1. Block diagram of 8.4 GHz front-end.

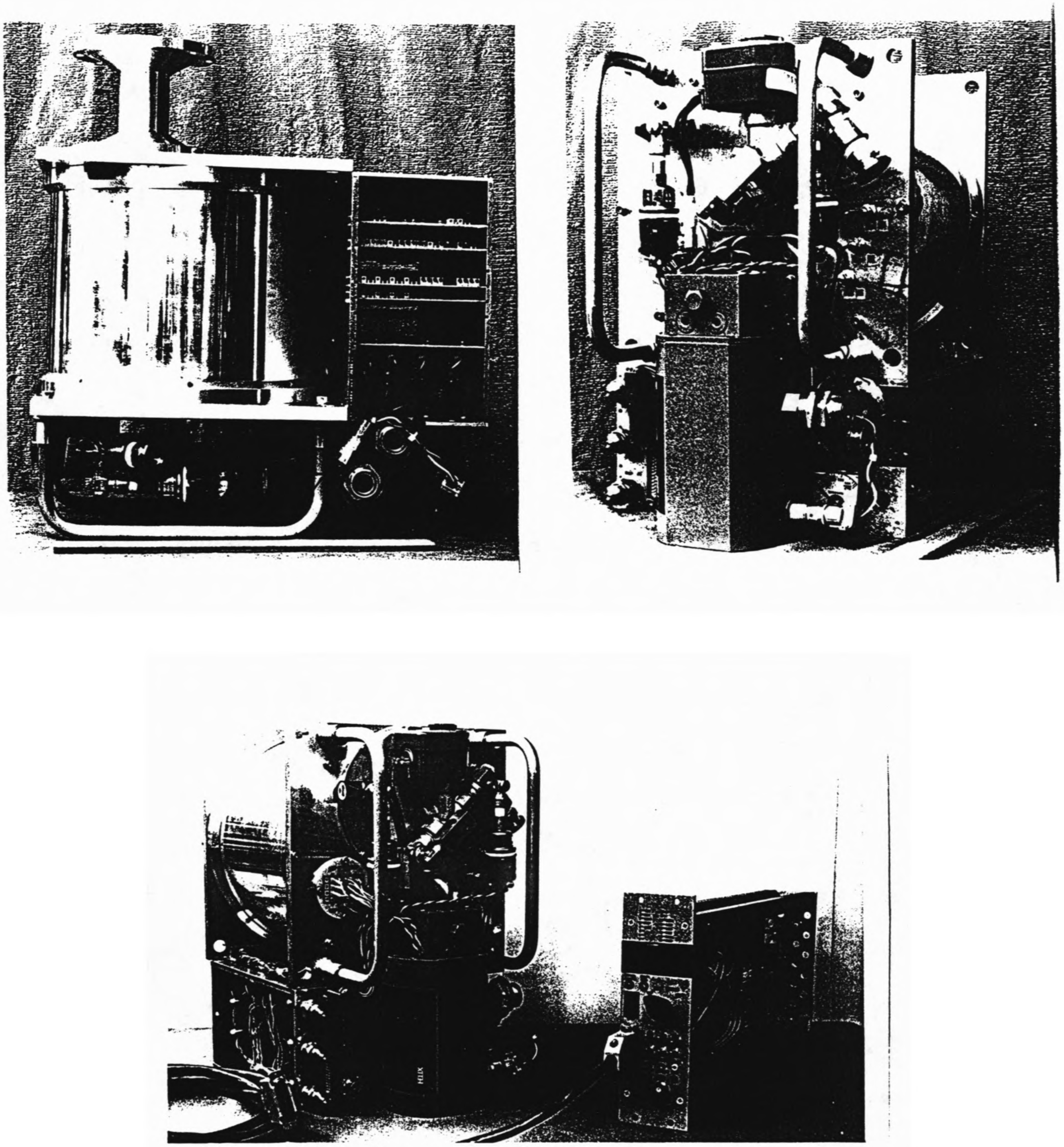

Fig. 1.1-2. Three photographs of the 8.4 GHz front-end. The top left-hand photo shows the circular waveguide input at top and circuit-card cage on right. The top right-hand photo shows vacuum control components, refrigerator motor, and output connectors. The lower photo also shows a test control, monitor, and DC power module.

cables made of low conductivity alloys to support the 18K to 300K temperature drop with small (~ 45 mW) heat flow.

The two dewar output signals feed room temperature GASFET amplifiers having ~ 3.5 dB noise figure and ~ 27 dB gain. The amplifiers are mounted along with input and output isolators on an RF components circuit card which also supports calibration components. Three types of calibration signals are provided:

a) a low-noise calibration signal, ~ 4K, for continuous pulsed gain and noise calibration of the system,

b) a high noise calibration signal, ~ 1500K, which may be useful for solar or other large signal observations, and

c) an externally applied signal, coupled -56 dB to both inputs, for the purposes of phase or time-delay calibration of the system.

The cryogenic components are cooled with a Cryogenics Technology, Inc. Model 22 refrigerator which requires an external helium compressor. Vacuum service, as provided by a two-stage mechanical pump, is also required and is connected to the dewar through a solenoid-operated valve. The vacuum on each side of the valve is monitored, along with dewar temperature, by circuitry on a sensor card. The sensor outputs, along with two external control bits, are input to a control card which controls the vacuum solenoid, the refrigerator power, and a cold-station heater which is used to add a 0.5 watt load for cryogenics stress testing or a 35 watt load for fast warmup. The states of the two control bits are OFF, COOL, STRESS, and HEAT. Two GASFET bias regulator cards, each providing constant drain-current bias for a cooled LCP or RCP amplifier with up to four stages, are included in the card cage.

1.2 Specifications

Unless otherwise stated the specifications apply to the system at its cryogenic operating temperature. A set of test data which will be required for all front-ends is given in Appendix I.

1.2.1 Noise Temperature - The receiver noise temperature measured at the 300K side of the window shall be $\leq$ 38K at 8.4 GHz and $\leq$ 75K over the 8.0 to 8.8 GHz frequency range. The noise temperature must be measured with a circular waveguide, liquid-nitrogen, noise temperature standard and an automated system which gives the noise temperature at 100 MHz intervals from 7.4 to 9.4 GHz.

1.2.2 Input Return Loss - The return loss for two orthogonal linear TE_{11} modes in the input circular waveguide must be $\geq$ 18 dB at 8.4 GHz and $\geq$ 15 dB from 8.0 to 8.8 GHz. This measurement is performed with a WR112 rectangular waveguide reflectometer followed by a well-matched ($\geq$ 35 dB return loss) WR112 to 1.02" circular waveguide transition, and a lossy septum to terminate the orthogonal mode.

1.2.3 ø Cal Coupling - The calculated coupling from the ø Cal input jack J6 to the CRYOFET input shall be 56 $\pm$ 2 dB from 8.0 to 8.8 GHz. (Not measured on all systems.)

1.2.4 ø Cal Gain - The ø Cal gain as measured between the ø Cal input jack J6 and either LCP output jack J4 or RCP output jack J5 and shall be -2 $\pm$ 2 dB at 8.4 GHz and -3 $\pm$ 4 dB from 8.0 to 8.8 GHz. (This gain is the sum of 30 dB CRYOFET gain, 27 dB post amp gain, -3 dB for losses, and -56 dB ø Cal coupling.)

1.2.5 ø Cal Input Return Loss - The return loss at the ø Cal input jack J6 shall be $\geq$ 15 dB from 8.0 to 8.8 GHz.

1.2.6 Output Return Loss - The output return loss for LCP and RCP channels, at jack J4 and J5, shall be $\geq$ 15 dB from 8.0 to 8.8 GHz.

1.2.7 Calibration Noise Temperature - The noise added to the system in each channel when +28 volts is applied to the Cal control line shall be 4 $\pm$ 1K and calibrated with an accuracy of $\pm$ 0.1K from 8.0 to 8.8 GHz.

1.2.8 High Calibration Noise Temperature - The noise added to the system in each channel when +28 volts is applied to the High Cal control line shall be 1500 $\pm$ 300K and calibrated with an accuracy of $\pm$ 30K from 8.0 to 8.8 GHz.

1.2.9 Output Total Noise Power - With a short-circuit plate placed across the input waveguide, the noise power out of LCP and RCP output jacks, J4 and J5, shall be (-37 $\pm$ 2) dBm; the value shall be measured with an accuracy of $\pm$ 0.2 dB.

1.2.10 Output Noise Power Stability - The receiver input is short-circuited and a test receiver with 30 MHz I.F. bandwidth and 1 kHz post-detection bandwidth is connected to the LCP output and then to the RCP output. With the receiver tuned to 8.4 GHz and gain adjusted for 5 $\pm$ 1 volts DC output from the receiver, the peak-to-peak AC (> 2 Hz) receiver output shall be less than 250 mV peak-to-peak as viewed on an oscilloscope. This test shall be passed under conditions of light tapping upon the dewar, RF card, and output coaxial cables. (The purpose of the test is to check for mechanical looseness, vibration sensitivity, 60 Hz modulation, and refrigerator induced 2.4 Hz modulation.)

1.2.11 Cold Station Temperatures - The temperature of the refrigerator first stage shall be $\leq$ 55K; the second stage temperature as measured on the cold strap shall be $\leq$ 17K.

1.2.12 FET Bias Data - The optimum drain voltage V_D, drain current I_D, and gate voltage V_g, at 300K and cryogenic operating temperature, shall be recorded for each of three stages of the two CRYOFET amplifiers.

1.2.13 Cool-Down Time - The time required to cool the cryogenic components from 300K to operating temperature shall be $\lesssim$ 12 hours.

1.2.14 Physical Weight and Size - The front-end shall weigh less than 50 pounds and shall have the outline shown in Figure 1.3-1.

1.3 Interface Description

1.3.1 Mechanical Interface

Locations of the input waveguide, helium supply and return, vacuum port, and mounting holes are shown in Figure 1.3-1. The input waveguide connection to the antenna feed must be pressurized with dry nitrogen or sealed with a dessicant to prevent condensation of water on the input window which cools slightly due to radiation into the dewar; the pressure should be limited to < 3 psi.

The intended mounting concept is to rigidly align the front-end to the antenna feed using the large input waveguide flange and then take up most of the front-end weight with somewhat flexible and adjustable supports (such as 1/2" threaded rods) through the four .531" diameter holes in the four corners of the dewar top and bottom plates.

1.3.2 Vacuum and Helium Interface

The vacuum port connection is through a Leybold-Heraeus type KF16 flange, type 18321 centering ring, and type 18346 quick-disconnect clamp. The dewar volume is 8.8 litres and a pumping speed of 0.18 litres/sec (10.5 litres/minute or 0.37 CFM) will bring the dewar from atmosphere to 5 µm in 10 minutes. Of greater importance is the blank-off pressure of the pump; a value of < 10 µm is required and < 5 µm is desirable. A control signal, PUMP REQUEST, is output by the control card when vacuum pumping is needed; this may be either used to turn on a pump or open a solenoid-operated valve to a pump manifold.

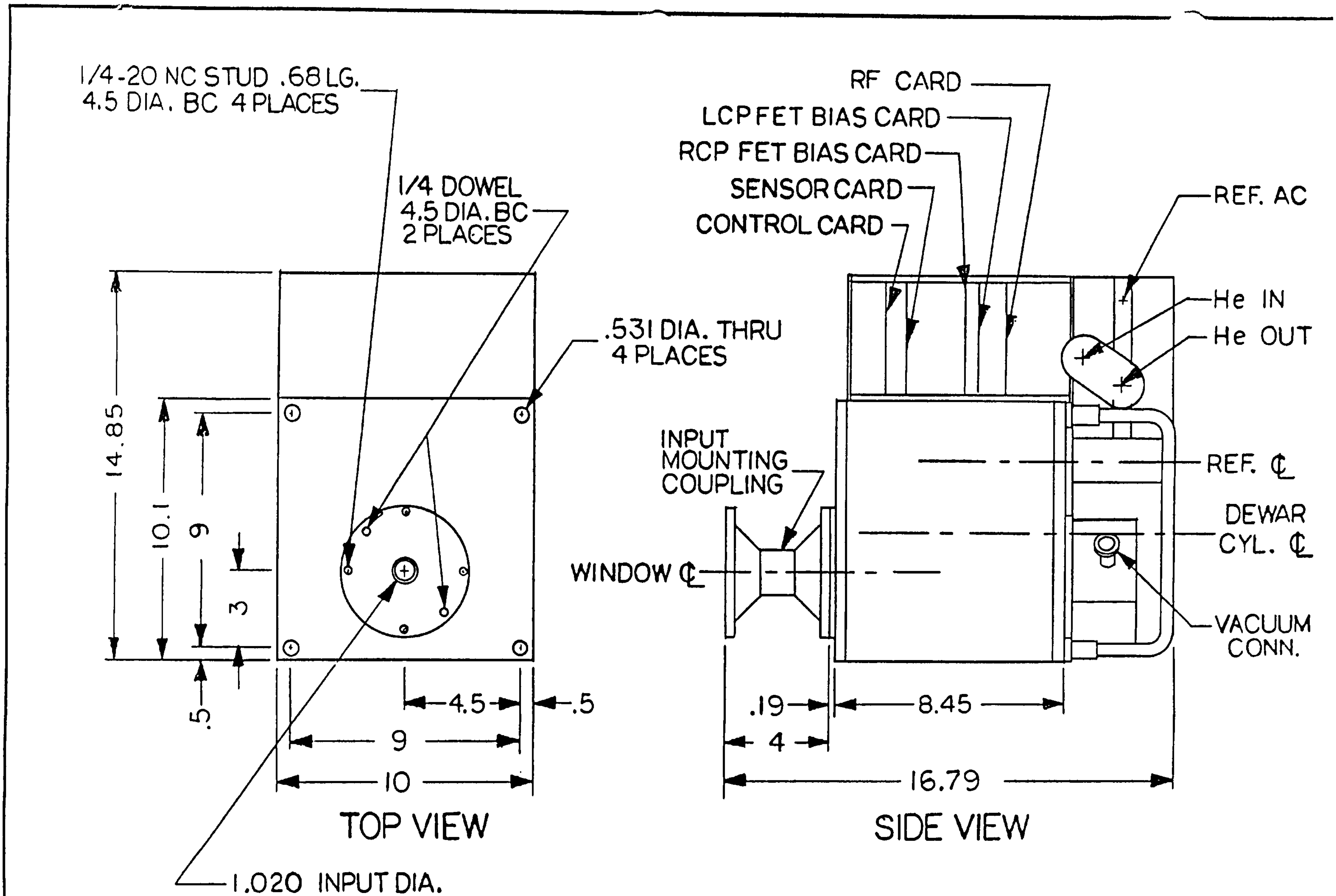

Fig. 1.3-1. Outline drawing of front-end.

The helium interface is through Aeroquip 5400-S5-8 self-sealing fittings. The helium supply pressure should be 225 $\pm$ 5 psi static and 250 $\pm$ 10 psi dynamic, and the return pressure is 60 $\pm$ 15 psi; the flow rate is 7.3 $\pm$ 0.2 SCFM. The helium may be compressed by a CTI Model 08032224 compressor or by a larger compressor which accommodates several refrigerators.

1.3.3 RF Interface

The RF outputs J4 and J5, and ø Çal input J6, are coaxial type N female connectors. The return loss at these connectors will be $\geq$ 18 dB from 8.0 to 8.8 GHz. The receiver following the front-end must have a noise temperature under 50,000K (noise figure $\leq$ 24 dB) including cable losses to add less than 0.3K to the receiver noise temperature with 54 dB of front-end gain.

1.3.4 DC Power, Control and Monitor Connector, J2

The pin assignments for the above functions are given in Table I. The circuitry is designed so that if this connector is unplugged the system will revert to the normal COOL mode; this allows maintenance of a portion of the system without causing a warm-up.

The two control bits C and $\bar{H}$ have the following effect:

C	$\bar{H}$	Mode	Comment
0	1	OFF	No refrigerator power, heater power, or vacuum pumping
1	1	COOL	Normal cooled operation
0	0	STRESS	COOL with added 0.5 watt heat load to stress-test cryogenics
1	0	HEAT	Fast warm-up of dewar with 35 watts of heat and vacuum pumping on

TABLE I - Control and Monitor Connector, J2, Pin Functions
(Dewar receptacle is DB25P mating with plug DB25S)

Function		Des.	Pin
DC Power, +15		+15	21
DC Power, Ground		0	22
DC Power, -15		-15	23
Quality Ground for Monitor Circuits		Gnd	18
C Control Bit		C	13
$\bar{H}$ Control Bit		$\bar{H}$	14
CAL Drive	ON = +28 volts, OFF = 0 volts	C_L	19
HI CAL Drive	ON = +28 volts, OFF = 0 volts	C_H	20
Vacuum Pump Request		P	15
Vacuum Solenoid Monitor		S	16
16K Temperature Monitor, 10 mV/^{o}K		T_A	3
50K Temperature Monitor, 10 mV/^{o}K		T_B	4
Ambient Temperature Monitor, 10 mV/^{o}K		T_M	17
Dewar Vacuum Monitor	0 V = 0 µm, +10 V = ATMOS	V_D	1
Pump Vacuum Monitor	0 V = 0 µm, +10 V = ATMOS	V_p	2
LCP Gate Bias #1		LG1	5
LCP Gate Bias #2		LG2	6
LCP Gate Bias #3		LG3	7
LCP Gate Bias Spare		LG4	8
RCP Gate Bias #1		RG1	9
RCP Gate Bias #2		RG2	10
RCP Gate Bias #3		RG3	11
RCP Gate Bias Spare		RG4	12
Spare		-	24
Spare		-	25

Note that a control data failure which produces all 1's or all 0's will keep the system in COOL or STRESS mode (which should also provide normal operation at the front-end). There is no memory in the dewar control circuitry and switching from one mode to another can be performed without damage; the control card protects the dewar from removal of high vacuum from the cold dewar and from overheating. The control bits are TTL levels with C presenting 5 LS loads and $\bar{H}$ 3 LS loads.

The CAL and HI CAL control signals directly drive the calibration noise sources and in the case of HI CAL also drive a one-stage noise calibration amplifier. The CAL's are turned on with +28 volts at 4 to 10 mA for CAL and 34 to 40 mA for the HI CAL. The coefficient of calibration power output versus supply voltage is < 0.1 dB/% for CAL.

The pump request signal, P, is a TTL level which should be monitored and connected to the vacuum manifold control circuits. The vacuum solenoid signal, S, is a TTL signal for monitor purposes; S = 1 when the vacuum valve is open.

The analog monitor signals are self-explanatory and are generated by circuitry described in other sections of this report. The gate bias monitor signals will normally range between 0 and -2 volts, and should not vary by more than $\pm$ .02 volts from the values recorded in the test data for each CRYOFET amplifier. A value ≥ 0 volts (usually ~ +14 volts) indicates insufficient drain current and ≤ -2 volts (usually -14 volts) indicates a drain circuit short. The vacuum pressure as a function of vacuum monitor output voltage is given in Figure 2.8-4.

The front-end DC power requirements are 100 mA at -15 volts and 500 to 700 mA at +15 volts dependent upon FET requirements and the control bit state of the system.

1.3.5 AC Power Interface, J3

The CTI Model 22 refrigerator requires two-phase, 150 volt, 60 or 50 Hz AC power which is supplied into a three-pin receptacle, Deutsch DM9606-3P, with mating plug, DM9702-3S. The pin assignments, a simplified AC power schematic, and a suggested power source schematic are shown in Figure 1.3-2. The rms current drawn by the various loads are as follows:

Refrigerator Motor	-	0.7 amps
Vacuum Solenoid*	-	0.25 amps
Heater in HEAT Mode	-	0.20 amps
Heater in STRESS Mode	-	0.03 amps

*If the vacuum solenoid is powered but through a fault does not actuate, it will draw 0.40 amps.

Note that the plug may be removed from J3 and plugged directly into the refrigerator motor to preserve the COOL mode while removing AC power from the control circuits.

1.4 System Parameter Budgets

1.4.1 Noise Temperature

At the center frequency of 8.4 GHz a typical noise temperature budget is given in the following table. The noise temperature is highly dependent upon the input transistor and the best device out of six samples gave 6K lower noise temperature.

Component	Cumulative Noise Temperature	Added by Component
One-Stage CRYOFET	21K	18K
Second-Stage of CRYOFET	26K	5K

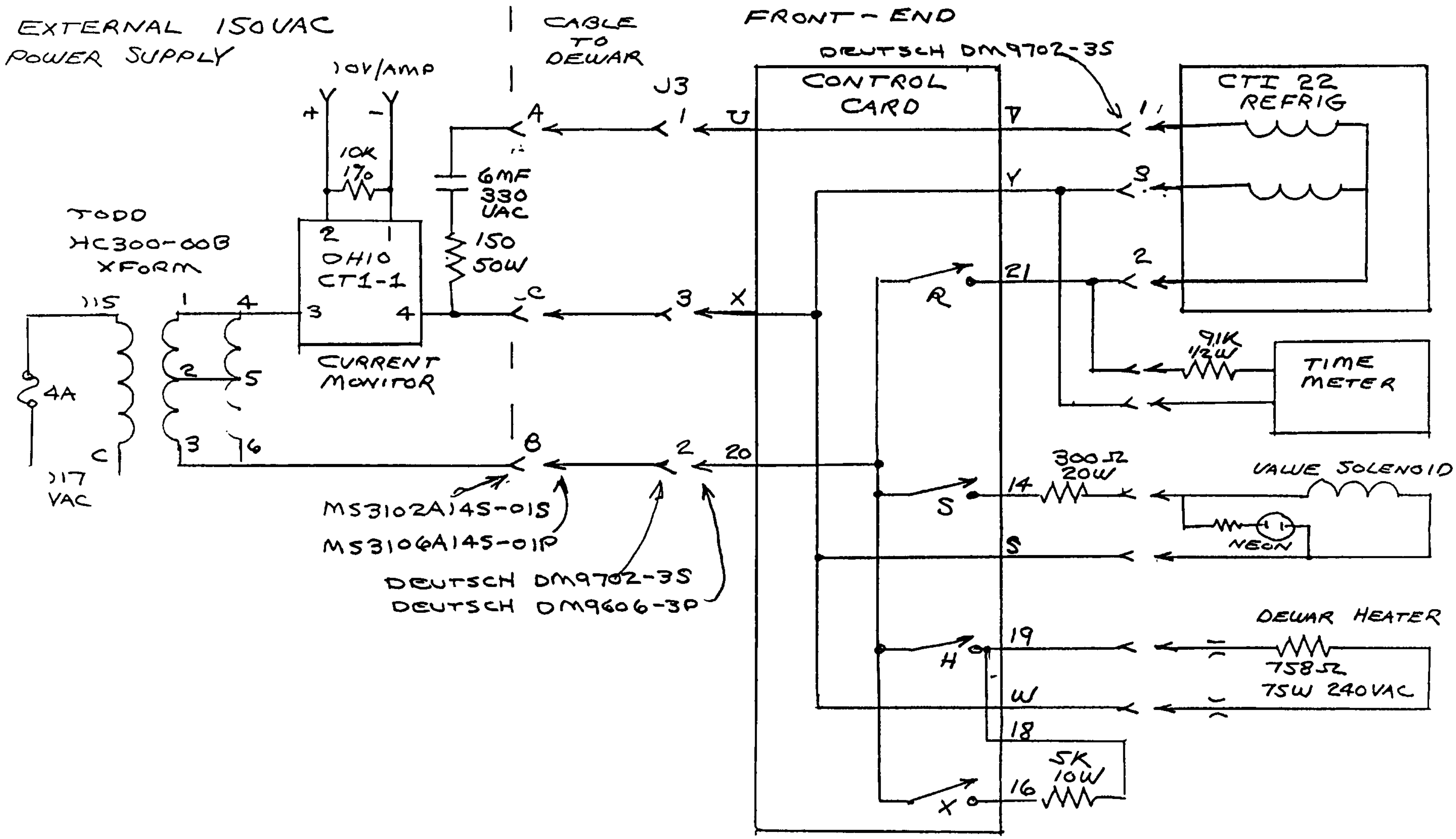

Fig. 1.3-2. Front-end AC wiring. Note that the dewar AC cable can be unplugged from J3 and plugged into the refrigerator to keep the system cold while servicing the control card.

Component	Cumulative Noise Temperature	Added by Component
Isolator, 0.4 dB loss @ 18K	30.2K	4.2K
30 dB Coupler, 0.15 dB @ 18K	31.9K	1.7K
6" 0.141" Cable, 0.20 dB @ 18K	34.3K	2.3K
Polarizer, .05 dB @ 25K	35.0K	0.7K
Window, .001 dB @ 300K	35.1K	0.1K
Receiver Noise Temperature	35.1K	
Feed Loss, .02 dB @ 300K	36.6K	1.5K
Spillover, Scattering	41.6K	5K
Atmosphere, Zenith	43.6K	2K
Cosmic Background	46.6K	3K
System Noise Temperature	46.6K	

1.4.2 Gain @ 8.4 GHz

Input Losses	- 0.7 dB
3-Stage CRYOFET	+ 30 ± 1 dB
9" .085" D. SS/AG Cable	- 0.9 dB
11" .085" D. CU/CU Cable	- 0.5 dB
Two 300K Isolators	- 0.8 dB
3-Stage Post Amp	+ 27 ± 1 dB
4" .085" D. CU/CU Cable	- 0.2 dB
NET GAIN	+ 53.9 ± 2 dB

1.4.3 Heat Load on 15K Station

Radiation into Polarizer	0.23 watts
Polarizer Supports	0.20 watts

3 - Coaxial Lines to 300K	0.08 watts
2 - 7 x 38 40% Cu Wire	.03 watts
14 - #32 Brass Wire	.03 watts
FET Amplifier DC Bias	.39 watts
TOTAL	0.96 watts

Temperature is 9.5K + 5.5K/w x (heat load) = 15K

1.4.4 Heat Capacity Change (Enthalpy) for 300K to 15K Cooldown

(See Section 2.1)

COMPONENT	ENTHALPY (Joules)
Prototype Polarizer (14.5 oz. Al + 14 oz. brass)	101,700
New Polarizer* (10.6 oz. Al)	(51,300)
2 - FET Amplifiers (14 oz. Cu)	31,500
Isolators, Couplers (2.5 oz. Al)	12,100
RF Plates and Cold Strap (25 oz. Cu)	56,200
First-stage Load and Misc. Cables, Brackets (17 oz. Cu or 7.8 oz. Al)	37,900
Total Enthalpy Change	239,400

*The change of polarizer will decrease the total enthalpy change by 21% and thus reduce the cool-down time from 11 to 8.5 hours.

Section 2. COMPONENT DESCRIPTION

2.0 Drawings

A number of key drawings are shown in Appendix II. These drawings include bill-of-materials (BOM) documents and assembly drawings which index other drawings.

2.1. Vacuum Dewar and Refrigerator

The vacuum dewar is machined from two aluminum plates (both 10" square, top .375 thick, bottom .450 thick) and an aluminum pipe (.5" wall x 9" inside diameter). Joints are sealed with O-rings and no welding or brazing is required. Many reliable dewars have been fabricated in this manner at NRAO.

A cross-section view of the dewar is shown in Figure 2.1-1 and interior photographs are shown in Figures 2.1-2 and -3 (also see the photographs of Figure 1.1-2). It can be disassembled into three portions:

1) An inspection cover which includes dewar vacuum-sensor, pump-line solenoid-operated valve, pump vacuum-sensor, and a manual vent valve. The entire cover is an easily replaceable assembly common to the dewars for several other frequencies. It is fastened to the bottom-plate with four 8-32 socket-head (9/64") cap screws.

After removal of the inspection cover, it is possible to remove the two RF coax connections to the polarizer (2 SMA connectors), the 15K heat strap (2 #10 screws), and a 50K heat strap (1 #6 screw). Do not forget to make these five connections upon re-assembly. The dewar can then be separated into two portions described below.

2) A top-plate, cylinder and polarizer portion. This is separated from the remainder of the dewar by removing the six 10-32, socket-head (5/32") cap screws holding the cylinder to the dewar bottom plate and two 10-32, socket-head bolts attaching the top plate to the card cage.

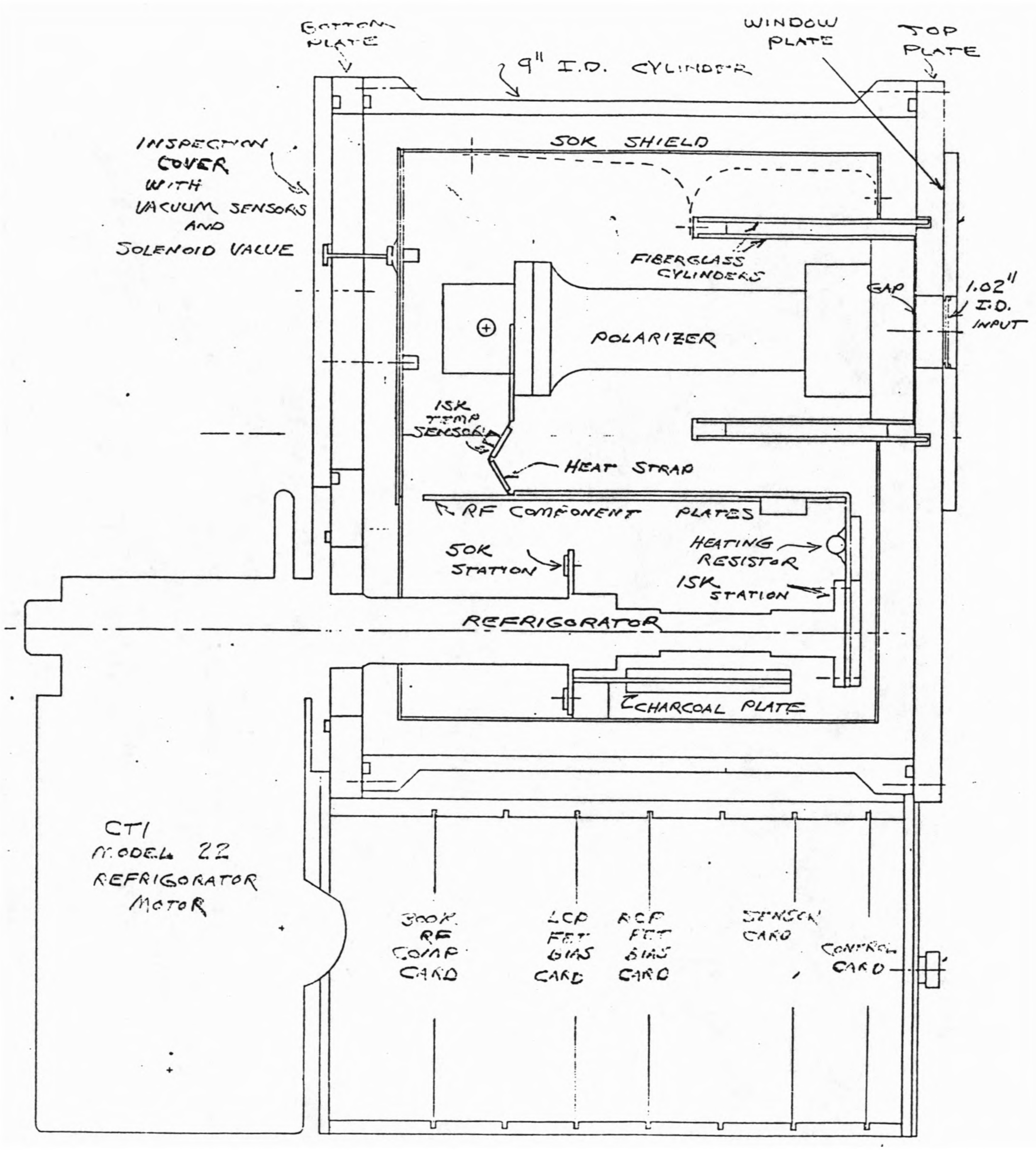

Fig. 2.1-1. Cross-section view of front-end. After removing the inspection cover and disconnecting five internal connections, the cylinder, top plate, and polarizer can be removed in one assembly from the remainder of the system.

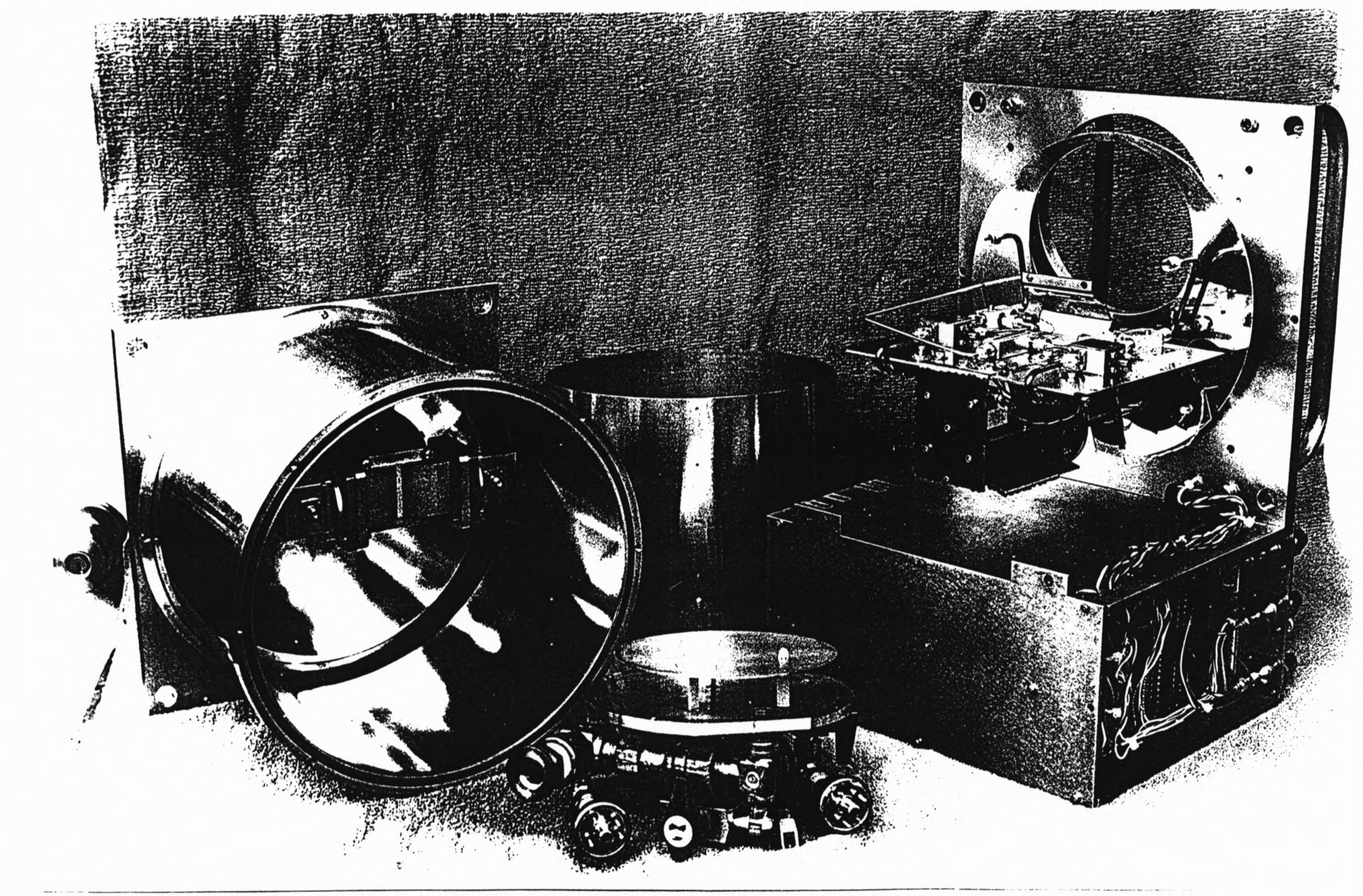

Fig. 2.1-2. Front-end disassembled into major subassemblies, from left to right: a) dewar outer cylinder with top plate and polarizer; b) 50K radiation shield; c) inspection cover with vacuum accessories; and d) card cage, refrigerator, bottom plate and cold plates.

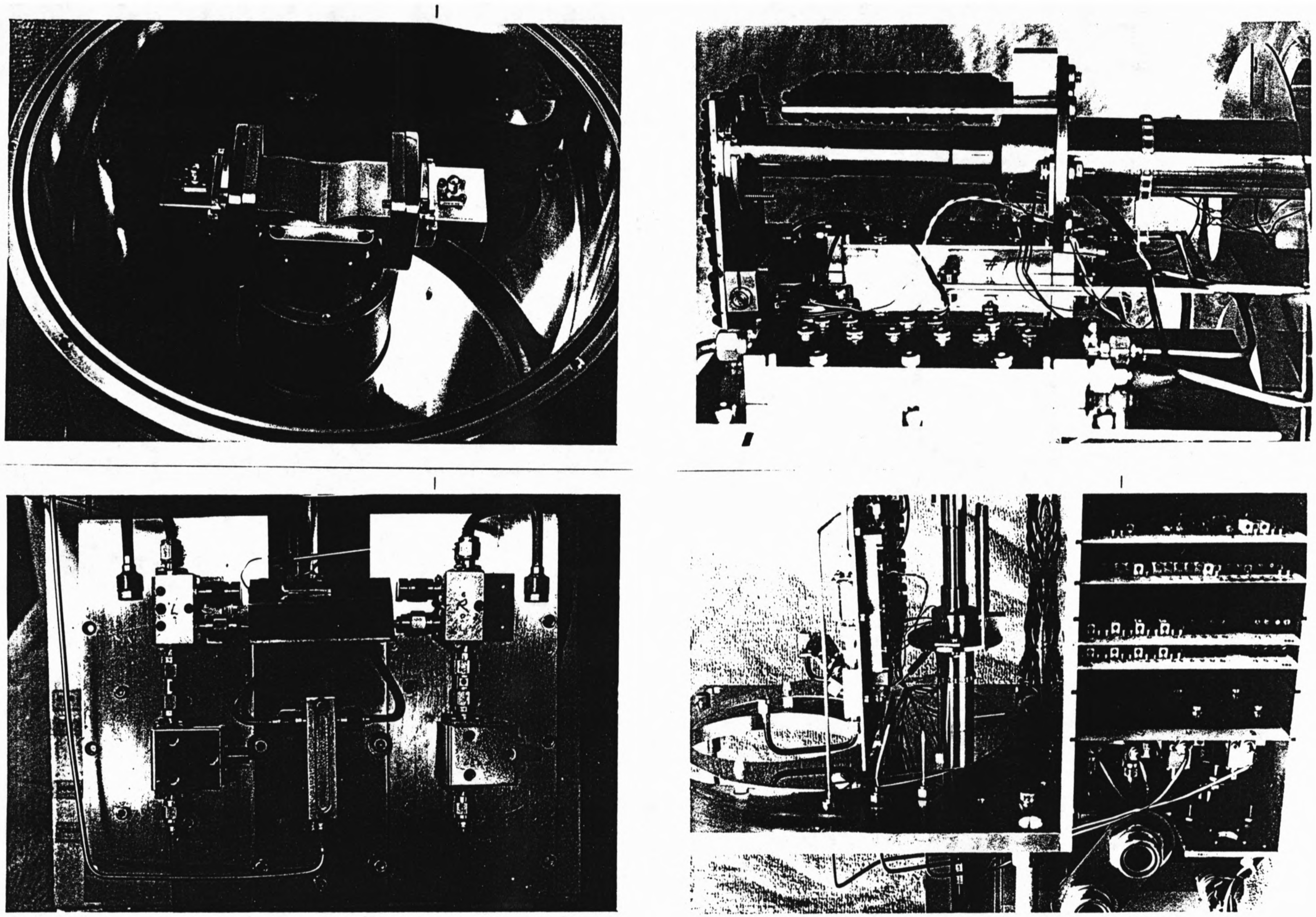

Fig. 2.1-3. Views of dewar interior, clockwise from top left: a) prototype polarizer; b) refrigerator cylinder, charcoal plates, and CRYOFET's; c) isolators and calibration couplers; and d) dewar top plate and card cage.

3) The remainder of the dewar includes the card cage, refrigerator, cold RF component plates, and a 50K cylindrical shield. The 50K shield is removed by removing five #6-32 cap screws. (Upon re-assembly, do not forget to install the screw near the card cage which attaches the 50K shield to the 50K refrigerator station.) The RF component plates are now easily accessible and can be removed for replacement or maintenance.

The dewar volume is 8.8 liters and the inside surface area is 2,372 cm^2. If a dewar is opened to the atmosphere for several hours and then is pumped to ~ 10 μm pressure and valved off, the vacuum rise will typically be 7 μm/minute. This implies that 1.35×10^{-3} cm^3/sec of gas is being introduced into the dewar or a surface outgassing rate of 5.7×10^{-7} cm^3/cm^2 sec or 4.3×10^{-7} torr-liters/cm^2 sec which is in the appropriate range for metal surfaces which are not very clean (see Holkeboer, et al., Vacuum Engineering, p. 198). After 10 hours of pumping the typical vacuum rise rate is 0.3 μm/minute or 5.8×10^{-5} cm^3/sec of gas. This outgassing rate would continue to decrease with time (say, a factor of ten at 100 hours) under mechanical or cryopumping and is of no consequence. It has been experimentally verified that 600 cm^3 of air can be introduced into the dewar when it is cold and after a few minutes the temperature and pressure return to normal values; this would correspond to ~ 2 years of outgassing or leaking at a 10^{-5} cm^3/sec rate.

The most critical vacuum requirement occurs during cool-down. At pressures above 5 μm the thermal conductivity of air between the dewar inside wall and heat shields (a distance of ~ 1 cm) is constant at .03 mW/cm ^{o}K. With a surface area of 2,372 cm^2 and spacing of 1 cm, the heat conduction load is .07 watts/^{o}K or 14 watts at 100K first-stage temperature. The first-stage cooling capacity is of the order of 15 watts so that equilibrium would be reached at ~ 100K if the pressure remains above 5 μm. This situation does not occur because the cryopumping of ~ 10 gms of charcoal on the refrigerator first stage will reduce the pressure to << 5 μm at 100K unless a large leak is present. (An early prototype of the dewar with 0.5 cm of shield-to-wall spacing and no first stage charcoal would fail to cool lower than 200K because of this problem.) As a point of reference it should be noted that 5 μm pressure can be reached with a 1.65×10^{-3} cm^3/sec leak rate and a 0.25 liter/sec typical mechanical pump rate. However, it is the cryopumping which brings the pressure to << 5 μm and the pumping rate of the ~ 10 gms of charcoal as a function of temperature is not known at this time. The tolerable leak rate for successful cool-down has not been experimentally determined at this time.

Chart recordings of a typical cool-down and HEAT mode warm-up are shown in Figures 2.1-4 and -5; these tests are with the prototype polarizer which has considerably more mass than the final polarizer. The cool-down time is approximately 11 hours to a final temperature of 15.5 ± 1K on second stage and 48 ± 3K on the first stage. The warm-up time with 35 watts of heat applied is 1.9 hours. The ratio of these times gives an average refrigerator cool-down power of 6.4 watts including 0.4 watts to compensate for FET DC bias power. The total enthalpy change from 300K to 15K is 239,400 joules (35 watts x 1.9 hours). A budget for this heat capacity is given in Section 1.4.4 utilizing component weights and the known 300K to 15K enthalpy change for copper and aluminum, 2,250 joules/oz. and 4,840 joules/oz., respectively. A plot of the refrigerator first- and second-stage temperature as a function of first- and second-stage loading is given in Figure 2.1-6; a breakdown of the second-stage heat load is given in Section 1.4.3.

In the event of a cool-down failure, it is often difficult to ascertain whether the problem is a vacuum leak which loads the refrigerator or a refrigerator problem which gives poor vacuum due to insufficient cryopumping. If initial

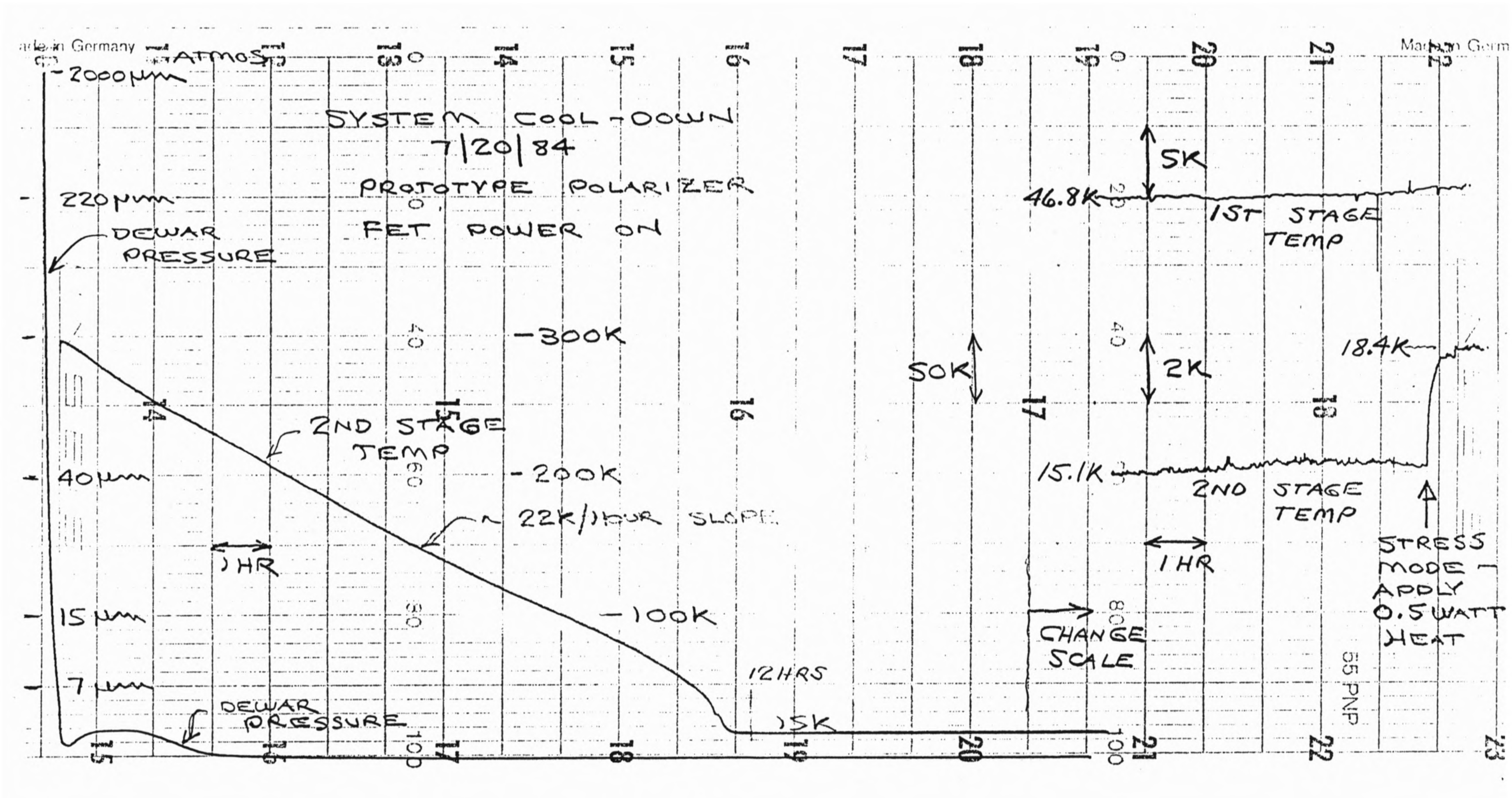

Fig. 2.1-4. Chart recording of system cool-down on July 20, 1984. The dewar had partial vacuum at the beginning of test but results are similar when starting from atmospheric pressure. The stability of ± 0.1K variation of second-stage temperature in one hour was unusual; ± 0.5K was typical in previous data.

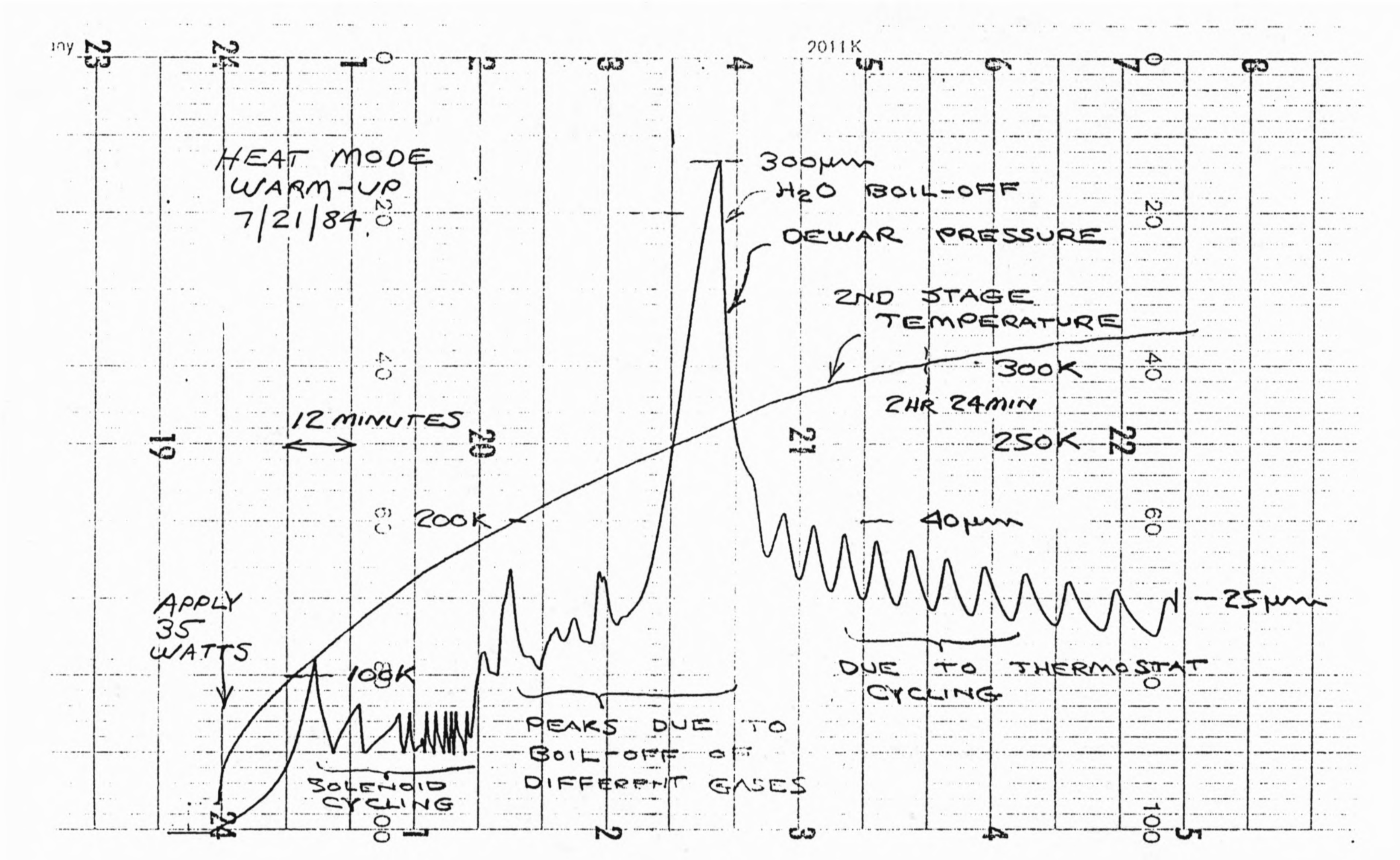

Fig. 2.1-5. Chart recording of system HEAT mode warm-up. The variations in pressure are due to the solenoid opening and closing at low pressure, to boil-off of various substances as the temperature rises, and to cycling of the heater thermostat at higher temperatures.

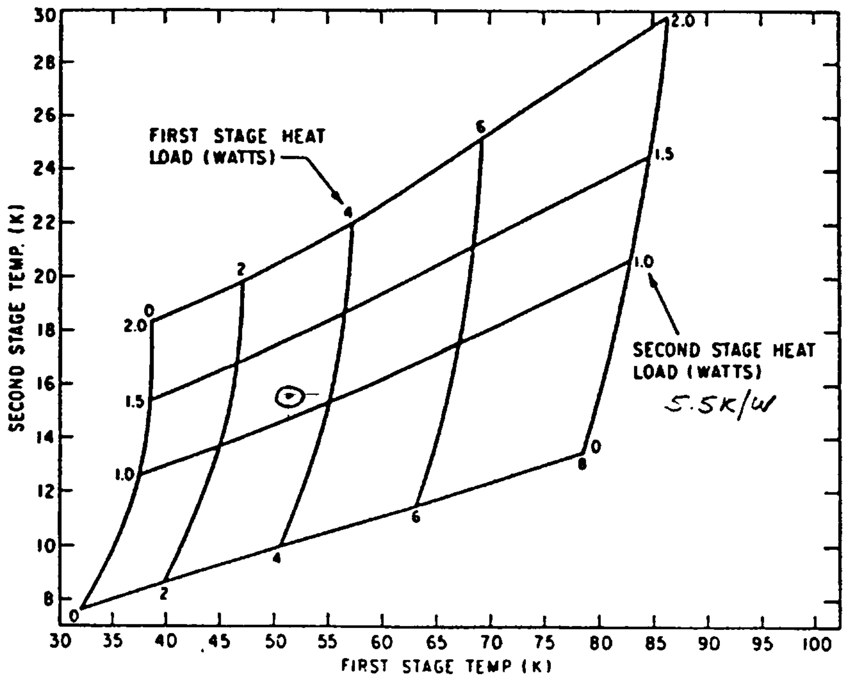

Fig. 2.1-6. Refrigerator temperature as a function of heat load (from CTI 21 manual). The operating point is 15.5K @ 1.2 watts on the second stage amd 51K at 3.2 watts on the first stage. A budget for the second stage load is given in Section 1.4.3.

checks of refrigerator motor current, refrigerator sound, and compressor supply and return helium pressures do not reveal the problem, it is necessary to warm up the front-end to room temperature and observe the vacuum with the refrigerator off. A leak tester may be necessary, but it is also possible to observe the rate of vacuum rise after pumping for > 1 hour at 300K (use COOL mode with refrigerator unplugged). The system is then commanded to OFF (closes solenoid valve) and a vacuum rise rate > 10 μm/min is indicative of a leak.

When assembling or re-assembling the dewar, the following precautions should be observed:

1) Note the surfaces which must seal against an O-ring and be careful not to scratch these surfaces. When closing the dewar, check that there is no dirt or foreign objects on O-ring surfaces.

2) The emissivity of surfaces is greatly increased by the presence of a film on the surface. (A doubling of the emissivity was noted for an aluminum surface cleaned with acetone compared to cleaning with Freon.) This is important for the interior of the dewar walls and exterior of the 50K radiation shields. These surfaces should be initially cleaned with Freon and then not touched. The 15K components should be kept reasonably clean but can be handled for maintenance without cleaning.

3) When closing the dewar, make sure all connections are made and are tight.

2.2 Window

A circular waveguide window is necessary to preserve vacuum within the cryogenics dewar. The window is built into a replaceable plate as shown in Figure 2.2-1. A cross-section view of the window is shown in Figure 2.2-2. The basic design is a mylar sheet matched by inductive irises on both sides; one iris forms a convenient lip for epoxy bonding of the mylar. Other dielectrics

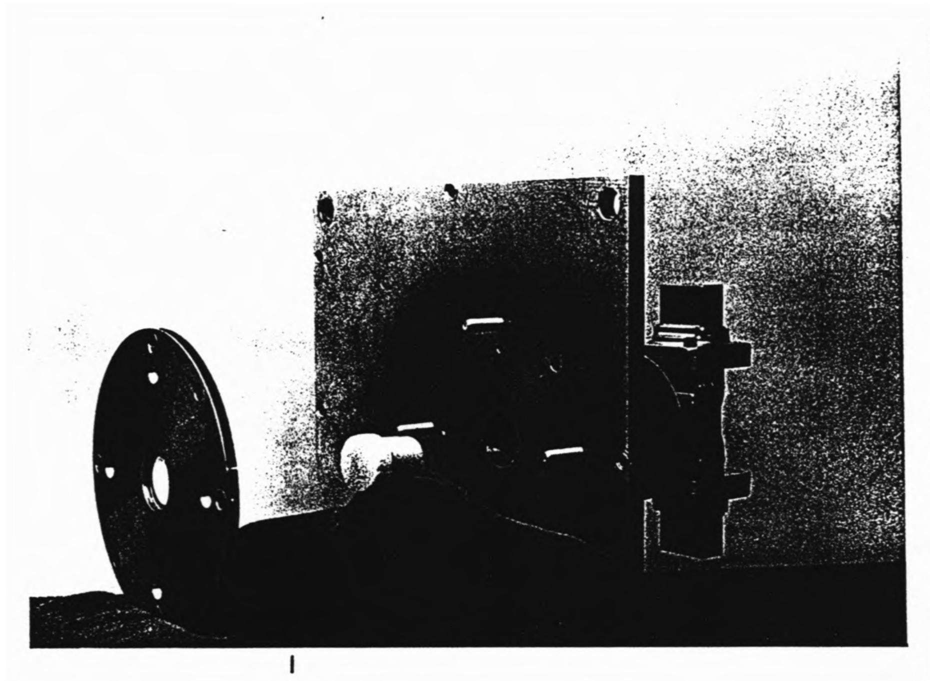

Fig. 2.2-1. **Window plate, foam plug IR absorber, dewar top plate and prototype polarizer.**

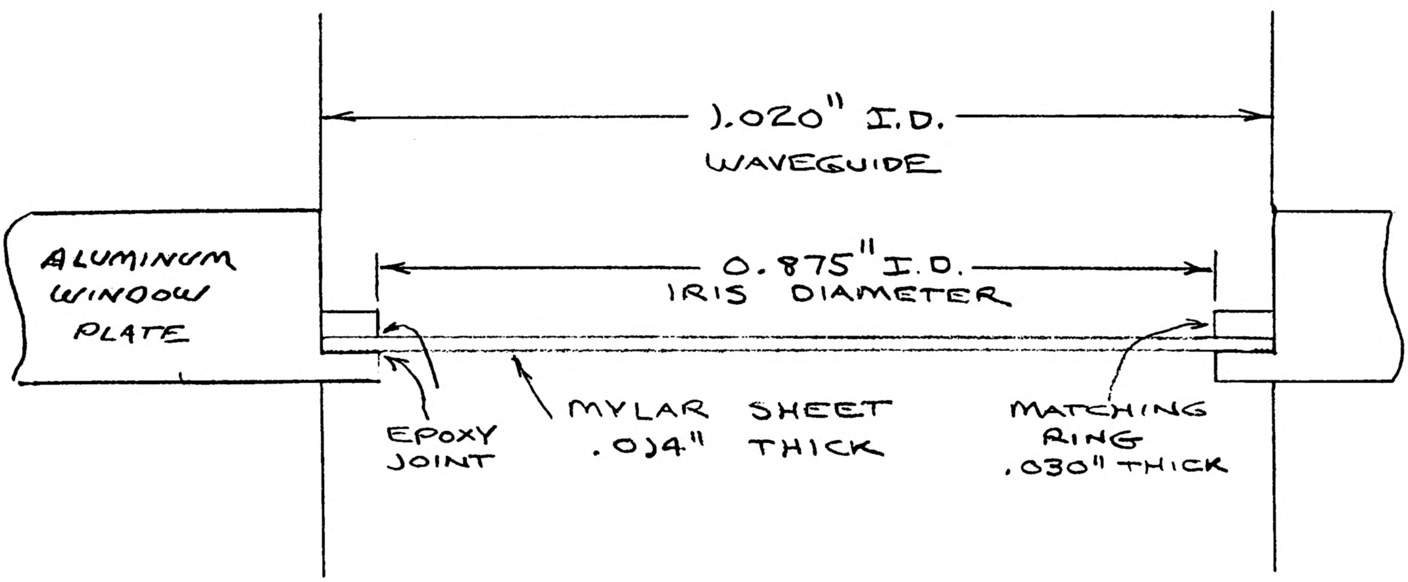

Fig. 2.2-2. Cross-section view of window. The mylar disc is bonded with Eccobond 45 (Emerson and Cuming, Canton, MA) mixed for medium flexibility.

such as polyethylene, polystyrene, and mica were considered and tested; all are probably satisfactory but mylar appears to be easy to bond and can tolerate mechanical shock. Some of the considerations in the window design are as follows:

A) Stress Due to Pressure - By isolating the forces on a ring of material, it can be shown that the maximum stress, S, in the window occurs at the outer edge and is given by:

$$S = \frac{Dp}{4t \sin\theta}$$

where D is the diameter, p is the pressure, t is the thickness, and θ is the angle of deflection at the window edge; a window which is perfectly flat requires infinite stress in the material. The measured value of θ for a mylar window with D = 1.02", t = .014", and p = 15 psi is .15 radian. This gives a maximum stress of S = 1,821 psi which should be compared to an ultimate tensile strength of 25,000 psi for mylar (Dupont Bulletin M-2D). As an experimental check, a completed window was subjected to a pressure of 3 atmospheres and did not burst.

It should be noted that the handbook formula (for example, Oberg and Jones, Machinery Handbook, 17th ed., p. 418) for stress in a round plate, $S = .39W/t^2$, where $W = p\pi D^2/4$ is the total force, gives S = 19,920 psi. This is incorrect because the formula is based upon metals which are much stiffer than mylar and cannot deform (increase θ) to reduce the stress.

B) Gas Permeation - All polymers are porous to gas penetration to some degree; the quantity of gas which permeates through a membrane is proportional to the area and partial pressure and inversely proportional to the thickness. The permeability figures for mylar in Dupont Bulletin M-1J, applied to the 1.02" diameter, .014" thick window, give leak rates of 6.7×10^{-7} cm^3/sec for hydrogen, 6.7×10^{-9} cm^3/sec for nitrogen, 4×10^{-8} cm^3/sec for oxygen, and 1.2×10^{-8} gms/sec for water at one atmosphere pressure. No data is given for helium but a figure of 3.2 x 10^{-7} cm^3/sec was measured for the completed window on a leak detector. The partial pressure of helium in the atmosphere is 5.2 x 10^{-6} atmosphere this gives 5.2 x 10^{-5} cm^3 of helium in a year which would give a negligible pressure of .005 μm assuming no cryopumping. The one-year accumulation of nitrogen, oxygen and water are .17 cc, .25 cc and .37 grams, respectively; these should be easily cryopumped.

C) Microwave Reflection and Attenuation - An Apple BASIC program was written to analyze the iris-window-iris configuration given dimensions, dielectric constant (2.8), and loss tangent (3 x 10^{-3}); the quoted material values are for mylar at 1 GHz from Dupont Bulletin M-1J. The iris susceptance as a function of diameter and thickness was described by equations fitting the data given by Ragan, Microwave Transmission Circuits, p. 213.

The computer analysis was not too useful because the frequency dependence of iris susceptance was not known and is the key factor in determining the bandwidth of the low-reflection frequency range. The analysis also neglects the interaction of the closely spaced irises (a difficult problem) and thus the predicted optimum iris diameter was not correct. The program loss prediction of .0012 dB (.08K noise contribution) should be valid. The program predicted narrower bandwidth for an iris on only one side; this is probably a valid conclusion. The final iris diameter was experimentally determined by testing rings of varying diameter which were a snug fit in the waveguide. The frequency for lowest reflection is fairly critical to iris inner diameter; it shifts from 8.2 GHz at .870" I.D. to 8.55 GHz at .880" I.D. The final value of .875" gives $\geq$ 29 dB return loss from 8.0 to 8.8 GHz and $\geq$ 35 dB from 8.15 to 8.5 GHz. With no irises the return loss is a constant 20 dB.

2.3 Polarizer

The polarizer couples left- and right-circular polarization waves in a 1.02" diameter circular waveguide to two SMA coaxial line outputs. It is described in NRAO Specification A53200N1, Rev. A; a summary of the electrical specifications is given below:

Specification	8.0 - 8.8 GHz Requirement	8.2 - 8.6 GHz Requirement
Ellipticity	$\leq$ 0.6 dB	$\leq$ 0.25 dB
Isolation	> 25 dB	> 28 dB
Return Loss	> 19 dB	> 22 dB

A stepped-septum type of polarizer, manufactured by Atlantic Microwave of Bolton, MA, is utilized in the front-end because of its compactness and good electrical characteristics. A prototype version of this polarizer having separate waveguide-to-SMA adaptors was evaluated for ellipticity and return loss. The ellipticity was $\leq$ 0.2 dB from 7.8 to 8.6 GHz and increases sharply to 1.4 dB at 8.8 GHz. Similarly, the return loss is $\geq$ 22 dB from 7.8 to 8.6 GHz, 17 dB at 8.8 GHz, and 6 dB at 9.0 GHz. (The prototype polarizer is tuned ~ 200 MHz too low.)

The ports of the polarizer are identified by noting that the left-circular polarization port is on the left side when looking in the circular waveguide with the septum (fin) on the bottom wall.

The inside finish of the polarizer is not specified. Polishing and plating of the inside surface are both difficult and unnecessary. The theoretical loss of an equal length of aluminum waveguide is .015 dB and, allowing a factor of 3 for poor surface finish, the noise temperature is increased by 0.5K. As for infrared radiation heating, it is futile to try to reflect the 0.24 watts of radiation coming in the 1.02" diameter input waveguide because of the glancing angle and odd shapes within the polarizer.

The polarizer is supported by a folded cylindrical support utilizing G-10 epoxy-glass tubing; see Figure 2.1-1. An aluminum ring at the junction of the two tubes is tied to the 50K refrigerator station. The calculated conduction load is .33 W on the 50K station and .05 W on the 15K station. The G-10 tubes are coated with evaporated gold, 1500 $\pm$ 500 angstroms thick, to reduce thermal radiation coupling.

The gap between the polarizer input flange and dewar top plate is maintained at .016" by the G-10 cylinders; the spacing is accurately set by maintaining a .016" thick shim in the gap as the epoxy adhesive bonding the outer cylinder to the top plate is being cured; a round plug is also inserted in the waveguide during this time to maintain axial alignment. The waveguide gap is surrounded by a choke groove (1.66" I.D., 1.86" O.D., x 0.40" deep) in a 2.50" diameter flange as shown in drawing B53206M012. This flange is part of the prototype polarizer but is a separate part in the final polarizer.

The .016" gap was chosen as a result of previous loss measurements of a 15 GHz rectangular waveguide cavity having a variable gap, surrounded by a choke groove, at a high current point in the waveguide. The loss was determined by Q measurements as a function of gap and was determined to be .02 dB at .012" gap. Scaling these results to 8.4 GHz, the gap loss is estimated to be .013 dB which should increase receiver noise $\leq$ 0.9K.

2.4 Noise Calibration System

The noise calibration components are shown in the block diagram, Figure 1.1-1. A 30 dB coaxial directional-coupler in each input signal line couples in a cal signal (~ 4K), a high cal signal (~ 1500K), and an externally applied phase calibration signal. A coaxial power divider within the dewar splits the common calibration signal to the two receiver channels. The dewar calibration input is through a SMA hermetic feedthru; the coupling from this jack to each receiver input is ~ 35 dB.

The remainder of the calibration components are mounted on the RF component circuit card which also mounts the RF post amplifiers, as shown in Figure 2.4-1. The high cal originates in an avalanche diode noise source having ENR = 35 dB*, is amplified by an ~ 9 dB gain cal amplifier, and feeds through the main line of a 10 dB coupler to the dewar input. With 2 dB of losses the ENR referred to the receiver input is 35 + 9 - 2 - 35 = 7 dB which is ~ 1500° noise temperature. The high cal is turned off by removing +28 volts from the HIGH CAL control line; this supplies the noise source (4 to 10 mA) and, through a 12 volt zener drop, the 30 mA for the high cal amplifier. Note that the cal amplifier must be turned off to prevent ~ 1K of noise from being added to the receiver when the high cal noise source is off.

The normal cal signal originates in a second 35 dB ENR noise source which drives through a 6 dB pad into the main line of a second 10 dB coupler and into the -10 dB port of the first coupler. Allowing 2 dB for losses, the ENR referred to the receiver input is 35 - 6 - 10 - 2 - 35 = -18 dB which is 4.6K. The cal control line must supply +28 volts at 4 to 10 mA.

The temperature and voltage coefficients of the noise sources are specified by the manufacturer, Microwave Semiconductor Corporation, as $\leq$ .01 dB/°C and $\leq$ .1 dB/%; typical coefficients are stated to be a factor of two better than this. According to MSC, a factor of two improvement in temperature coefficient

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*Excess noise temperature = $290 \times 10^{ENR/10}$.

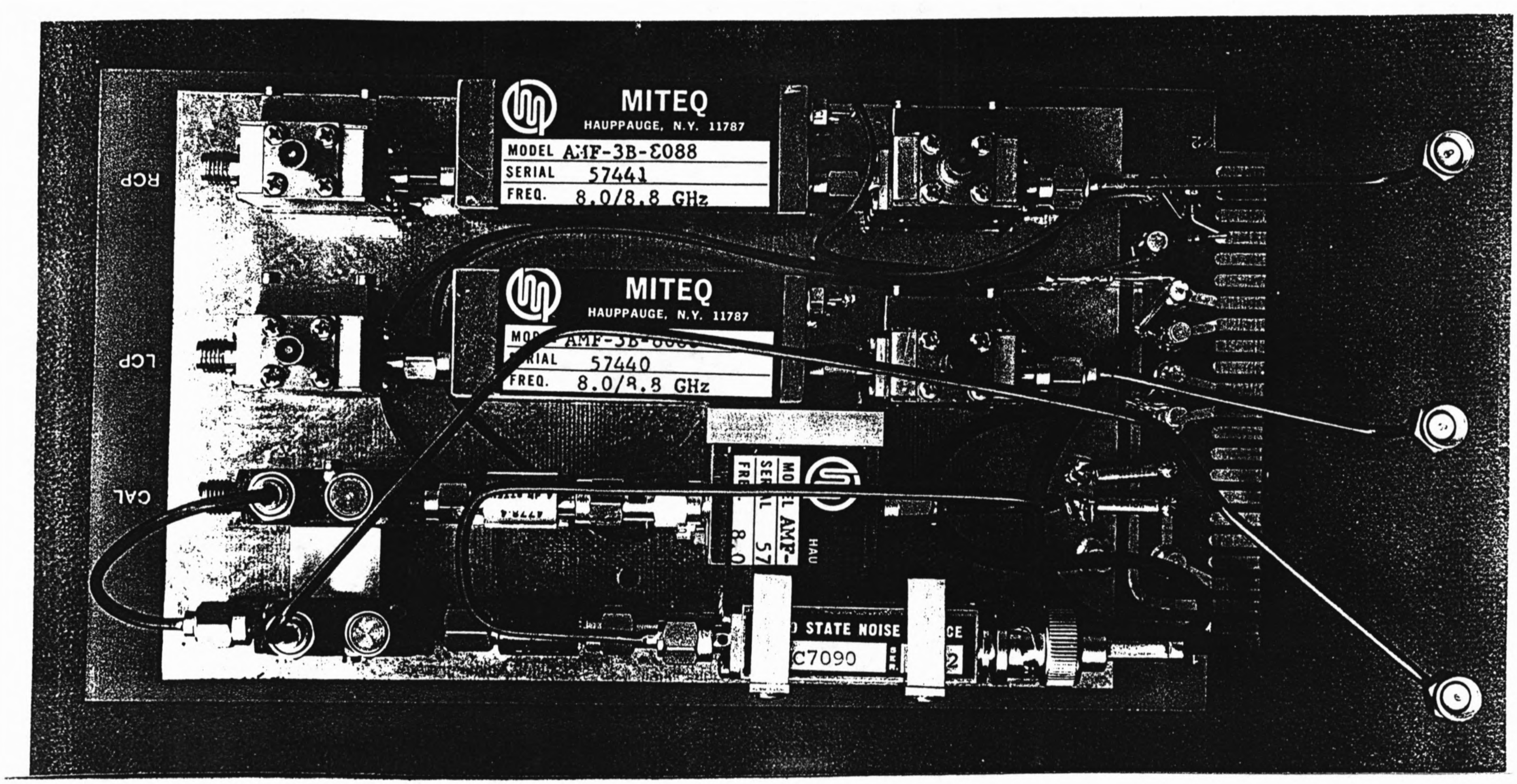


Fig. 2.4-1. Photograph of RF components card showing calibration components and post amplifiers. The ambient temperature sensor is mounted on this card.

can be obtained by driving the source with a constant current. This was not judged to be necessary but could be added at a later date; a supply voltage > +28 volts would be needed, perhaps from a DC/DC converter. This is a more reasonable step for the normal cal than the high cal where the amplifier temperature coefficient will also affect stability and another control line would be needed to turn the amplifier on and off.

2.5 CRYOFET's and Isolators

The 3-stage FET amplifier and cooled input isolator are described in a separate report. A photograph of a 30 dB calibration coupler isolator and amplifier mounted on a dewar cold plate is shown in Figure 2.5-1. The gain and noise temperature of this cascade for a prototype amplifier are shown in Figure 2.5-2; the isolator, coupler and cable have increased the noise temperature by ~ 6K (see Section 1.4.1). The typical power dissipated by each amplifier is 0.19 watts (see heat load budget of Section 1.4.3).

2.6 Dewar Internal Wiring and Coaxial Lines

There are 16 wires between the 300K dewar RFI feedthru plate and components at 15K and 2 more wires to the 50K temperature sensor. To reduce the heat load of these wires, a special brass wire is used. The wire is #32 soft brass (type 260) which gives a factor of 8 lower heat load and higher strength than copper at a sacrifice of 2.3 times greater resistance at 300K. It is coated with polyurethene insulation which can be burned off with a soldering iron and is bonded into a red/green pair with polyvinyl butral which can be dissolved with alcohol. The wire is part number B2322111-001 from MWS Precision Wire in Chatsworth, CA. Within the dewar the wires are cut to a length of 12" and the total heat load for 14 wires (FET bias and 15K temperature sensor) is .03 watts. For the 2 wires to the dewar heater which must pass 0.23 amps, 12" of 7 x #38 stranded copper-clad steel wire (type W-12 manufactured by Microtech, Boothwyn, PA) is

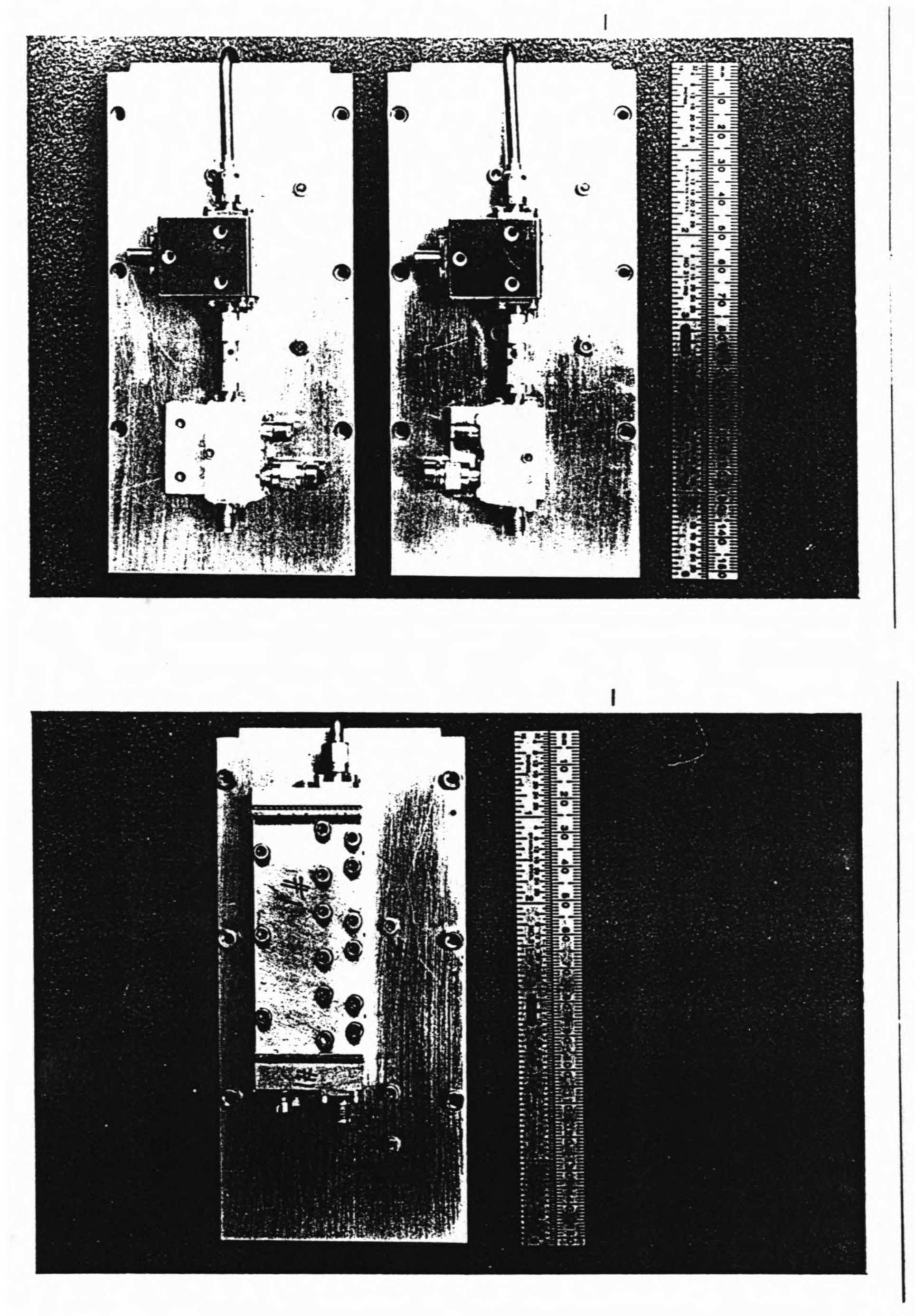


Fig. 2.5-1. Top photograph shows calibration coupler and isolator on LCP and RCP mounting plates; the plates are interchangeable by flipping over the coupler. The bottom photograph shows the CRYOFET on the reverse side of either plate.

```
1)  PLATE #1; OPTIMAL BIAS FOR COLD OPERATION
20:39.5 05/23/84 TAU=34.3 TLO=27.4 @ 8500 GL=28 GH=31.1 T=12.5K
3.48,11.1,-.461  4.02,17.4,-.486  5,17.1,-.667
20:41.0 05/23/84  ZERO=4 ADB=23 TF=15.1 -NDB=5.4
```

F,GHZ	NOISE	GAIN,DB	F,GHZ	NOISE	GAIN,DB
7.8	95.9	26.7	7.9	75.4	31.8
8	57	30.8	8.1	40.3	29
8.2	30.9	29.3	8.3	28	30.6
8.4	27.7	31.1	8.5	27.4	31
8.6	29.2	30.5	8.7	33.9	29.5
8.8	44.8	28	8.9	64.5	25.6

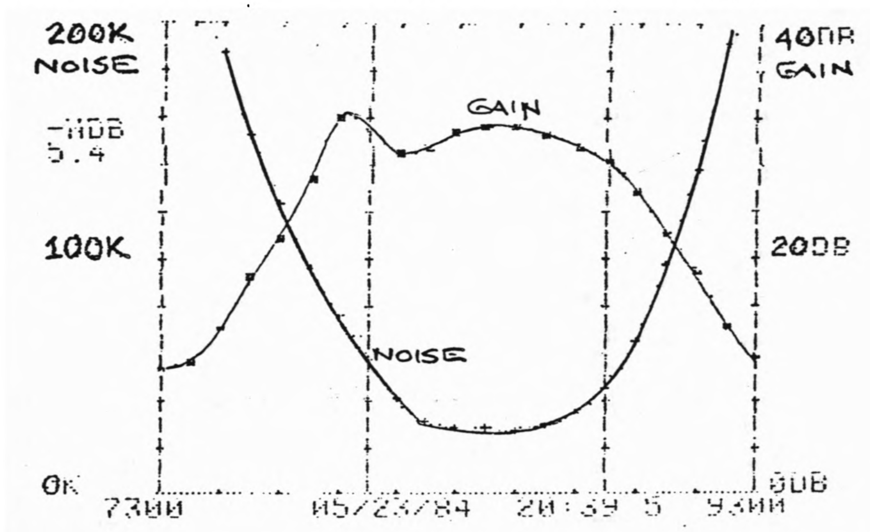


Fig. 2.5-2. Gain and noise temperature of coupler, isolator, and amplifier mounted on the plate shown in Fig. 2.5-1 at a temperature of 15K.

used and gives an additional heat load of .03 watts. The 50K temperature sensor is connected with the brass wire.

The heat flow and attenuation of various types of coaxial cables at cryogenic temperatures are given in NRAO EDIR #223. The coaxial lines from the polarizer to the amplifier plates are fabricated of ~ 3 inch lengths of .141" copper coaxial line, have .075 dB loss at 15K, and have no heat flow since both ends are at the same temperature. The other coaxial lines within the dewar are summarized as follows:

Purpose	Length - Type	Heat Loss, watts	RF Loss
Calibration Input	12" - .085" SS/BC*	.022	-1.3 dB
LCP Output	9" - .085" SS/BC	.030	-0.9 dB
RCP Output	9" - .085" SS/BC	.030	-0.9 dB

*Coaxial cable with stainless-steel outer conductor and silver-plated, beryllium-copper inner conductor.

2.7 Post Amplifier

The recommended post amplifier in the front-end is a three-stage Mitec (Hauppauge, NY) AMF-3B-8088 which has 27 ± 1 dB gain, < 4 dB noise figure, > +10 dBm 1 dB gain compression output power, and ≤ 2:1 input and output VSWR from 8.0 to 8.8 GHz. An alternate two-stage amplifier is the Mitec AMF-2B-8088 with 18 ± 1 dB gain and > +5 dBm 1 dB compression output power. The receiver noise figure to give ≤ 0.3K noise contribution and the CW input signal power which will give < 1 dB gain compression are 24 dB and -44 dBm (3 x 10^6K for 1 GHz bandwidth) for the three-stage amplifier and 15 dB and -39 dBm (10^7K for 1 GHz bandwidth) for the two-stage amplifier (see gain budget, Section 1.4.2). The receiver noise figure must include the contribution of cable loss.

The temperature coefficients of a two-stage Mitec amplifier SN 48143 were meaured as -.015 dB/^{o}C for gain, independent of frequency, and +0.2^{o}/^{o}C at 8.9 GHz and +0.3^{o}/^{o}C at 7.9 GHz for phase. No gain change was noted for DC voltage variation of +10 to +20 volts and the amplifier had no output oscillation for a sliding short applied to the input.

2.8 Sensor Card

The sensor card contains two temperature monitor circuits, A and B, for the 12K and 50K refrigerator stations, and two vacuum monitor circuits, D and P, for the dewar and pump line vacuums. A complete schematic of the card is shown in Figure 2.8-1 and an assembly drawing is shown in Figure 2.8-2. Connections to sensors and the control card are shown in Figure 2.9-1.

Silicon diode temperature sensors, type DT-500KL manufactured by Lake Shore Cryotronics of Westerville, Ohio, are used in the system. The diodes are forward biased with 10 µA and the nominal voltage across the diode as a function of temperature is as follows:

T (k)	V (mV)	dV/dT (mV/K)
13	1949	-38
15	1860	-53
18	1693	-67
50	1053	-2.3
80	978	-2.6
300	369	-2.9

The sensor output is linearized with a modified version of the circuit designed by Balister (NRAO EDIR #204). This circuit approximates the V vs. T curve of the sensor with two straight-line approximations. The gain and offset of the circuit are switched at ~ 27K to give an output of approximately 10 mV/^{o}K. The circuit can be adjusted to give exact agreement with a specified sensor curve at four temperatures. Originally these were 300K, 80K, 15K, and 4K but it is now realized that 300K, 50K, 18K, and 13K are more appropriate for front-ends using 15K

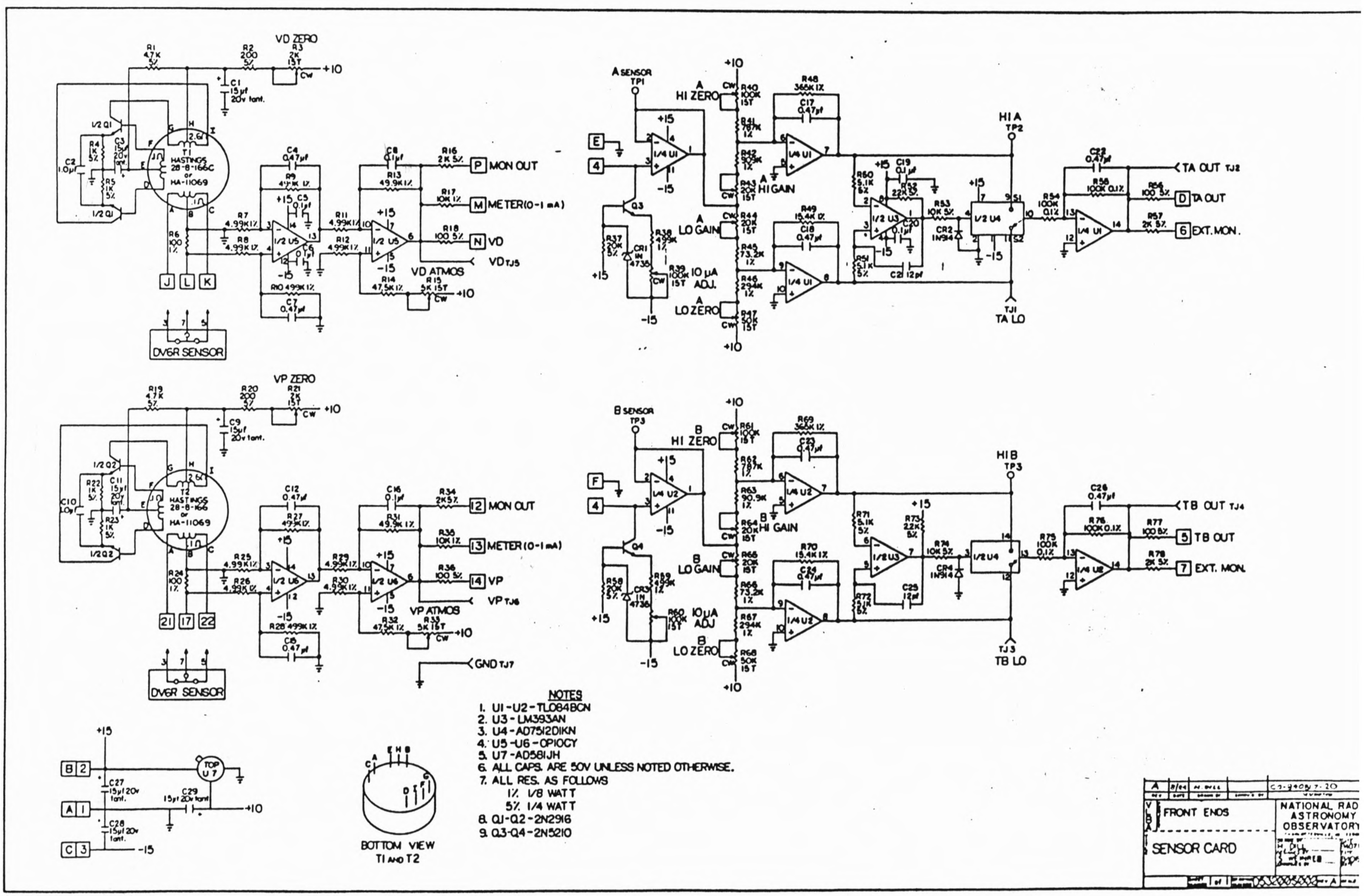

VD ZERO
VP ZERO
MON OUT
METER (0-1 mA)
VD
VD ATMOS
VP
VP ATMOS
DV6R SENSOR
DV6R SENSOR
A SENSOR TP1
B SENSOR TP3
A HI ZERO
A HI GAIN
A LO GAIN
A LO ZERO
B HI ZERO
B HI GAIN
B LO GAIN
B LO ZERO
10 μA ADJ.
HI A TP2
HI B TP3
TA LO
TB LO
TA OUT TJ2
TA OUT
EXT. MON.
TB OUT TJ4
TB OUT
EXT. MON.
GND TJ7
NOTES
1. U1-U2-TL084BCN
2. U3-LM393AN
3. U4-AD7512DIKN
4. U5-U6-OP10CY
5. U7-AD581JH
6. ALL CAPS. ARE 50V UNLESS NOTED OTHERWISE.
7. ALL RES. AS FOLLOWS
1% 1/8 WATT
5% 1/4 WATT
8. Q1-Q2-2N2916
9. Q3-Q4-2N5210
BOTTOM VIEW T1 AND T2
FRONT ENDS
SENSOR CARD
NATIONAL RADIO ASTRONOMY OBSERVATORY

Fig. 2.8-1

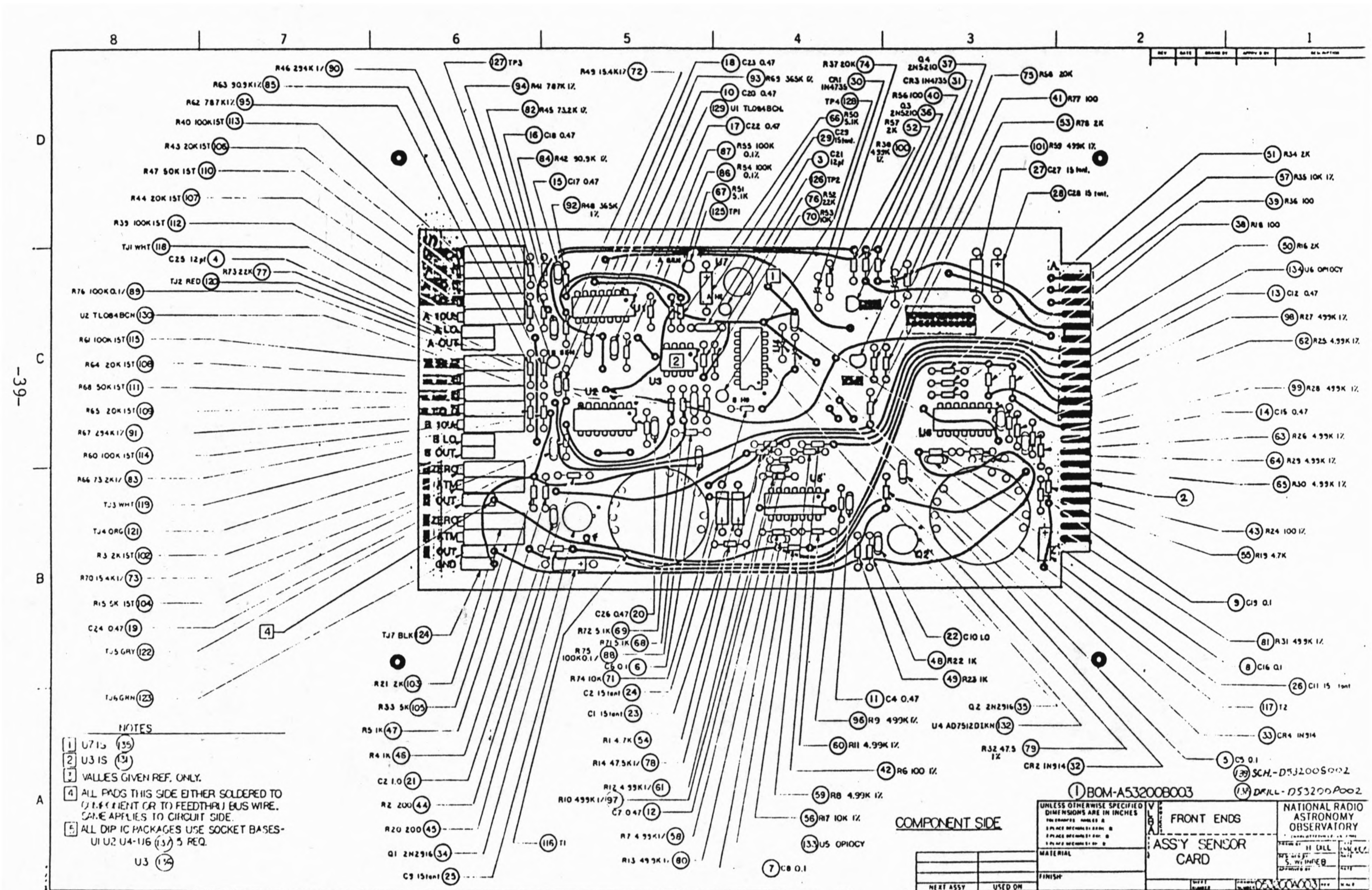


Fig. 2.8-2. Sensor card. The sensor card tester is required for adjustments except for slight touch-up of vacuum ZERO and ATMOS pots.

refrigerators. This change is being incorporated in the Sensor Card Tester which provides output voltages to simulate the sensor at the four temperatures.

The adjustment procedure for the 5 pots in each temperature monitor circuit utilizing the Sensor Card Tester (see Section 3.4) is as follows:

1. Set the DVM switch to T_A.
2. Set the MODE switch to A-10 μA and adjust the A-10 μA pot for a reading of 1000 on the tester DVM.
3. Set the MODE switch to T_A/T_B and the TEMP switch to SHORT and adjust the A HI Z pot for 4350 mV on the tester DVM. Adjust the A LO Z pot for 445, on the A-LO test point read with an external DVM.
4. Set the TEMP switch at 50 and adjust the A HI G pot for 500 on the tester DVM.
5. Set the TEMP switch at 300 and re-adjust the A HI Z pot for 3000 on the tester DVM. Repeat 4 and 5 until 500 and 3000 readings are obtained.
6. Set the TEMP switch at 13 and adjust the A LO G pot for 130 on the tester DVM.
7. Set the TEMP switch at 18 and re-adjust the A LO Z pot for 180 on the tester DVM. Repeat 6 and 7 until 130 and 180 readings are obtained.
8. Repeat 1 thru 7 for B circuit.

The vacuum sensors are thermocouple type DV-6R manufactured by Teledyne-Hastings of Hampton, Virginia. Two thermocouples, one in vacuum and one in atmosphere, are heated by an 8 mW, 3.7 kHz square wave. The lower thermal conductivity in the vacuum causes that thermocouple to rise in temperature (300 C at high vacuum) and a DC output voltage, 10 mV at high vacuum, is produced by the two thermocouples in series. The 10 mV is amplified and offset so the circuit produces 0 ± 200 mV output in high vacuum and 10,000 ± 50 mV output at atmospheric pressure. A calibration curve is given in Figure 2.8-3; at high vacuum the output is 161 mV per μm pressure.

The 3.7 kHz square-wave is generated in a saturating-transformer circuit similar to that used by Hastings. The high vacuum zero of the sensor circuit is critical to the oscillator power (approximately 1 μm change for 1.5% power change) and is adjusted by varying the oscillator power. The zero stability is dominated by the transformer temperature coefficient. One transformer gave 1 μm drift for 2°C temperature change where 5 other transformers from the same and different lots gave 1 μm drift for 20°C temperature change. Another test of the entire system showed 1 μm drift for 5°C temperature change. At this time the stability appears to be adequate since the vacuum control system is not effected by vacuum changes $<$ 3 μm; however, future tests may warrant a redesign of the oscillator circuit.

Each vacuum sensor circuit has two pots, ZERO and ATMOS, which are adjusted using the Sensor Card Tester. The ZERO pot is adjusted to give an output voltage of 161 mV times the reading in μm (typically 2 or 3 printed on the side of the DB-20 reference tube) with the V_D/V_P toggle switch in the position of the circuit under adjustment. The toggle switch is then set at the opposite position and the ATMOS pot is adjusted for an output voltage of 10,230 mV (in this position an open circuit is presented in place of the sensor and an output slightly above atmospheric pressure is simulated.) The DVM switch is set to V_D or V_P dependent on which circuit is being adjusted.

2.9 Control Card

The control card accepts as input 2 control bits and analog signals representing dewar temperature, T_D, dewar vacuum, V_D, and pump vacuum, V_P. The outputs of the card are contact closures to control refrigerator motor power, heater power, and the vacuum solenoid-operated valve, a vacuum pump request logic level, P,

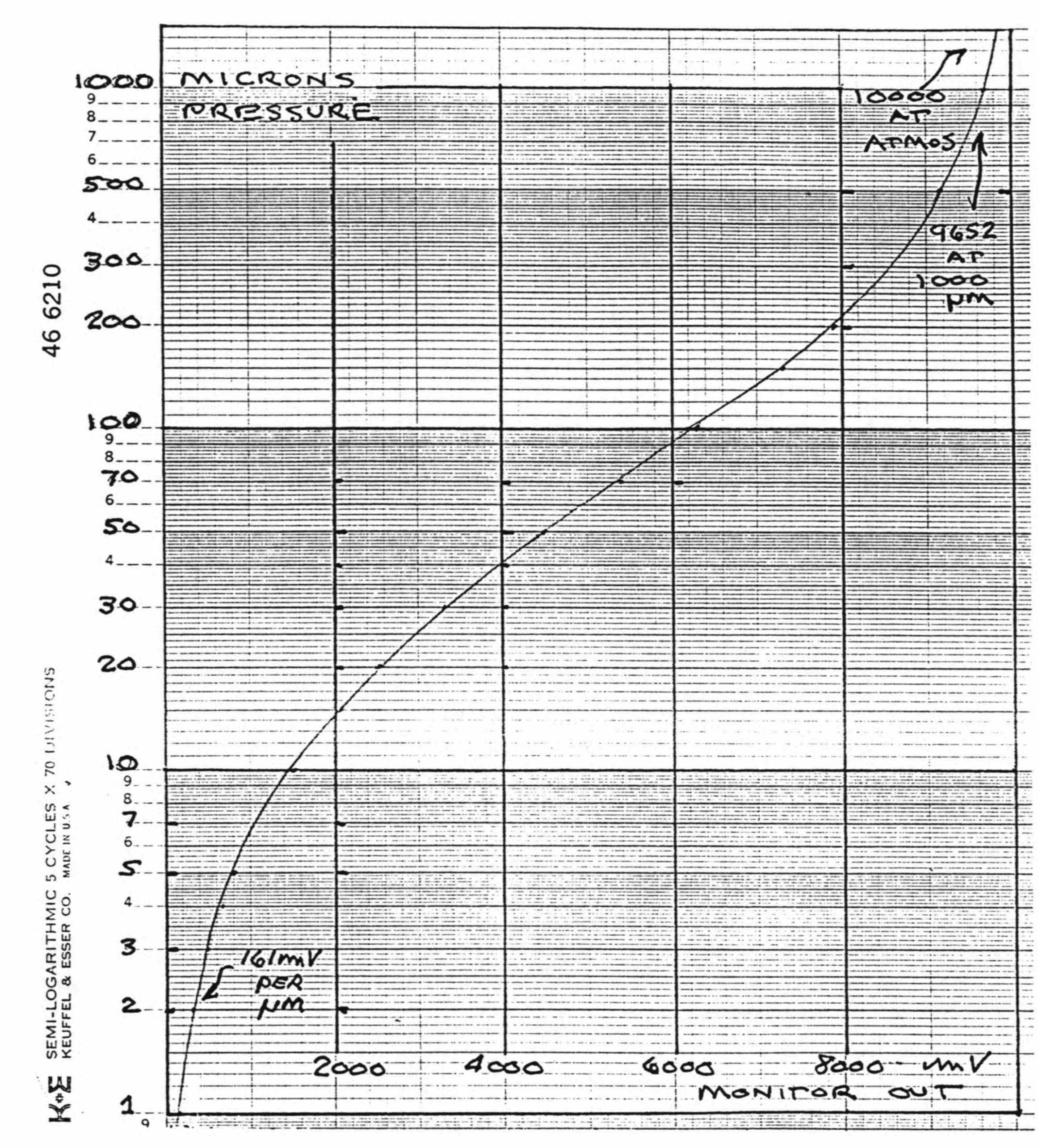


Fig. 2.8-3. Vacuum pressure as a function of monitor output voltage.

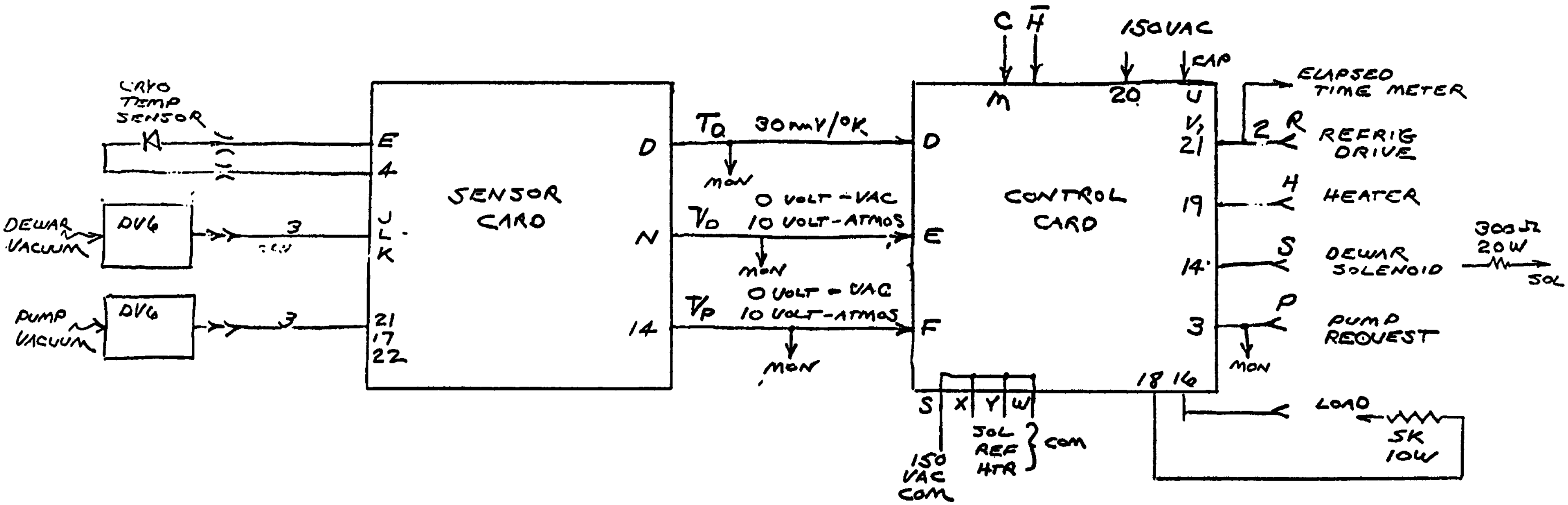
and a monitor logic level, S, which indicates whether the solenoid valve is open. A block diagram showing the connections to the control card and the logic equations for its functions is given in Figure 2.9-1; a schematic is shown in Figure 2.9-2 and an assembly drawing in Figure 2.9-3. There is no memory or adjustment pots on the control card. In words the function of the control system is as follows:

The refrigerator power is applied if COOL mode ($C = 1$, $\bar{\bar{H}} = 1$) or STRESS mode ($C = 0$, $\bar{\bar{H}} = 0$) is selected and the dewar vacuum is < 1000 μm ($V_D < 9.6$ volts). If STRESS mode is selected, a 0.5 watt heat load is also applied to the cold station but is turned off if the dewar temperature is > 360K.

The pump request logic level, P, becomes a 1 if any mode except OFF is requested and the dewar vacuum becomes > 5 μm (800 mV on V_D); the request becomes 0 if OFF is selected or if the dewar vacuum becomes < 3 μm (480 mV on V_D).

The solenoid valve opens if any mode except OFF is requested and <u>either</u> the vacuum is > 1000 μm and dewar temperature is > 280K <u>or</u> the vacuum is > 7 μm (V_D > 1000 mV) and pump vacuum is < dewar vacuum and dewar temperature is > 30K. The solenoid valve is closed if AC power is removed or if OFF mode is selected.

The Control Card Tester allows T_D, V_D, and V_P inputs to the control card to be varied from 0 to 10 volts with linear 10 turn dials. Outputs are indicated with LED indicators. The card is tested by varying the inputs and observing that outputs change in accordance with the previous two paragraphs. As an intermediate check the input comparators circuits can be checked by observing test points T_1, T_2, T_3, V_1, V_2, V_3, and V_4 as the variables are changed. The switching levels for the comparators are indicated on the schematic. Each comparator has a controlled amount of hysteresis in its switch level to prevent oscillation near the trip point.



CONTROL STATES

C	$\bar{H}$	ACTION
1	1	COOL, PUMP IF REQUIRED
0	0	AS ABOVE + 1/2W HEAT LOAD
1	0	HEAT, PUMP IF REQUIRED
0	1	NO COOL, HEAT, OR PUMP

VARIABLE DEFINITIONS

R=1 REFRIG PWR ON

X=1 HEATER PWR ON

S=1 SOLENOID PWR ON, DEWAR VALVE OPEN

P=1 TURN ON VAC PUMP MANIFOLD VALVE OPEN

W=1 1/2 WATT HEATER ON

CONTROL LOGIC

$R = [C \cdot \bar{H} + \bar{C} \cdot H](V_D < 1000)$

$X = C \cdot H \cdot (T_D < 360K)$

$S = (C + \bar{C} \cdot H) \cdot [(V_D > 7\mu)(V_P < V_D)(T_D > 30\mu) + (V_D > 1000)(T > 2$

$P = (C + \bar{C} \cdot H) \cdot (V_D > 3\mu)$

$W' = \bar{C} \cdot H \cdot (T_D < 360K)$

Fig. 2.9-1. Block diagram and logic definition of dewar control.

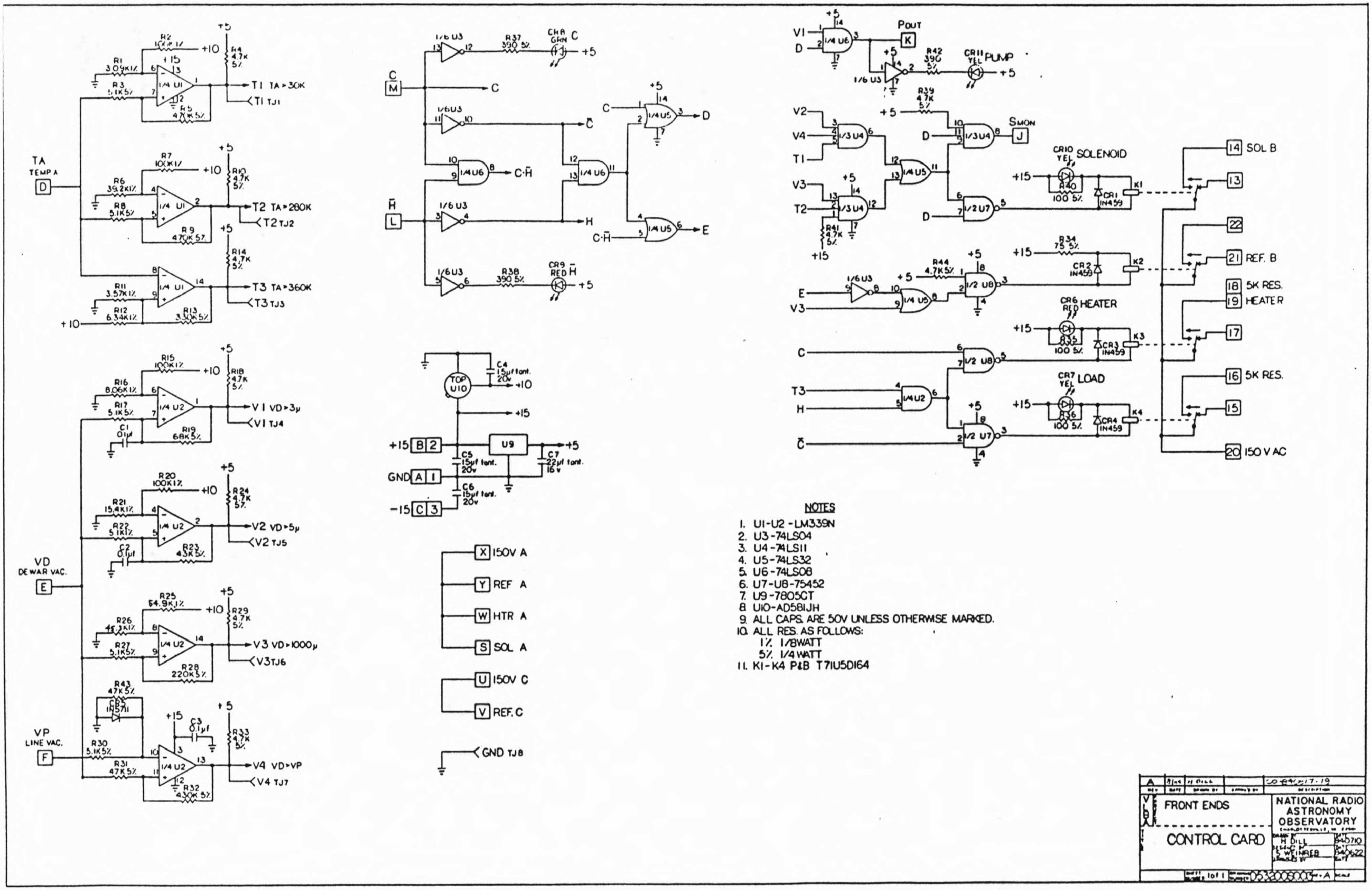

NOTES
1. U1-U2 - LM339N
2. U3-74LS04
3. U4-74LS11
4. U5-74LS32
5. U6-74LS08
6. U7-U8-75452
7. U9-7805CT
8. U10-AD581JH
9. ALL CAPS. ARE 50V UNLESS OTHERWISE MARKED.
10. ALL RES. AS FOLLOWS:
1% 1/8WATT
5% 1/4WATT
11. K1-K4 P&B T71U5D164
FRONT ENDS
CONTROL CARD
NATIONAL RADIO ASTRONOMY OBSERVATORY
TA TEMP A
VD DEWAR VAC.
VP LINE VAC.
SOL B
REF. B
5K RES.
HEATER
150 V AC
SOLENOID
PUMP
LOAD
150V A
REF A
HTR A
SOL A
150V C
REF. C
GND TJ8

Fig. 2.9-2

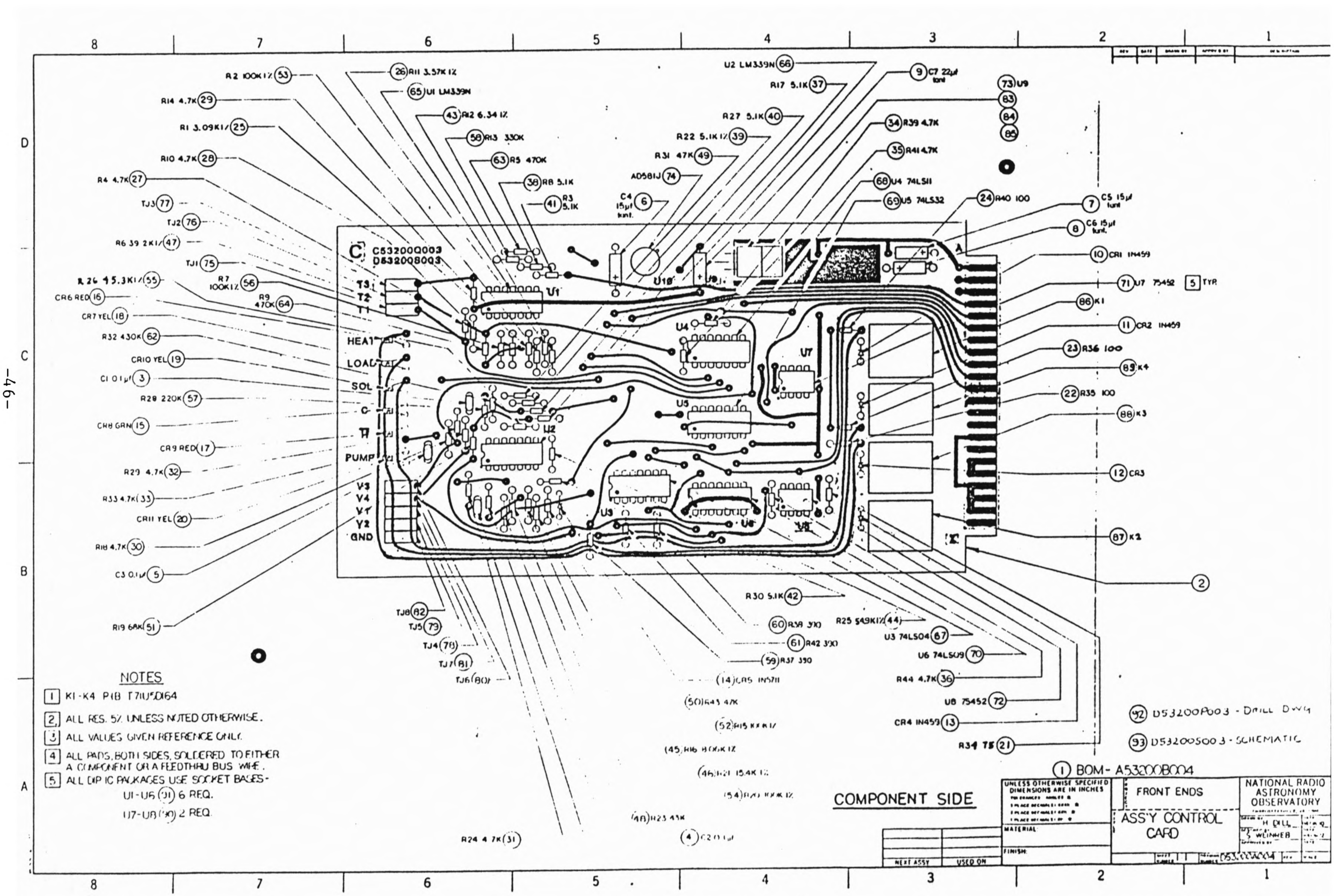

NOTES
1 K1-K4 P/B T71U5D164
2 ALL RES. 5% UNLESS NOTED OTHERWISE.
3 ALL VALUES GIVEN REFERENCE ONLY.
4 ALL PADS, BOTH SIDES, SOLDERED TO EITHER A COMPONENT OR A FEEDTHRU BUS WIRE.
5 ALL DIP IC PACKAGES USE SOCKET BASES-
U1-U6 (91) 6 REQ.
U7-U8 (90) 2 REQ.
C532000003
D532008003
HEAT
LOAD
SOL
PUMP
GND
COMPONENT SIDE
(1) BOM- A53200B004
(92) D53200P003 - DRILL DWG
(93) D53200S003 - SCHEMATIC
FRONT ENDS
ASS'Y CONTROL CARD
NATIONAL RADIO ASTRONOMY OBSERVATORY
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
MATERIAL
FINISH
NEXT ASSY
USED ON

Fig. 2.9-3

2.10 Bias Card

A schematic and an assembly drawing of a bias card are shown in Figures 2.10-1 and -2. There are two bias cards per system, one for the LCP channel and one for the RCP channel, with four circuits per card. Only 3 of the circuits, for a 3-stage amplifier, are used in the 8.4 GHz system.

Each circuit has a drain voltage, V_d, and drain current, I_d, adjustment pots accessible from the front of the card. The circuit controls the GASFET gate voltage, V_g, to maintain the desired drain current. The gate voltage is monitored by a card-edge test point and also thru the remote monitor system whereas V_d and I_d can be monitored only at the card edge; the I_d monitor gives .1 volt per mA of drain current.

The optimum bias point (V_d, I_d) for each stage of the GASFET amplifier is determined during the testing of each amplifer. These values along with the resulting V_g are recorded on the data sheet for each amplifier and normally the V_d and I_d pots are set to these values. In order to allow replacement of a bias card without adjustment, all new or spare cards will be adjusted for V_d = 4 volts and I_d = 10 mA (1 volt on monitor); these values should give a functioning GASFET until the optimum settings can be made.

The normal range of V_g is between 0 and -1 volts. The value is a function of temperature with a typical change of 100 to 300 mV from 300K to 15K. At 15K the value should be within $\pm$ 20 mV of the data sheet value. An open in the drain circuit will result in ~ +14 volts at V_g. (Forward gate current will be limited to 7 mA by series resistors.) A short in the drain or gate circuit will cause V_g to become ~ -14 volts. (The actual gate voltage will be limited to ~ -5 volts by the 1N821 protection diode.)

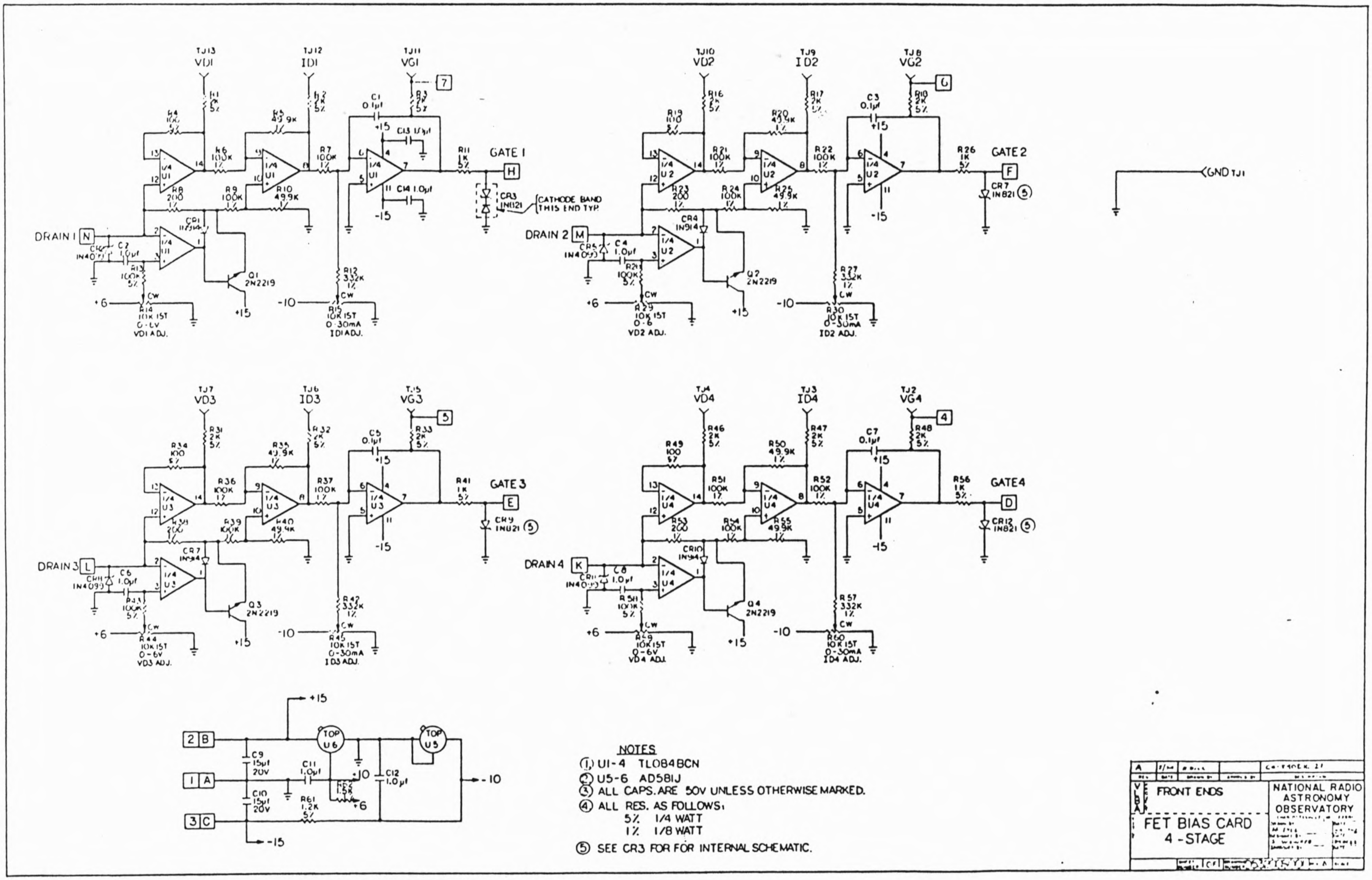


Fig. 2.10-1. Schematic of FET bias card. Each of the four bias circuits has two pots and three test jacks accessible from the front card edge.

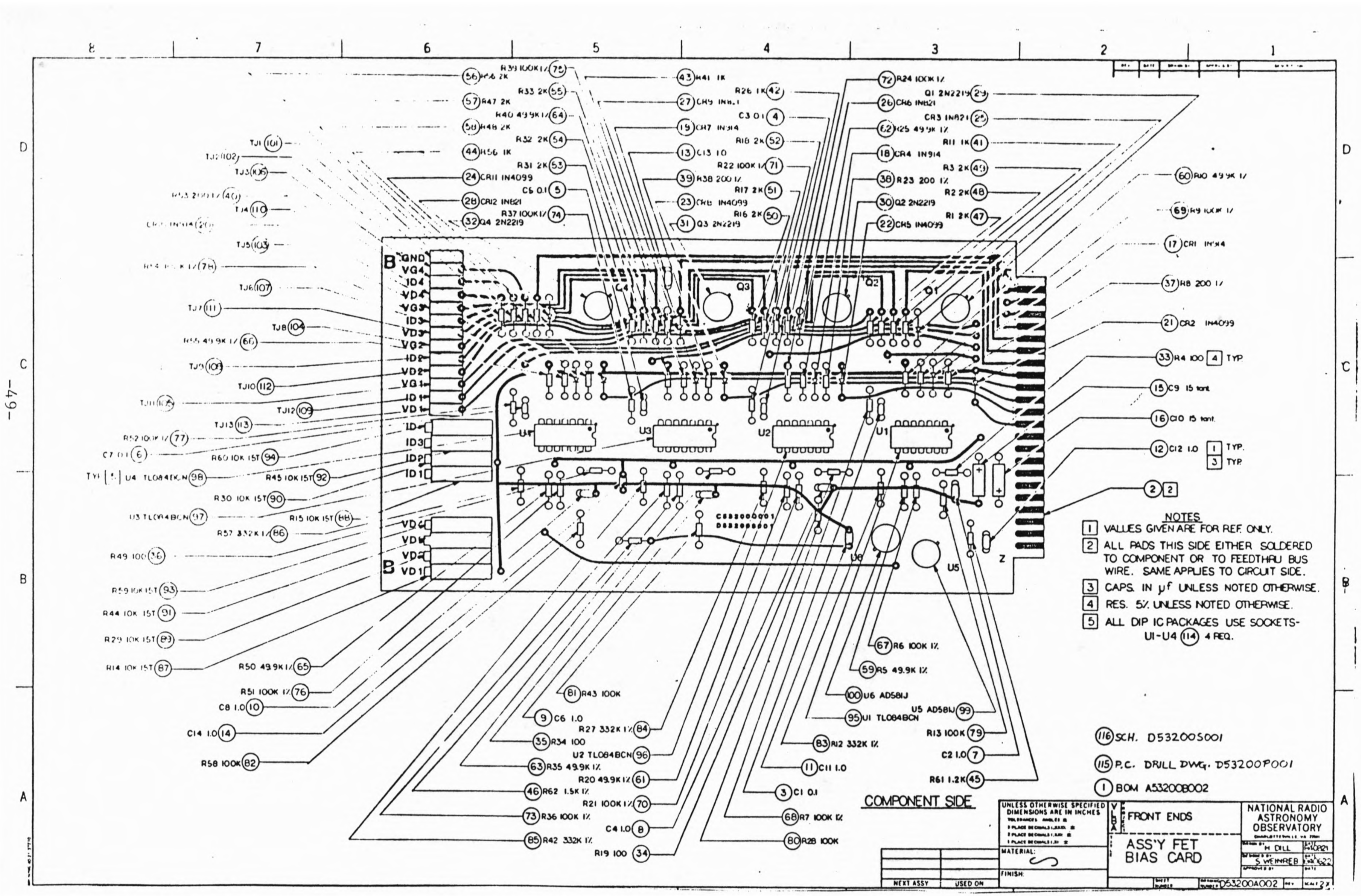


Fig. 2.10-2. Bias card. The V_d and I_d pots are set to values specified for each amplifier stage while monitoring V_d and I_d test jacks. Default values are 4 volts and 10 mA (1 volt on I_d test jack).

Section 3. TEST COMPONENTS AND CIRCUITS

In this section accessories required to test the front-end are briefly described.

3.1 Circular to Rectangular Waveguide Transition

A very well matched 1.020" circular-waveguide to WR112 rectangular waveguide transition is needed to measure window return loss and polarizer axial ratio and return loss. The window return loss is measured with a 10 dB high-directivity waveguide coupler followed by the transition, window, and a circular-waveguide lossy-spear sliding load. The polarizer return loss is measured with the same waveguide coupler followed by the transition, a septum (described next), the polarizer, and two well-matched coaxial-terminations on the polarizer. The receiver return-loss is measured in a similar manner with a window and gap preceding the polarizer and the receiver channels replacing the coaxial terminations.

Polarizer axial ratio can be measured either for the polarizer alone or for the operating receiver. A transmission path is set up consisting of sweep generator, coaxial isolator, well-matched coax-to-waveguide adaptor, transition, septum, polarizer, and well-matched coaxial detector on either port of the polarizer; the other port is terminated. Multiple-exposure photographs of the 7.4 to 9.4 Ghz transmission loss @ 0.5 dB/division are then taken as the septum-polarizer joint is rotated 180° in 45° steps.

A suitable transition was the Model H30-C purchased from Microwave Research Corp. of N. Andover, MA. The unit had 35 dB return loss from 8.0 to 8.8 Ghz when received and was improved to > 40 dB return loss by adding some small tuning screws as shown in the Figure 3.1-1 photograph.

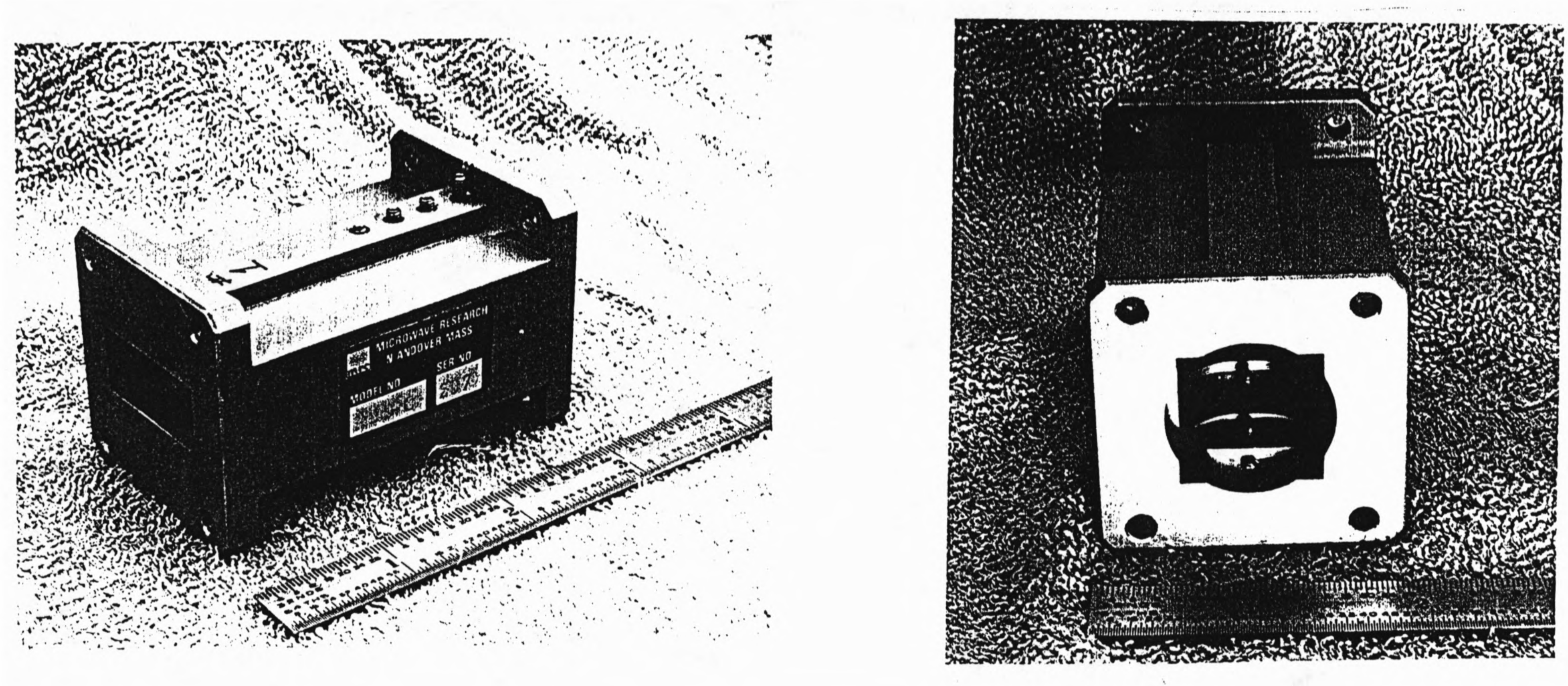


Fig. 3.1-1. WR112 rectangular waveguide to 1.02" I.D. circular waveguide adaptor. The unit has > 40 dB return loss from 8.0 to 8.8 GHz.

3.2 Septum

The septum terminates one linear mode in the circular waveguide and passes the orthogonal linear mode with little loss. It is fabricated by carefully gluing a .032" thick fibre-glass card having a 200 ohm/square resistance film (Solitron Microwave) shaped as shown in Figure 3.2-2 in a 4.84" long section of circular guide; the completed device is shown in Figure 3.2-1. A $\geq$ 37 dB return loss and $\leq$ 0.2 dB orthogonal mode loss is achieved from 8.0 to 8.8 Ghz.

3.3 300K and 77K Circular Waveguide Terminations

A sliding-spear load which terminates both orthogonal linear or circular modes with $\geq$ 35 dB return loss from 8.0 to 8.8 Ghz is shown disassembled in Figure 3.3-1. Best results were obtained with a pyramidal spear, .4" square base by 5.5" long, removed from an HP H910A rectangular waveguide termination; the composition of the spear is unknown.

A liquid nitrogen cooled noise-temperature standard was constructed to facilitate accurate receiver noise temperature measurements and also allow calibration of the system noise sources; photographs of this standard are shown in Figure 3.3-2. The standard utilizes four tapered, 4.5" long, lossy vanes, spaced 90°, and epoxied into grooves in an electro-formed copper 1.02" I.D. waveguide. The vanes are cut from .02" thick crystalline quartz (for high thermal conductivity) and are coated with Inconel to a resistance of 300 $\pm$ 50 ohms/square. The copper waveguide is attached to a spherical liquid-nitrogen tank and is enclosed in a 4" O.D. cylindrical vacuum jacket. The waveguide is supported by a fibre-glass cylinder and utilizes a gapped thermal transition and mylar window similar to that used in the receiver dewar.

The cooled termination has a return loss $\geq$ 30 dB from 8.0 to 8.8 Ghz including window reflections. The termination's physical temperature is measured with a calibrated platinum resistance temperature sensor; the typical measured temperature

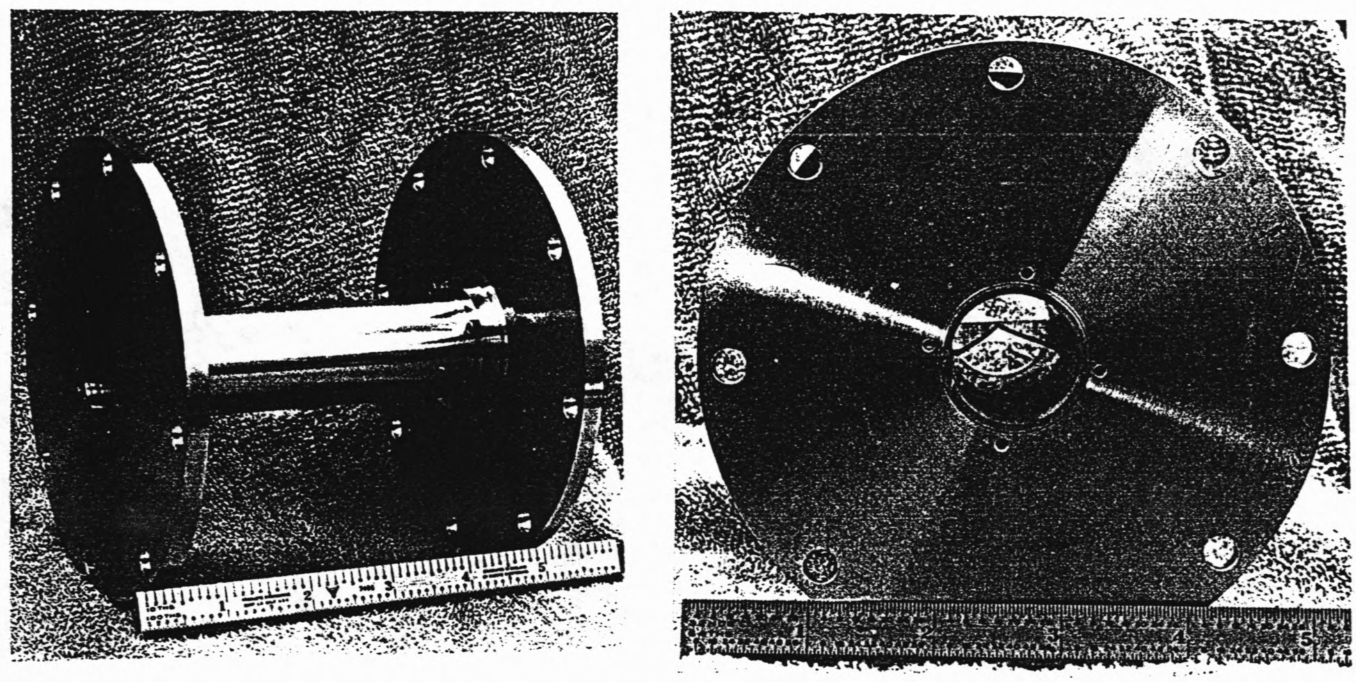


Fig. 3.2-1. Septum. This device terminates one linear polarization with > 37 dB return loss and passes the orthogonal mode with < 0.2 dB loss.

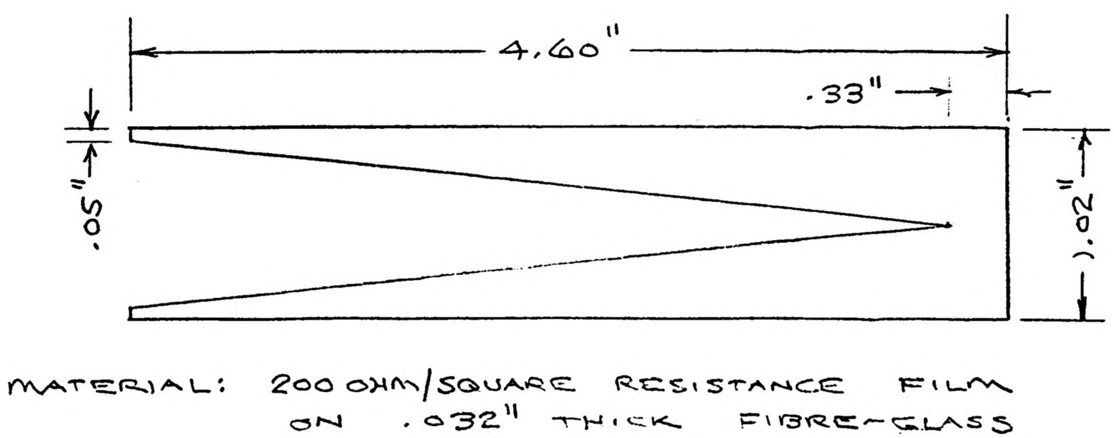


Fig. 3.2-2. Layout of vane in septum.

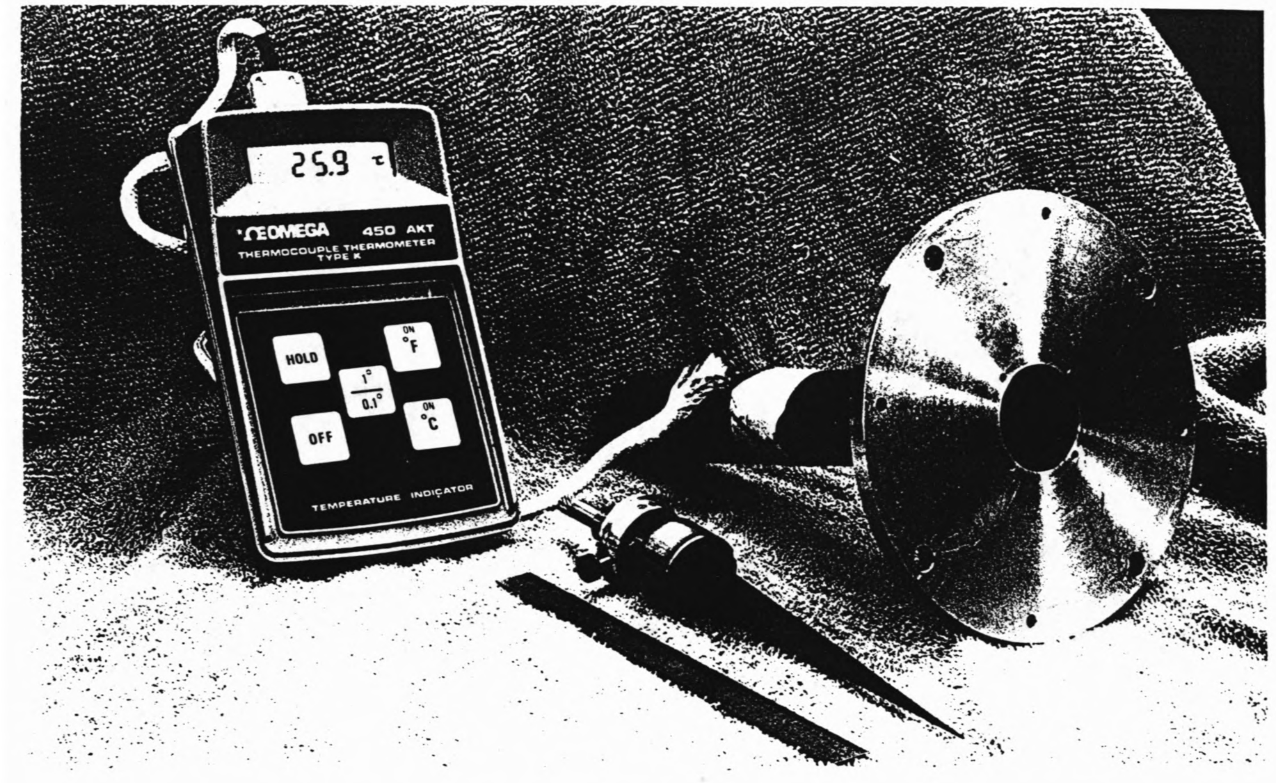


Fig. 3.3-1. Hot sliding termination with absorbing spear removed and temperature readout.

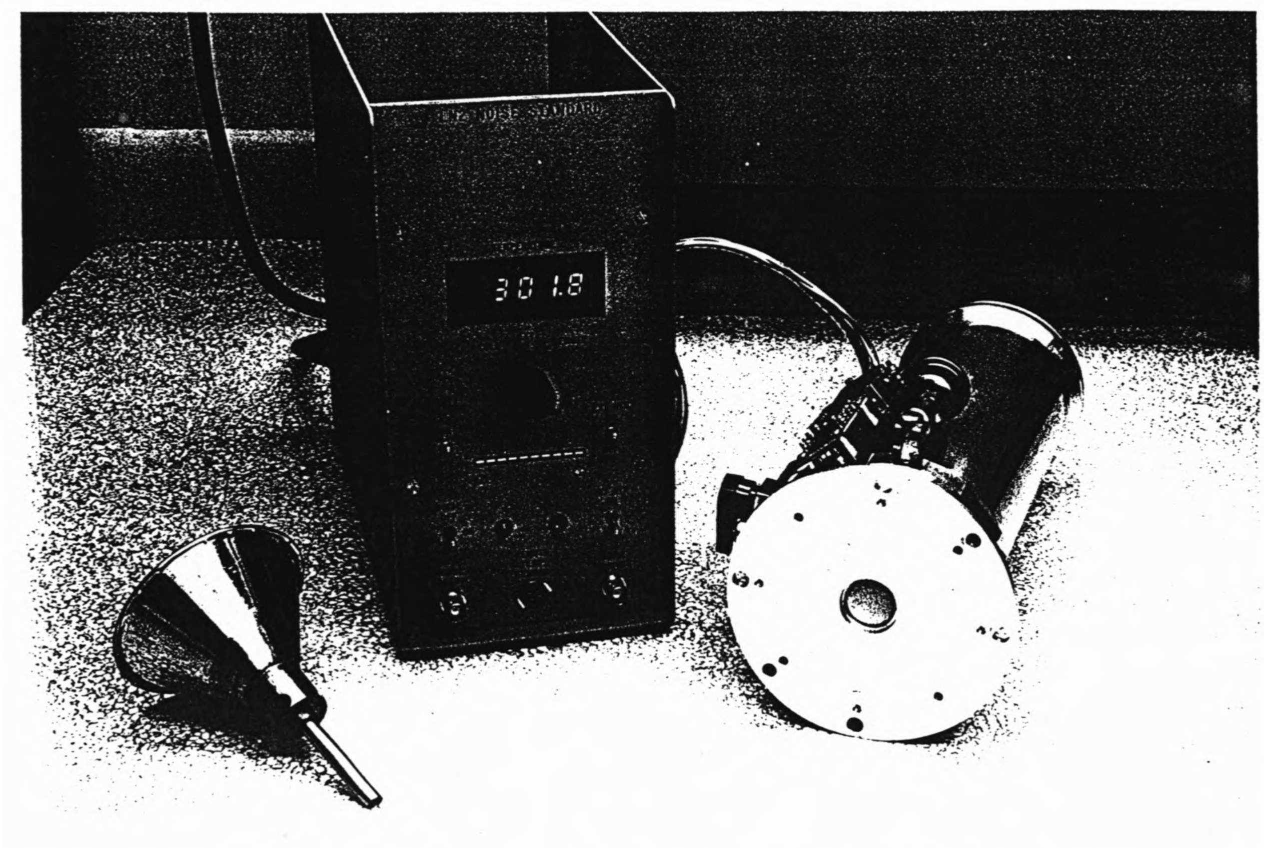


Fig. 3.3-2. Liquid nitrogen termination with control unit and funnel for pouring of LN_2.

is 78.6K. The noise temperature of the termination is assumed to be 0.58K higher than this (.08K from window, 0.5K from gap).

3.4 Sensor Card Tester

A photograph and schematic diagram of the sensor card tester are shown in Figures 3.4-1 and 3.4-2. The tester simulates vacuum and temperature sensors and includes a digital voltmeter to read the four outputs (T_A, T_B, V_D, V_P) of a sensor card. Internal pots are adjusted to give outputs equal to that of a Lake Shore Cryotronics DT-500KL sensor at temperatures of 300K, 50K, 18K, and 13K. A Hastings DB-20 reference tube is used to simulate the output of a Hastings DV-6R vacuum sensor at a low pressure which is printed on the DB-20 label. Adjustment of a sensor card utilizing the tester is described in Section 2.9.

3.5 Control Card Tester

A photograph and schematic diagram of the control card tester are shown in Figures 3.5-1 and 3.5-2. The tester supplies three dial-variable voltages in the 0 to +10 volt range to simulate the T_D, V_D, and V_P inputs to a control card. Control bits are switch selectable and the card outputs are indicated with LED's. Testing of a control card is described in Section 2.9.

3.6 Bias Card Tester

A photograph and schematic diagram of the bias card tester are shown in Figure 3.6-1. The tester contains four inexpensive FET's which exercise the feedback current control circuits within the bias card. A meter to monitor the gate bias voltages is provided.

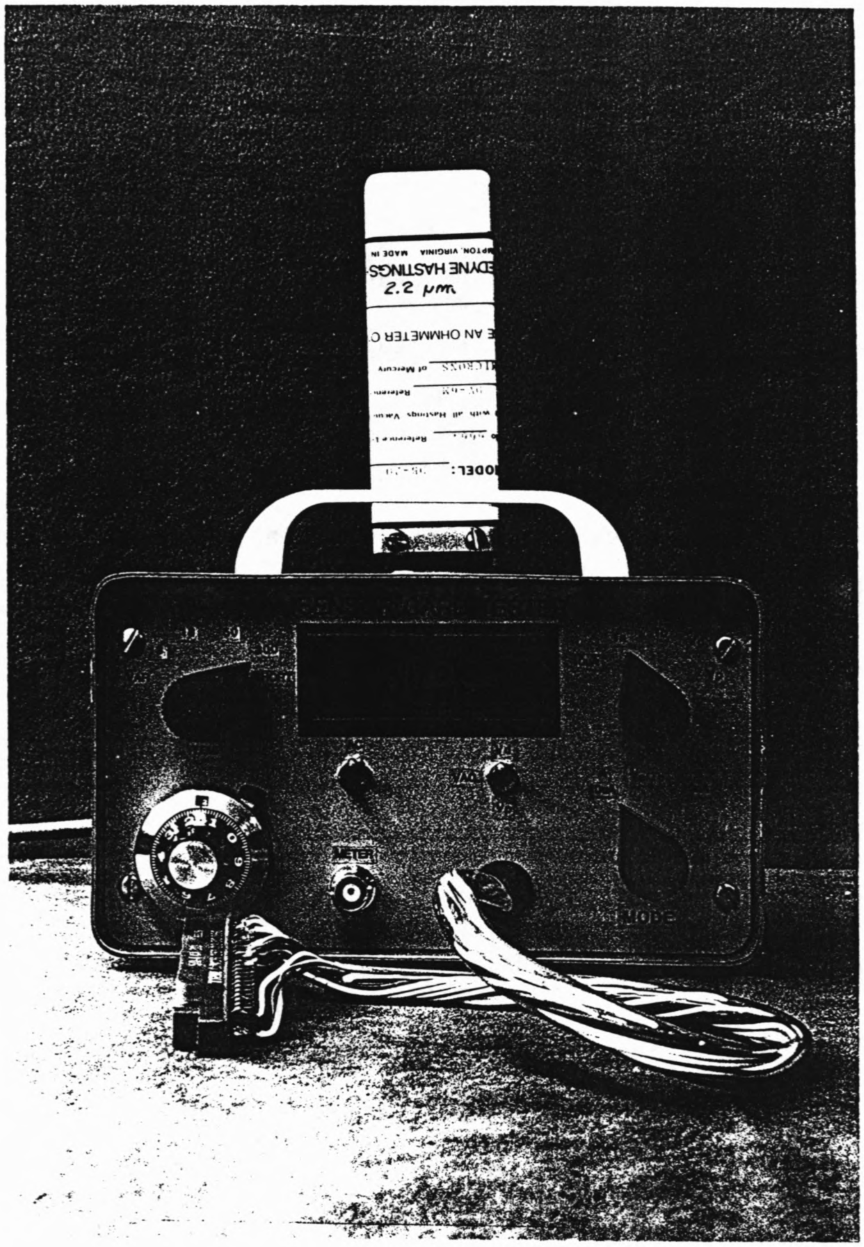


Fig. 3.4-1. Sensor card tester. The plug-in unit on top simulates a vacuum sensor at high vacuum. Sensors can be tested by plugging into this socket.

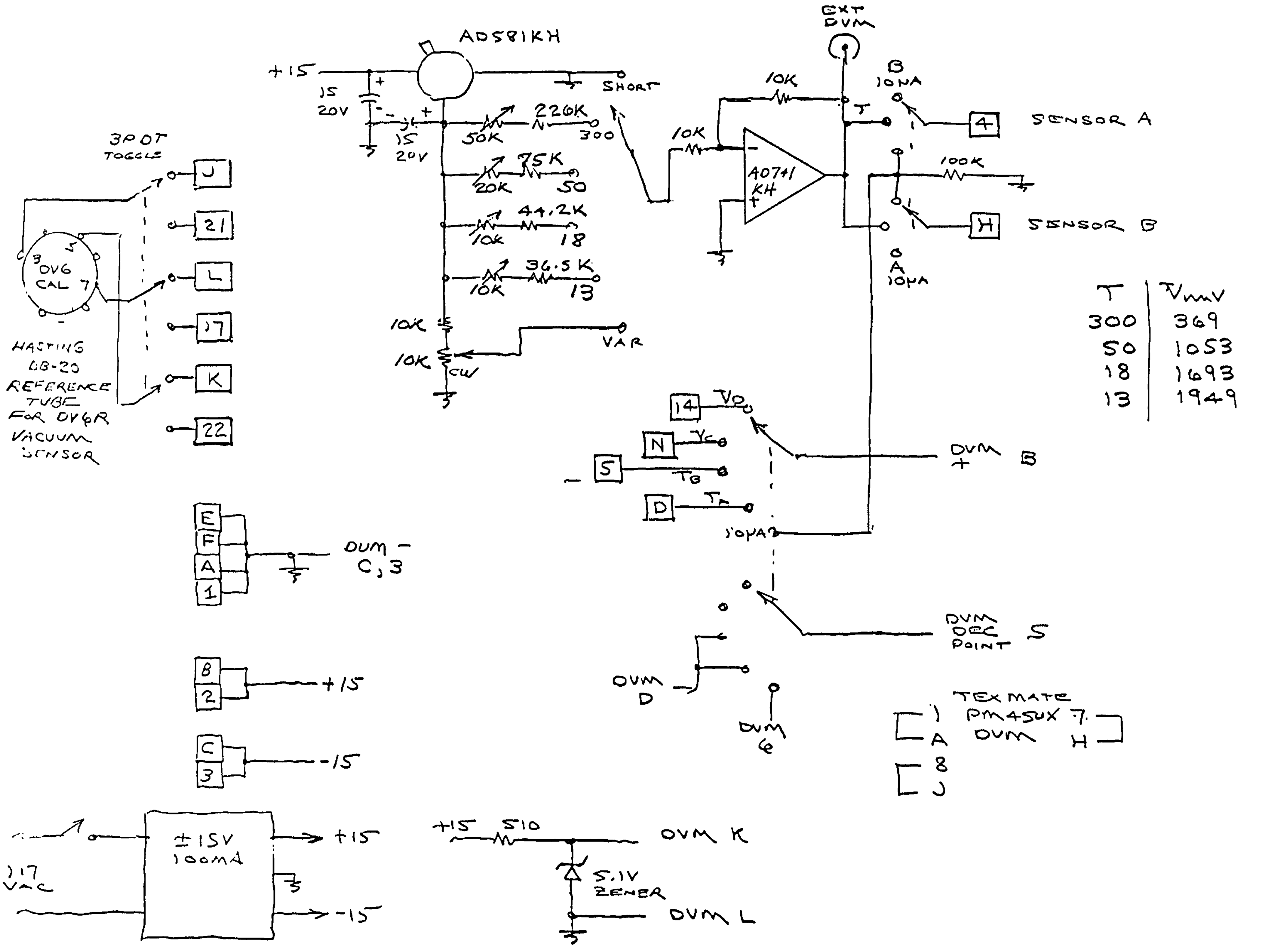


Fig. 3.4-2. Schematic of sensor card tester.

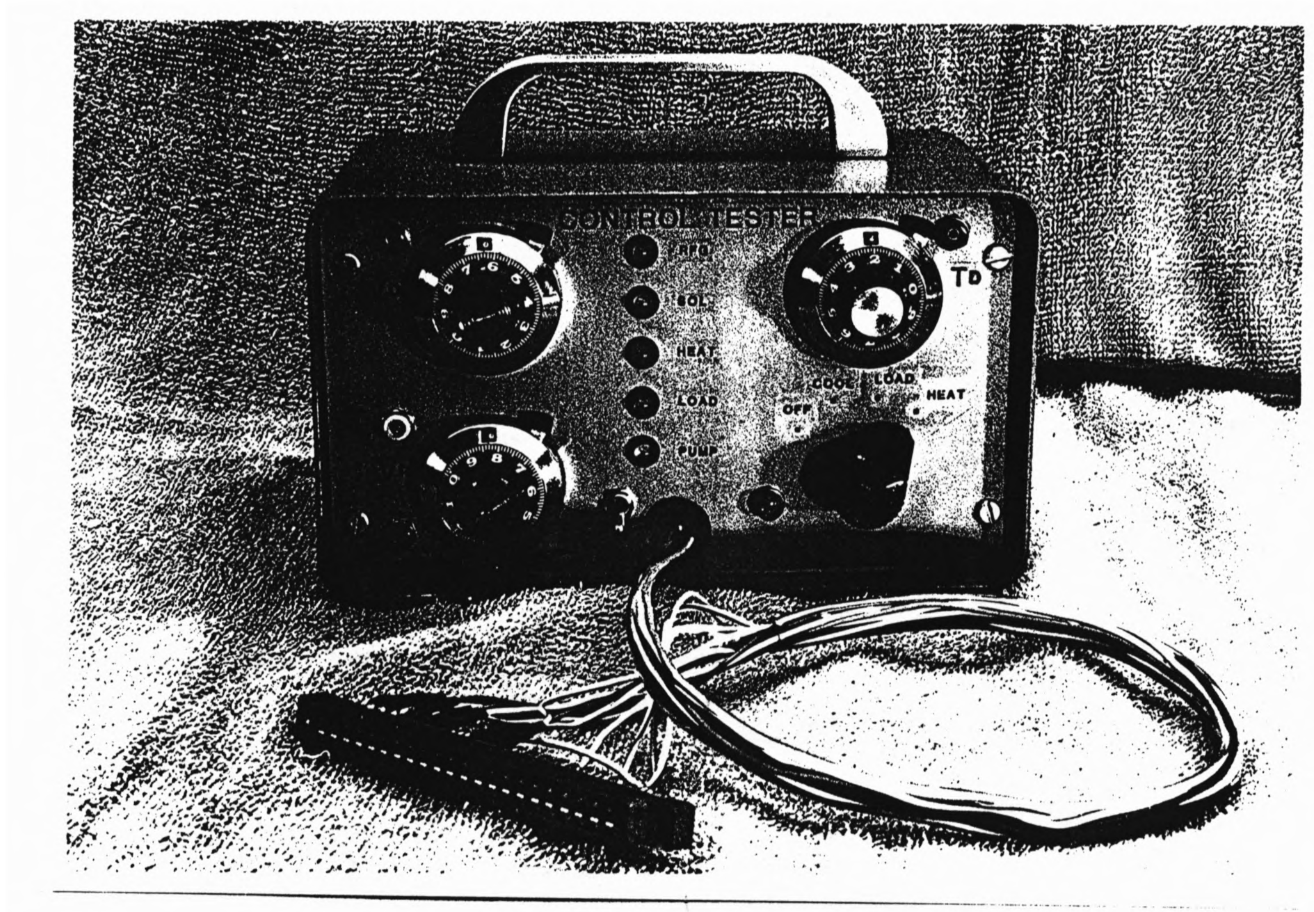


Fig. 3.5-1. Control card tester. The pots simulate control signals into the card and the LED's indicate output contact closures.

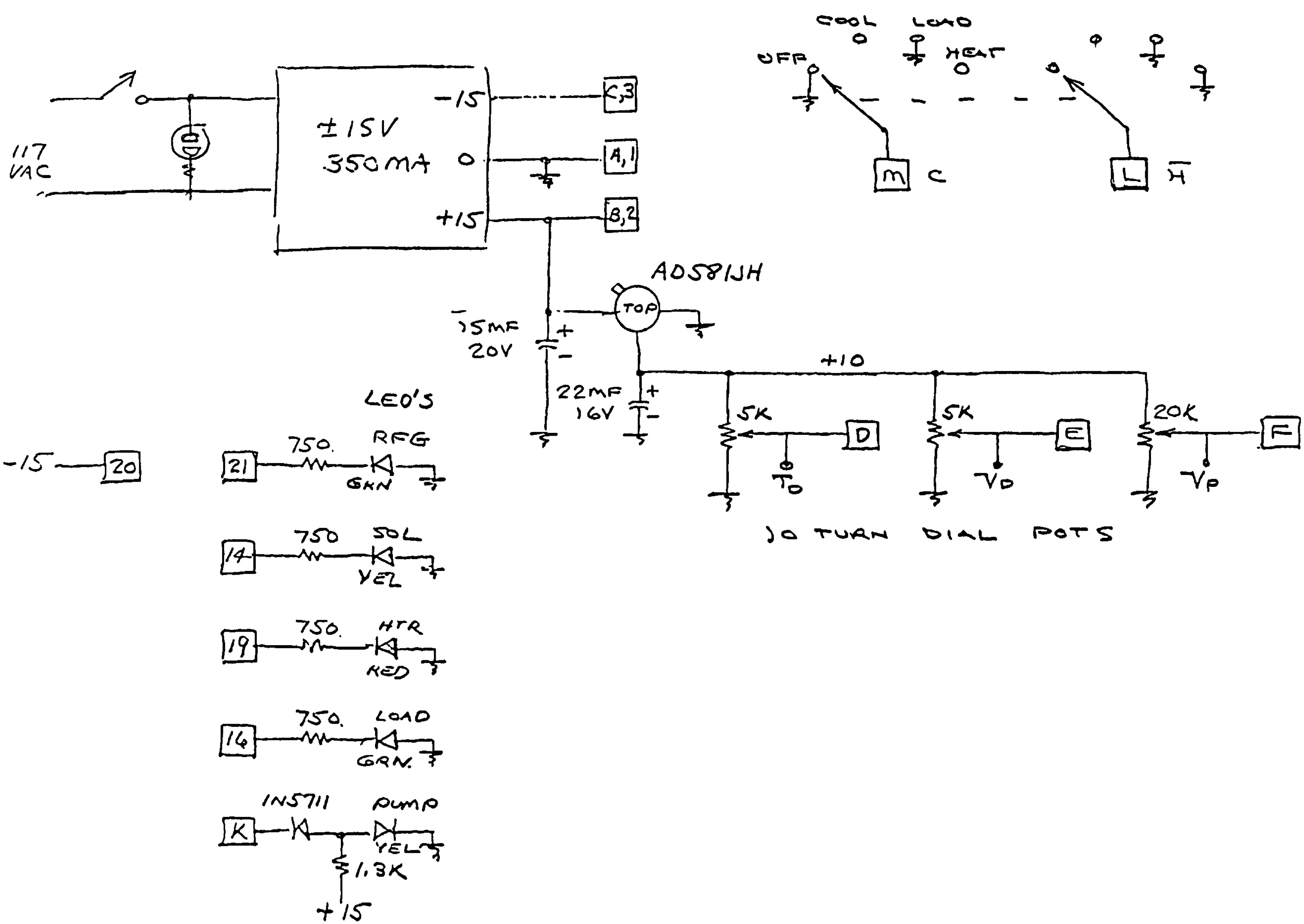


Fig. 3.5-2. Schematic of control card tester.

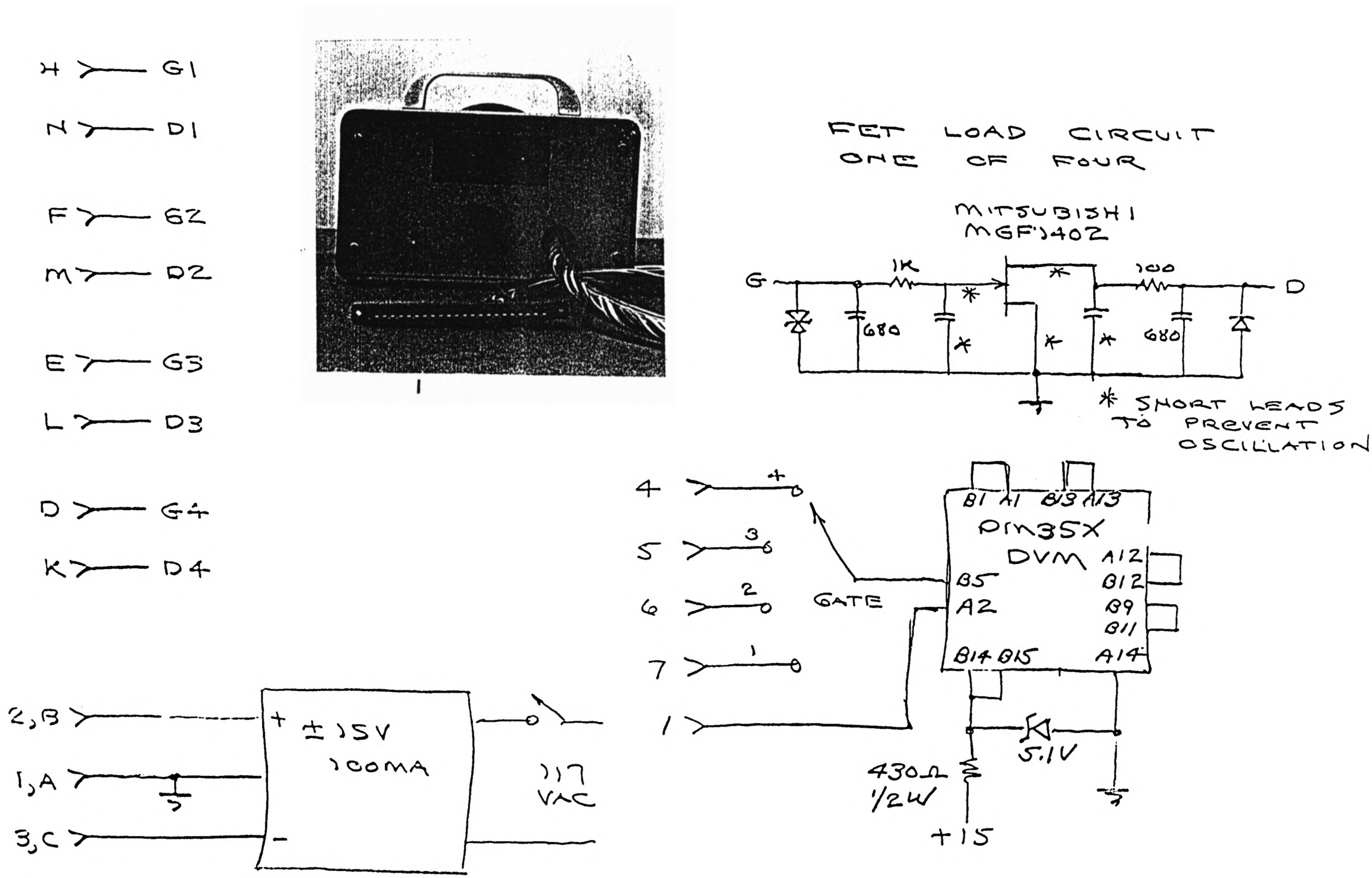
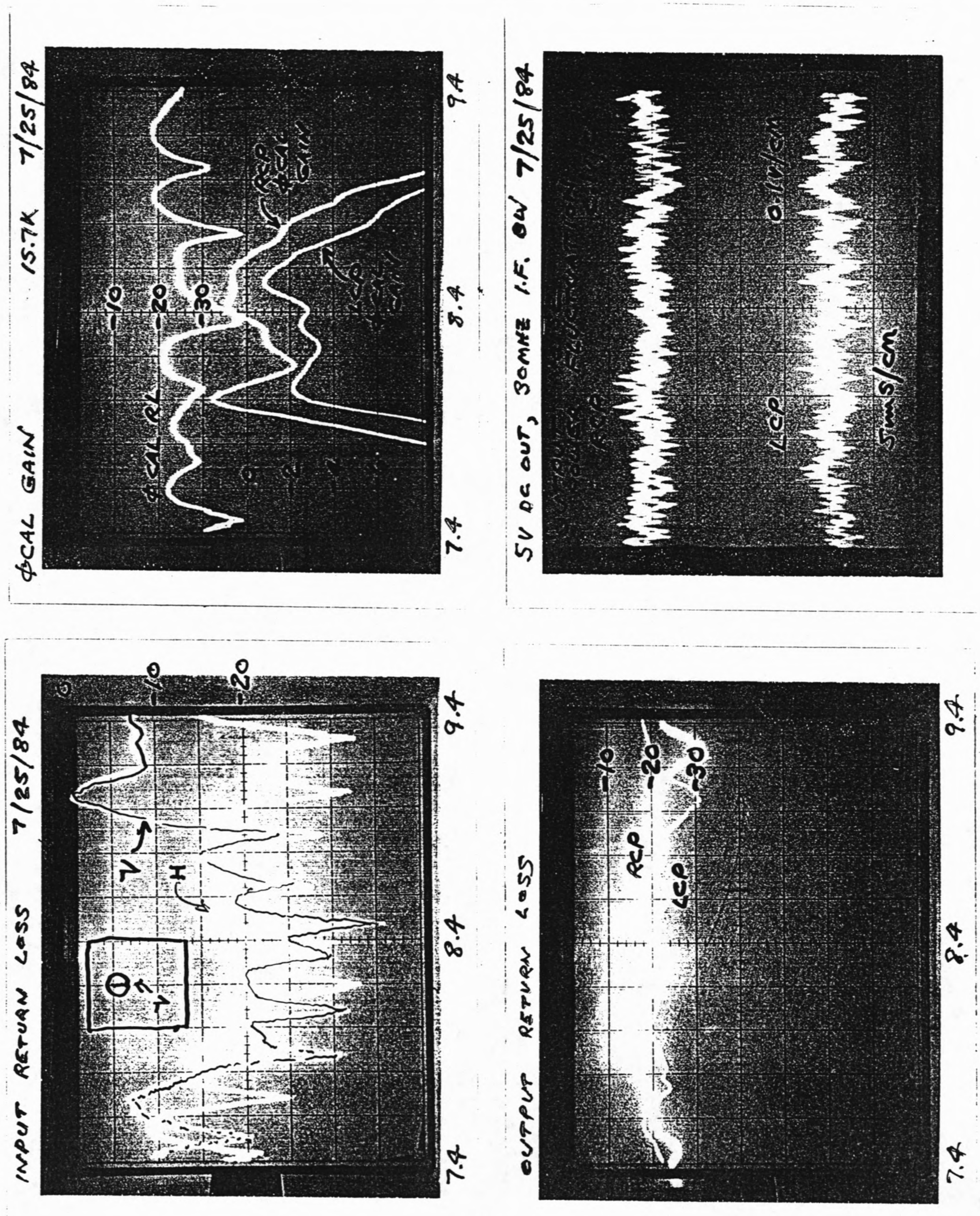


Fig. 3.6-1. Photograph and schematic of bias card tester.

APPENDIX I - RECEIVER TEST DATA

Front-End S/N: 1 Date: 7/25/84

By: S. Weinreb Remarks: May have test set errors



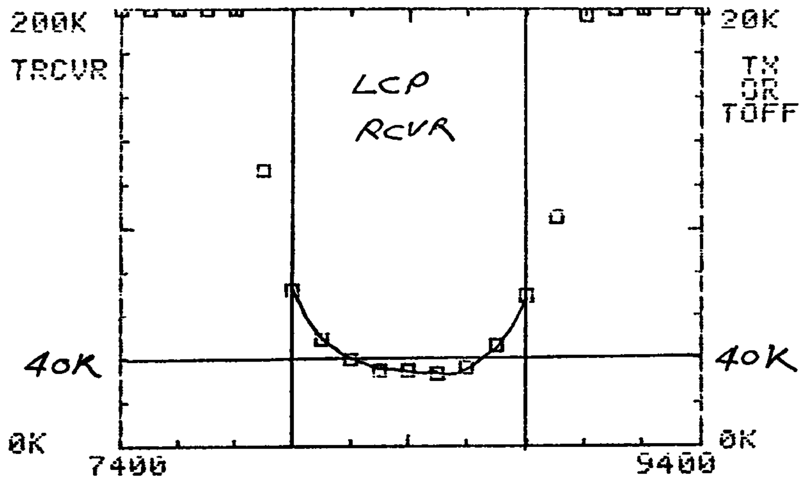
FET BIAS SETTINGS

Stage	LCP V_D	LCP I_D	LCP V_G 300K	LCP V_G 15K	RCP V_D	RCP I_D	RCP V_G 300K	RCP V_G 15K
1	2.99	8.18	- .817	- .875	3.48	11.22	-.465	-.463
2	4.02	17.44	-1.005	-1.042	4.00	17.53	-.443	-.448
3	5.20	19.73	-0.464	- .626	5.18	17.24	-.486	-.654

TOTAL RF POWER OUT INTO 1.4 GHz BANDWIDTH AS MEASURED WITH HP436/8484A POWER METER

Input Condition	15K LCP dBm	15K RCP dBm	300K LCP dBm	300K RCP dBm
302K Load	-29.95	-30.05		
79.7K Load	-34.22	-34.49		
Short	-36.86	-37.39	-32.32	-32.32
Short + Cal	-36.64	-37.12	-32.31	-32.30
Short + HI Cal	-25.10	-24.75	-28.60	-28.28

13:59.8 '08/04/84 THOT=304.8 TCOLD=80 LCP, LN2 P=0, -.871,-1.037,-.623



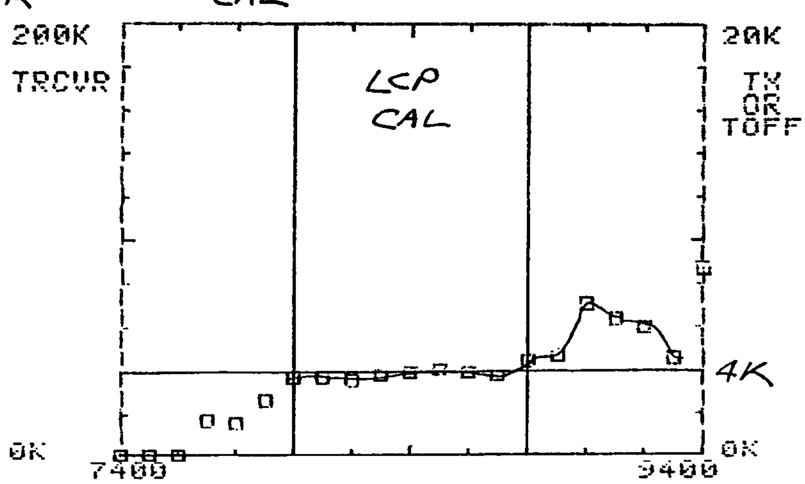
14:05.7 08/04/84 THOT=304.8 TCOLD=80 LCP CAL WITH 6DB PAD

+30 VOLT CAL DRIVE

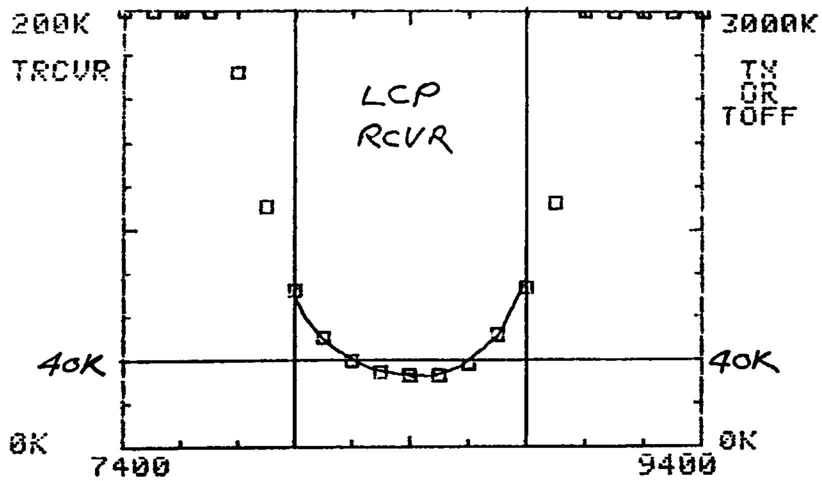
F,MHZ	TRCVR	TOFF	TX	NDB	GAIN
7400	560.8	85.1	0.0	-60.00	0.01
7500	475.5	82.7	0.0	-60.00	0.02
7600	391.4	80.9	0.0	-60.00	0.04
7700	284.2	79.2	1.7	-22.34	0.13
7800	205.1	79.1	1.6	-22.58	0.52
7900	126.4	79.3	2.6	-20.42	2.94
8000	70.9	79.9	3.7	-18.93	5.18
8100	48.4	80.0	3.7	-18.99	4.44
8200	39.8	79.9	3.6	-19.10	3.77
8300	34.2	79.8	3.9	-18.77	4.52
8400	34.1	79.8	3.9	-18.70	4.33
8500	32.8	79.8	4.1	-18.46	5.27
8600	35.1	79.9	3.9	-18.72	3.92
8700	46.5	79.9	3.9	-18.77	2.42
8800	69.1	79.9	4.4	-18.17	1.29
8900	104.6	80.0	4.8	-17.83	0.78
9000	197.0	80.6	6.9	-16.21	0.27
9100	250.0	80.6	6.3	-16.60	0.11
9200	304.0	81.0	5.9	-16.91	0.06
9300	441.9	82.8	4.6	-18.00	0.03
9400	696.1	84.3	8.6	-15.30	0.01

↑ LCP RCVR

↑ LCP CAL



14:09.1 08/04/84 THOT=305.2 TCOLD=79.8 LCP

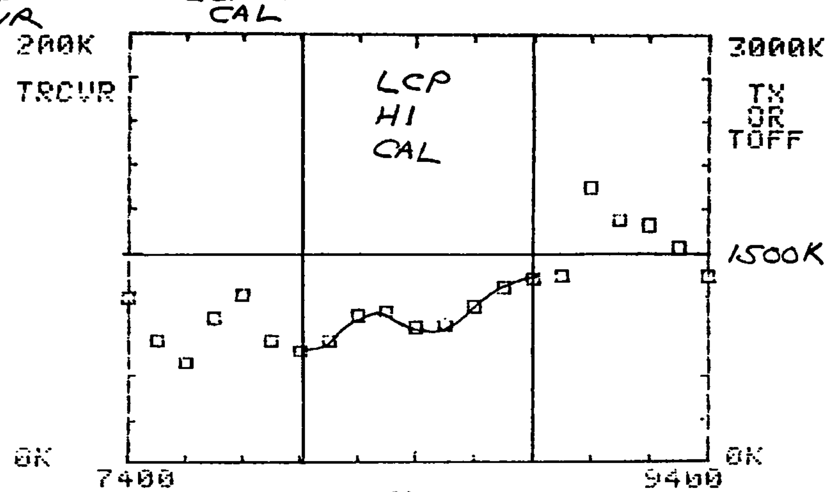


14:28.1 08/04/84 THOT=305.2 TCOLD=79.8 LCP HI CAL, -.461,-.445,-.651

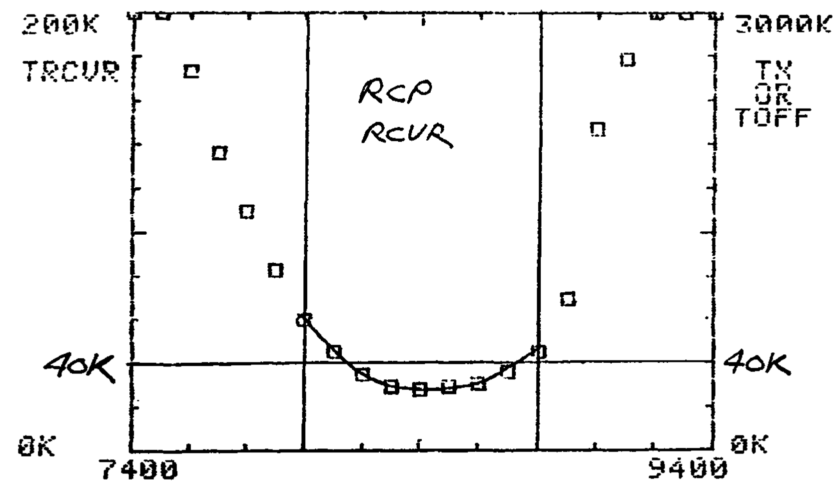
+30 VOLT CAL DRIVE

F,MHZ	TRCVR	TOFF	TX	NDB	GAIN
7400	528.3	68.3	1176.9	6.08	0.01
7500	457.8	70.4	866.6	4.75	0.02
7600	347.5	74.5	686.1	3.74	0.05
7700	245.2	75.9	1027.3	5.49	0.15
7800	170.7	76.7	1180.1	6.09	0.60
7900	110.2	78.4	868.0	4.76	3.20
8000	72.0	79.8	783.5	4.32	5.11
8100	50.4	80.0	868.9	4.77	4.34
8200	39.7	79.7	1046.5	5.57	3.76
8300	34.1	79.7	1070.1	5.67	4.51
8400	33.0	79.5	972.3	5.25	4.35
8500	33.2	79.7	990.2	5.33	5.22
8600	37.7	80.0	1105.4	5.81	3.81
8700	50.8	80.1	1254.3	6.36	2.33
8800	73.2	80.1	1317.3	6.57	1.25
8900	111.3	80.4	1325.7	6.60	0.74
9000	225.2	81.9	1924.0	8.22	0.24
9100	268.8	81.5	1705.1	7.69	0.11
9200	328.5	80.7	1663.0	7.58	0.06
9300	480.7	82.8	1520.5	7.20	0.03
9400	720.3	87.6	1322.3	6.59	0.01

LCP RCVR ↑ (TRCVR) LCP HI CAL ↑ (TX)



14:28.1 08/04/84 THOT=305.2 TCOLD=79.8 RCP -.461,-.445,-.651

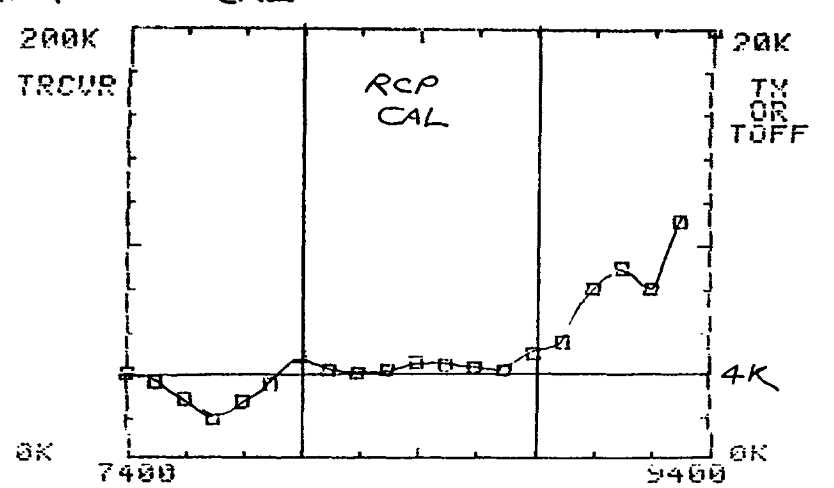


14:52.0 08/04/84 THOT=305.2 TCOLD=79.8 RCP 15.2K, 6DB PAD IN CAL

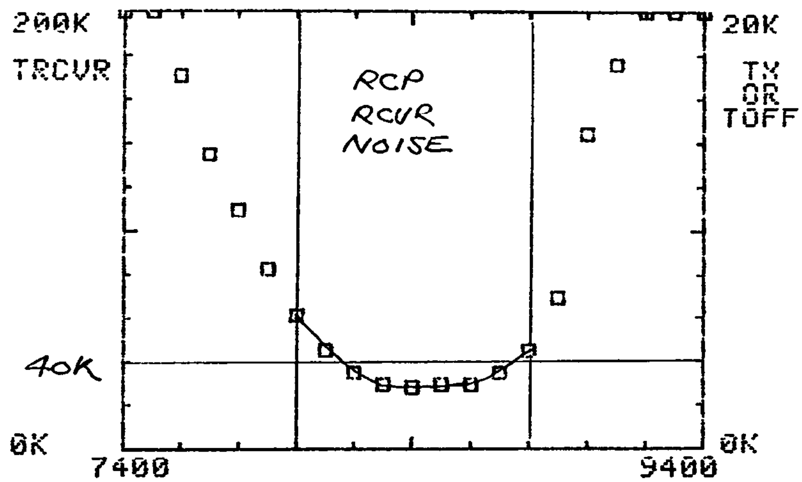
+30 VOLT DRIVE

F,MHZ	TRCVR	TOFF	TX	NDB	GAIN
7400	292.6	87.0	4.1	-18.53	0.02
7500	226.6	80.5	3.6	-19.04	0.06
7600	172.6	81.2	2.9	-20.01	0.10
7700	135.2	79.0	2.0	-21.66	0.26
7800	108.9	78.3	2.8	-20.20	1.38
7900	82.5	79.2	3.6	-19.10	5.13
8000	59.8	80.6	4.9	-17.74	4.43
8100	44.3	79.8	4.3	-18.34	2.74
8200	33.9	79.8	4.1	-18.50	3.46
8300	29.2	79.6	4.1	-18.45	4.09
8400	27.8	80.0	4.6	-18.04	4.75
8500	28.3	79.9	4.5	-18.08	4.01
8600	29.4	80.0	4.4	-18.20	3.39
8700	34.7	79.9	4.2	-18.43	2.39
8800	44.8	80.2	5.0	-17.60	1.68
8900	68.5	80.3	5.5	-17.20	0.93
9000	145.4	81.7	7.9	-15.63	0.25
9100	177.8	81.5	8.9	-15.13	0.13
9200	230.3	83.2	7.9	-15.63	0.06
9300	319.1	85.1	11.0	-14.23	0.03
9400	514.1	85.2	21.4	-11.33	0.01

RCP RCVR CAL



14:52.0 08/04/84 THOT=305.2 TCOLD=79.8 RCP REPEAT, 10DB AT MIXER INPUT, 40DB AT IF INPUT, 27DB ON INTERNAL IF ATTENUATOR



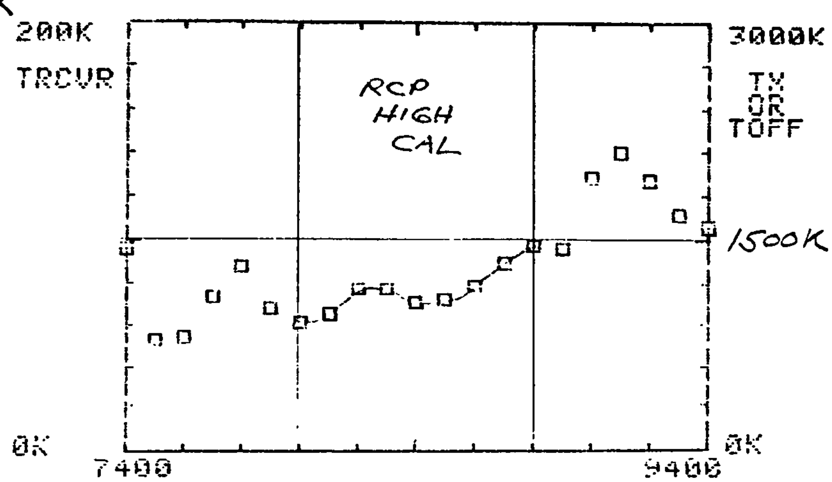
15:01.5 08/04/84 THOT=305.2 TCOLD=79.8 RCP HI CAL

+30 VOLT DRIVE

F,MHZ	TRCVR	TOFF	TX	NDB	GAIN
7400	288.1	80.3	1437.8	6.95	0.02
7500	219.8	79.6	799.7	4.41	0.06
7600	169.8	79.9	812.3	4.47	0.11
7700	134.3	78.9	1088.8	5.75	0.26
7800	108.3	79.3	1317.9	6.57	1.39
7900	82.3	79.6	1016.0	5.44	5.15
8000	60.1	80.2	900.7	4.92	4.45
8100	44.2	79.8	978.2	5.28	2.76
8200	33.9	79.9	1147.8	5.97	3.48
8300	29.1	79.8	1150.0	5.98	4.11
8400	27.8	80.0	1055.8	5.61	4.77
8500	28.3	79.9	1068.3	5.66	4.03
8600	29.3	80.0	1173.2	6.07	3.42
8700	34.6	79.9	1320.8	6.58	2.41
8800	44.6	80.2	1452.3	7.00	1.70
8900	69.0	80.2	1439.1	6.96	0.94
9000	143.7	80.4	1915.3	8.20	0.25
9100	175.9	80.9	2089.5	8.58	0.13
9200	227.9	81.1	1886.6	8.13	0.06
9300	312.3	82.2	1642.1	7.53	0.03
9400	504.8	74.5	1564.1	7.32	0.01

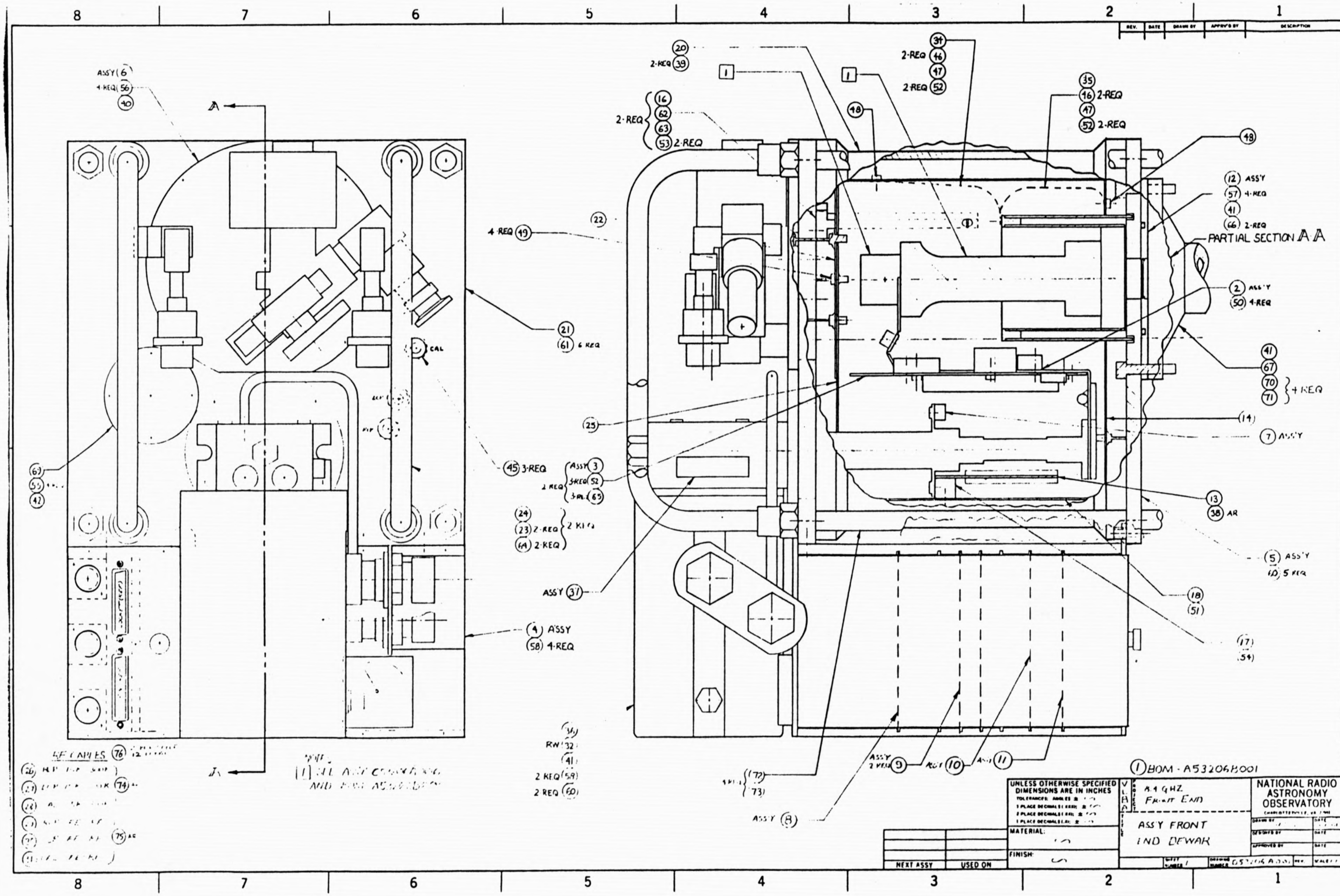
RCP RCVR

RCP HIGH CAL +30 VOLT DRIVE



APPENDIX II - Drawing Index

A set of drawings organized as assembly drawings, bill-of-materials, and part drawings have been prepared but are not included as part of this report. Some of the key assembly drawings and bills-of-materials are given in the next several pages.


PARTIAL SECTION A-A
① BOM - A53206B001
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
MATERIAL:
FINISH:
NEXT ASSY
USED ON
8.4 GHZ
FRONT END
ASSY FRONT
END DEWAR
NATIONAL RADIO
ASTRONOMY
OBSERVATORY

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

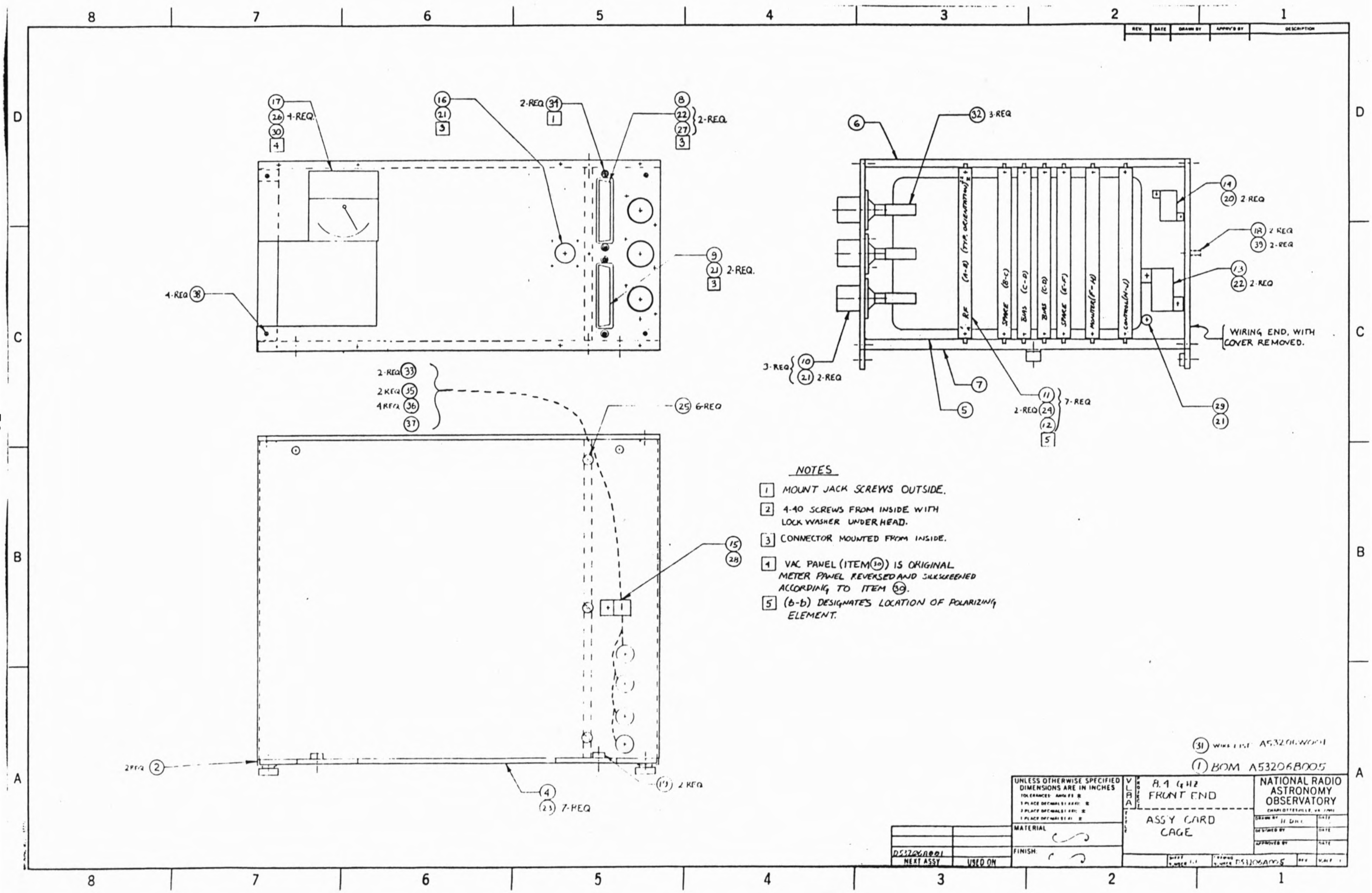
ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
0		NRAO	D53206A001	ASS'Y 8.4 GHZ FRONT END	SER
1		NRAO	A53206B001	BOM 8.4 GHZ FRONT END	1
2		NRAO	B53206A003	ASS'Y 2ND STAGE HEAT STRAP	1
3		NRAO	B53206A004	ASS'Y AMP. PLATE	2
4		NRAO	D53206A005	ASS'Y CARD CAGE	1
5		NRAO	C53206A006	ASS'Y TOP PLATE	1
6		NRAO	C53206A007	ASS'Y INSPECTION COVER	1
7		NRAO	A53200A001	ASS'Y TEMPERATURE SENSOR	1
8		NRAO	D53206A010	ASS'Y RF CARD	1
9		NRAO	D53200A002	ASS'Y BIAS CARD	2
10		NRAO	D53200A003	ASS'Y SENSOR CARD	1
11		NRAO	D53200A004	ASS`Y CONTROL CARD	1
12		NRAO	B53206A009	ASS'Y WINDOW	1
13		NRAO	A53206M004	CHARCOAL PLATE	1
14		NRAO	A53206M006	TOP SHIELD	1
15					
16		NRAO	A53206M009	SHIELD SUPPORT	2
17		NRAO	A53206M010	70 DEG K SHIELD CONNECTION	1
18		NRAO	B53206M011	SIDE SHIELD	1
19					
20		NRAO	D53206M015	DEWAR CYLINDER	1
21		NRAO	C53206M016	BOTTOM PLATE	1
22		NRAO	A53206M018	INSPECTION SHIELD	1
23		NRAO	A53206M019	HANDLE COLLAR	4
24		NRAO	B53206M020	HANDLE	2
25		NRAO	C53206M021	BOTTOM SHIELD	1
26		NRAO		RCP 15-300K CABLE	1
27		NRAO		LCP 15-300K CABLE	1
28		NRAO		CAL 15-300K CABLE	1
29		NRAO		RCP FE-RF CABLE	1
30		NRAO		LCP FE-RF CABLE	1

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
31		NRAO		CAL FE-RF CABLE	1
32		NRAO	A53206M049	CT1 MODEL 22-REWORK	RW
33					
34		NRAO	A53206M052	STRAP SIDE SHIELD	1
35		NRAO	A53206M053	STRAP TOP SHIELD	1
36		CTI CRYOGENICS	MODEL 22	REFRIGERATOR	1
37		NRAO	A53206A013	ASS'Y ET-INDICATOR	1
38		LINDE	AC-4051	CHARCOAL (6x8 PELLETS)	A/R
39		PARKER	2-270	O-RING (CYLINDER)	2
40		PARKER	2-251	O-RING (INS. COVER)	1
41		PARKER	2-230	O-RING (REF/WINDOW)	3
42		PARKER	2-130	O-RING (DC FEEDTHRU)	1
43					
44					
45		OMNI-SPECTRA	208	SMA FEED THRU HERMETIC	3
46		THOMAS & BETTS	54104	CU RED LUG 8 STR	4
47		CONNER WIRE	NE24-7-30T	CU BRAID	AR
48		SOUTH CO	74-13-106-24	#6-32 NC SS INSERT	2
49		AMERLOK	FPCS-8	NYLON SPACERS	4
50			#4-40 x 1/4 LG	S.S. SHCS	4
51			#6-32 x 3/16 LG	S.S. SHCS	1
52			#6-32 x 1/4 LG	S.S. SHCS	10
53			#6-32 x 1/2 LG	S.S. SHCS	4
54			#6-32 x 5/8 LG	S.S. SHCS	1
55			#8-32 x 3/8 LG	S.S. SHCS	4
56			#8-32 x 1/2 LG	S.S. SHCS	4
57			#8-32 x 3/8 LG	S.S. FHSS	4
58			#10-32 x 1/2 LG	S.S. SHCS	6
59					
60			#10-32 x 7/8 LG	S.S. SHCS	7
61			#10-32 x 1 LG	S.S. SHCS	6
62			#6-32 x 1/4 LG	NYLON PAN HEAD	2
63			#6	NYLON FLAT WASHER	2

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
64					
65			#6	S.S. FLAT WASHER	6
66			1/4 DIA. x 3/4 LG	S.S. DOWEL	2
67		NRAO	B53206M048	WAVEGUIDE	1
68		NRAO	A53206M058	FOAM WINDOW	1
69		NRAO	B53206A012	CABLE ASS'Y J1 TO DEWAR FEEDTHRU	1
70			1/4-20	S.S NUT	4
71			1/4-20	S.S. THREADED ROD	4
72		NRAO		S.S THREADED ROD	4
73		NRAO		1/2 S.S. NUT	4
74		UNIFORM TUBES	UT-85-50-SS-B	.085 SEMI RIGID CABLE SS-Be	AR
75		UNIFORM TUBES	UT-85A	.085 SEMI RIGID CABLE	AR
76		OMNI-SPECTRA	201-2A	SMA PLUG .085 DIA CABLE	12

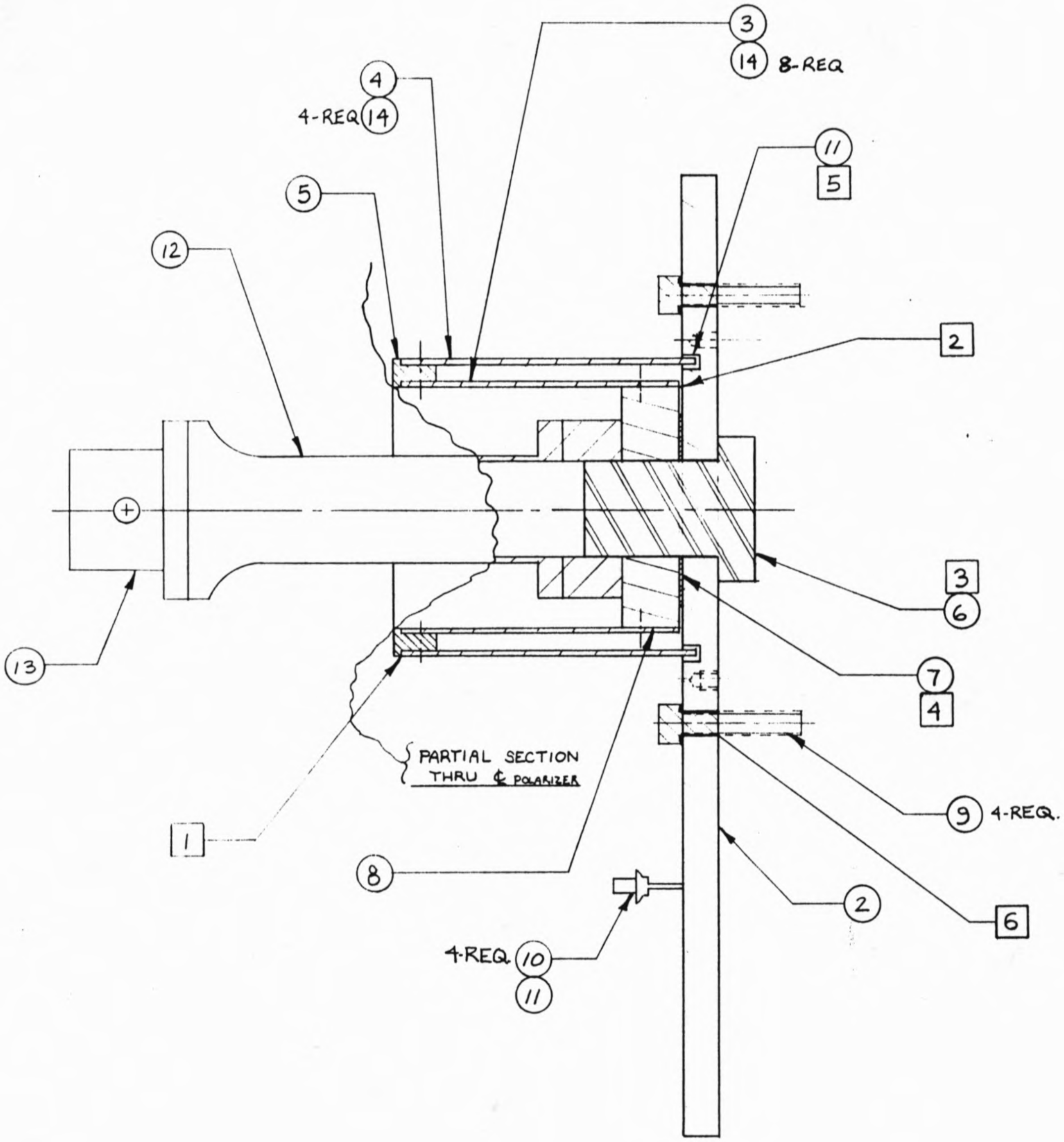

NOTES
1 MOUNT JACK SCREWS OUTSIDE.
2 4-40 SCREWS FROM INSIDE WITH LOCK WASHER UNDER HEAD.
3 CONNECTOR MOUNTED FROM INSIDE.
4 VAC PANEL (ITEM 30) IS ORIGINAL METER PANEL REVERSED AND SILKSCREENED ACCORDING TO ITEM 30.
5 (b-b) DESIGNATES LOCATION OF POLARIZING ELEMENT.
WIRING END, WITH COVER REMOVED.
RF
SPACE
BIAS
BIAS
SPACE
MONITOR
CONTROL
31 WIRE LIST A53206W001
1 BOM A53206B005
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
VLA
8.4 GHz FRONT END
ASSY CARD CAGE
NATIONAL RADIO ASTRONOMY OBSERVATORY
MATERIAL
FINISH
D53206A001
NEXT ASSY
USED ON
D53206A005

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
1		NRAO	A53206B005	BOM CARD CAGE	
2		NRAO	C53206M057	FRONT PANEL CARD CAGE	1
3					
4		NRAO	C53206M024	BACK PANEL	1
5		NRAO	C53206M025	MOTHER BOARD PLATE	1
6		NRAO	C53206M026	BOTTOM SIDE	1
7		NRAO	C53206M027	TOP SIDE	1
8		TRW	DBM-25P	TYPE "D" CONN. 25 PINS	1
9		TRW	DMB-25S	TYPE "D" CONN. 25 PINS	1
10		OMNI-SPECTRA	21011	SMA-TYPE N BULK HEAD	3
11		CINCH (TRW)	50-44A-30	EDGE CARD CONNECTOR	7
12		CINCH (TRW)	50-PK-2	POLARIZING KEY	7
13		DALE	RH-25	RESISTOR 300 25W, 1%	1
14		DALE	RH-10	RESISTOR 5K 10W, 1%	1
15		VOLTREX	ECC-6	CABLE CLAMP	1
16		DEUTSCH	DM9606-3P	AC INPUT CONNECTOR	1
17		SIMPSON	1212C	METER 1 MA.	1
18		SOUTH CO.	77-06-108-24	#8-32 NC S.S. INSERT STUD	2
19		SOUTH CO.	74-13-210-24	#10-32 NF SS INSERT	2
20			#2-56 x 3/16	S.S. SHCS	2
21			#4-40 x 3/16	S.S. SHCS	13
22			#4-40 x 1/4	S.S. SHCS	4
23			#4-40 x 5/16	S.S. SHCS	15
24			#4-40 x 3/8	S.S. SHCS	14
25			#4-40 x 3/8	S.S. FHSS	6
26			#4-40	S.S. HEX NUT	4
27			#4	S.S. LOCK WASHER	2
28			#10-32 x 1/4	S.S. SHCS	1
29			#4	GROUND LUG	1
30		NRAO	A53200I001	VAC GUAGE SCALE 1.5 x 1.5	1
31		NRAO	A53206W001	CARD CAGE WIRE LIST	REF
32		OMNI-SPECTRA	216	SMA, PLUG TO JACK	3

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
33		AMPHENOL	78-PF8-11	OCTAL SOCKET PLUG WITH CLAMP	2
34		AMPHENOL	17-893	JACK SOCKET KIT	2
35		MOLEX	03-09-1022	2 PIN CONN. RECEPTICLE	2
36		MOLEX	02-09-1103	FEMALE .093 DIA 14-20	4
37		DEUTSCH	DM9702-3S	AC CONNECTOR, PLUG	1
38			3/32 DIA	S.S ROLL PIN	4
39			#8-32	ALUM KNURLED NUT	2



<u>ASS'Y NOTES</u>

1. BUTT. SUPPORT TUBES (ITEMS 3 & 4) TIGHT AGAINST SUPPORT RING (ITEM 5)
2. ALIGN TUBE END (ITEM 3) FLUSH WITH CHOKE (ITEM 8).
3. ALIGNMENT FIXTURE FOR EPOXYING SUPPORT IN PLACE. REMOVE AFTER ASS'Y.
4. SHIM TOOL TO SET PROPER GAP. REMOVE AFTER ASS'Y.
5. FOLLOW INSTRUCTION BELOW FOR SURFACE PREP. INSIDE GROOVE. USE 2 PARTS A - 3 PARTS B FOR EPOXY MIX. CURE 2-HOURS 165°F

   Aluminium and Aluminium Alloys
   1. Degrease. If the bond is not as good as is required for the job, a chemical treatment is indicated.
   2. To four parts by weight of water add one part by weight of Eccoprime PP. (Be sure to add the Eccoprime to the water NOT the water to the Eccoprime.) Dip the aluminium into this solution after warming to 150 deg. F. Leave the aluminium in the solution for 8-10 minutes.
   3. Rinse thoroughly in cold running water, preferably deionized or distilled. Allow to dry before applying the adhesive or dry for 10 minutes at 150 deg. F.
6. PRIME THREAD IN PLATE AND ON 4 SCREWS WITH PRIMER T. DRY 3-5 MINUTES AND APPLY LOCTITE 271 TO THREADS .35 UNDER HEAD. ASSEMBLE SCREWS TO PLATE, CLEAN UP EXCESS LOCTITE AND LET CURE 3 HOURS.

1 BOM A53206B006

REV.	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
3 PLACE DECIMALS (.XXX): ±
2 PLACE DECIMALS (.XX): ±
1 PLACE DECIMALS (.X): ±

MATERIAL:

FINISH:

NEXT ASSY	USED ON
D53206A001	

VLBA PROJECT: 8.4 G-Hz F.E.

TITLE: ASS'Y TOP PLATE

NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901

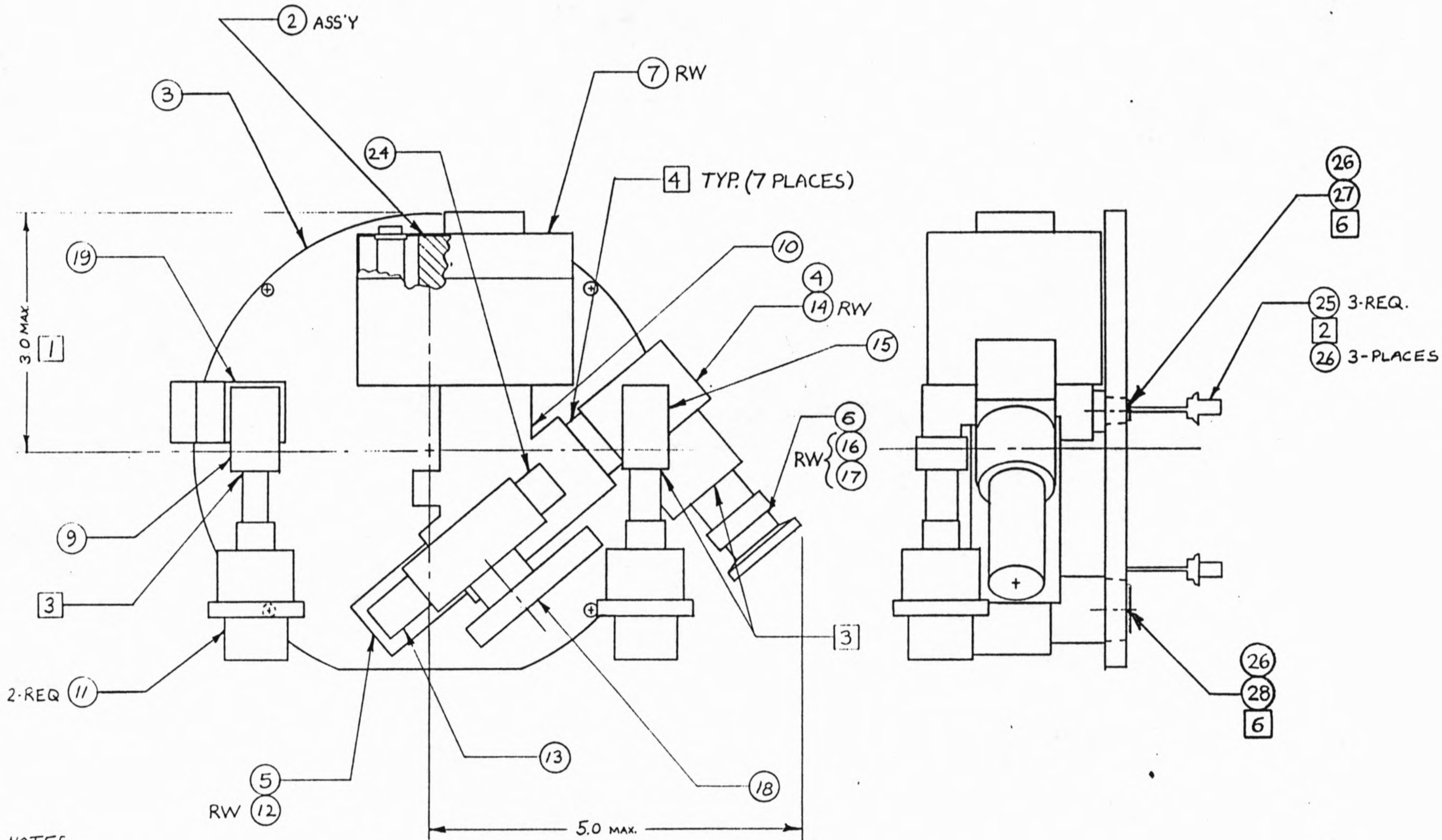
DRAWN BY H DILL	DATE 5-17-84
DESIGNED BY	DATE
APPROVED BY	DATE

SHEET NUMBER 1:1 — DRAWING NUMBER C53206A006 — REV. — SCALE 1:1

BRUNING 40-22 24984-1

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
1		NRAO	A53206B006	BOM TOP PLATE	
2		NRAO	C53206M014	TOP PLATE	1
3		NRAO	A53206M001	INNER SUPPORT	1
4		NRAO	A53206M002	OUTER SUPPORT	1
5		NRAO	A53206M003	SUPPORT RING	1
6				CENTERING PLUG	AR
7				SHIM	AR
8		NRAO	B53206M012	CHOKE RING	1
9			1/4-20 x 1 1/4 LG	S.S. SHCS	4
10		AMERLOK	FPCS-8	SPACERS	4
11				EPOXY	AR
12		ATLANTIC MICROWAVE		POLARIZER	1
13				COAX TRANSITIONS	2
14			#4-40 x 3/16	S.S. SHCS	12



NOTES

1. VALVE ASS'Y CAN BE ROTATED CW TO CLEAR 3.0 EDGE LINE.
2. TAILS OF SPACERS TO BE CUT .1 FROM BASE. SPACER EPOXIED IN PLACE.
3. TEFLON TAPE TO SEAL PIPE JOINT.
4. EPOXY (ITEM 26) USED TO SEAL JOINT.
5. STEM AND HANDLE OF ITEM 18 NEED TO BE DISASSEMBLED, ROTATED 90° AND REASSEMBLED.
6. EPOXY THE DISK OVER OPENINGS BY LAYING A BEAD AROUND PERIMETER OF DISK.

BOM A53206B007

NEXT ASSY	USED ON
D53206A001	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
3 PLACE DECIMALS (.XXX): ±
2 PLACE DECIMALS (.XX): ±
1 PLACE DECIMALS (.X): ±

MATERIAL: ~

FINISH: ~

PROJECT: VLBA 8.4 GHZ F.E.

TITLE: A'SSY INSPECTION COVER

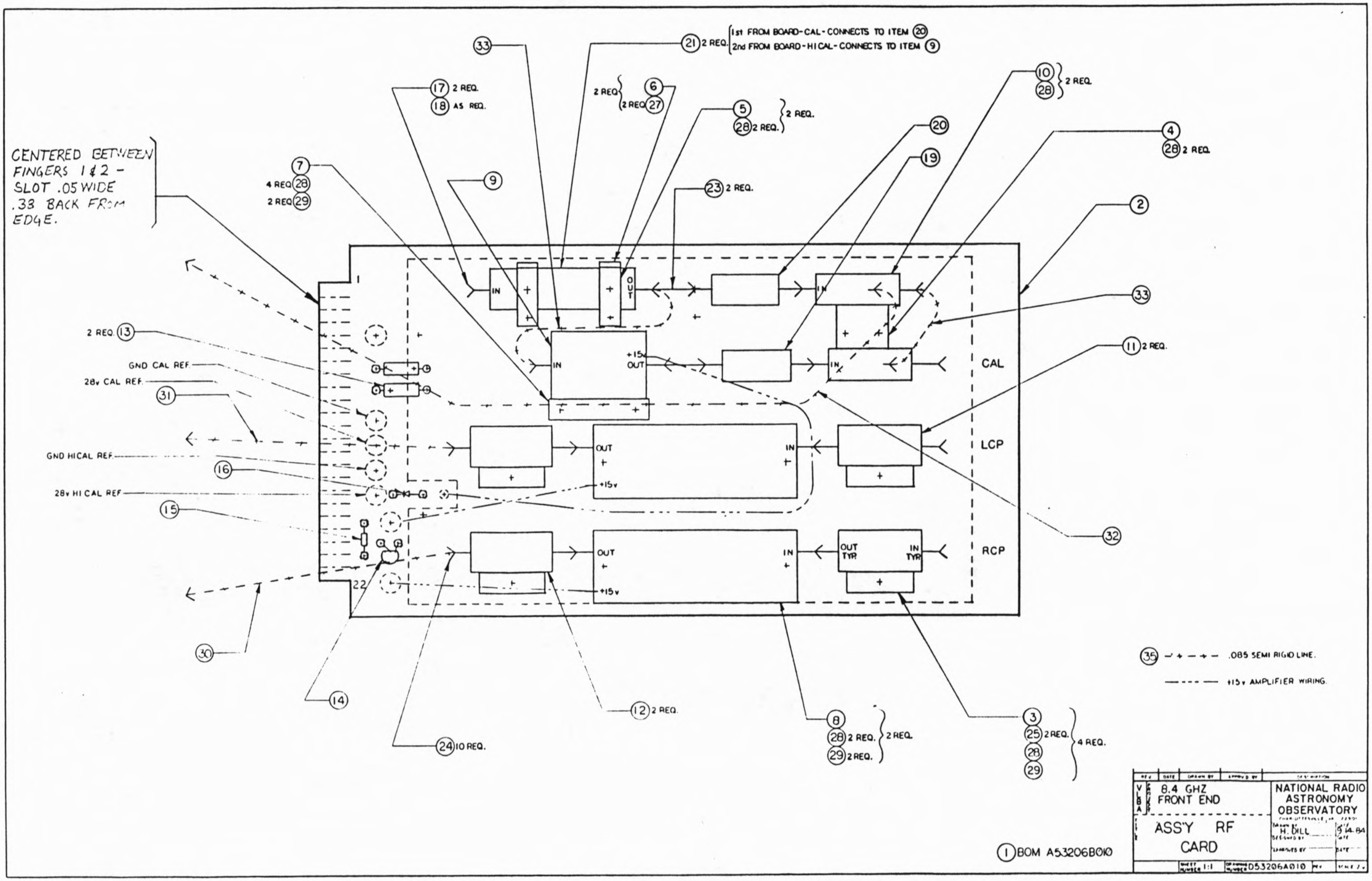
NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901

DRAWN BY	H DILL	DATE	5-17-84
DESIGNED BY		DATE	
APPROVED BY		DATE	

SHEET NUMBER 1:1 DRAWING NUMBER C53206A007 REV. SCALE ~

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
1		NRAO	A53206B007	BOM INSPECTION COVER	
2		NRAO	B53206A008	ASS'Y SOLENOID	1
3		NRAO	B53206M007	INSPECTION COUER	1
4		NRAO	A53206M028	SE FITTING REWORK (ITEM 14)	RW 1
5		NRAO	A53206M029	ME FITTING REWORK (ITEM 12)	RW 1
6		NRAO	A53206M050	VAC CONN. R.W. (ITEMS 16 & 17)	RW 1
7					
8					
9		CAJON	B-2-FE	FEMALE ELBOW 1/8 NPT	1
10		ASCO	8030A17VH	VALVE	1
11		TELEDYNE-HASTING	DV-6R	VAC. GAUGE TUBE	2
12		CAJON	B-8-ME	MALE ELBOW 1/2 NPT	1
13		CAJON	B-2-ME	MALE ELBOW 1/8 NPT	1
14		CAJON	B-8-SE	STREET ELBOW 1/2 NPT	1
15		CAJON	B-2-SE	STREET ELBOW 1/8 NPT	1
16		CAJON	B-8-HN	HEX NIPPLE 1/2 NPT	1
17		LEYBOLD-HERAEUS	910-280-019	FLANGE MALE KF-16	1
18		NUPRO	B-2P4T4	PLUG VALVE, 1/8 PORT FEMALE	1
19		NUPRO	B-2P4T2	PLUG VALVE, 1/8 PORT MALE	1
20					
21					
22					
23		VOLTREX		SHRINK WRAP	AR
24		ARO		FILTER	1
25		AMERLOK	PCS-16	SPACER	3
27				EPOXY (QUA GM)	
28		PSM	4-1	1/4 DIA. 1/16 BRONZE FILTER	1
29		PSM	10-1	5/8 DIA 1/16 TH BRONZE FILTER	1


21 2 REQ. 1st FROM BOARD-CAL-CONNECTS TO ITEM 20
2nd FROM BOARD-HICAL-CONNECTS TO ITEM 9
33
17 2 REQ.
18 AS REQ.
2 REQ 6
2 REQ 27
5 2 REQ.
28 2 REQ.
10 2 REQ.
28
20
19
4
28 2 REQ.
CENTERED BETWEEN FINGERS 1 & 2 - SLOT .05 WIDE .33 BACK FROM EDGE.
7
4 REQ 28
2 REQ 29
9
23 2 REQ.
2
33
2 REQ. 13
GND CAL REF.
28v CAL REF.
31
11 2 REQ.
GND HICAL REF.
16
28v HI CAL REF.
15
30
14
24 10 REQ.
12 2 REQ.
8
28 2 REQ.
29 2 REQ.
2 REQ.
3
25 2 REQ.
28
29
4 REQ.
32
IN
OUT
+15v
CAL
LCP
RCP
OUT TYP.
IN TYP.
1
22
35 .085 SEMI RIGID LINE.
+15v AMPLIFIER WIRING.
1 BOM A53206B010
VLBA
8.4 GHZ FRONT END
ASS'Y RF CARD
NATIONAL RADIO ASTRONOMY OBSERVATORY
H. DILL
9.14.84
1:1
D53206A010

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
0		NRAO	B53206S001	RF CARD	REF
1		NRAO	A53206B010	BOM RF CARD	1
2		NRAO	C53206Q001	RF CARD ARTWORK	1
3		NRAO	A53206M031	MOUNT ISOLATER	4
4		NRAO	A53206M032	MOUNT, COUPLER	1
5		NRAO	A53206M033	MOUNT, NOISE CAL	2
6		NRAO	A53206M034	CLAMP, NOISE CAL	2
7		NRAO	A53206M051	CAL. FET MOUNT	1
8		MITEQ	AMF-3B-8088-1	POST AMPLIFIER	2
9		MITEQ	AMF-1B-8088-1	CAL AMPLIFIER	1
10		MAC TEC	C3206-10	COUPLER 10dB	2
11		VIRTECH	V317011-2	ISOLATER, INPUT	2
12		VIRTECH	V317011-1	ISOLATER, OUTPUT	2
13				CAP. 15uf 20v tant.	2
14			LM335Z	TEMPERATURE SENSOR	1
15	R1			RES. 12K 5% 1/4W	1
16	CR1		1N4744	ZENAR DIODE 15V	1
17				BNC CONNECTOR PLUG	2
18				COAXIAL WIRE	0
19		NARDA MICROWAVE	4778-1dB	1 dB ATTENUATOR	1
20		NARDA MICROWAVE	4778-6dB	6 dB ATTENUATOR	1
21		MICROWAVE SEMICONDUC	MC7084	NOISE SOURCE ENR 35db	2
22					0
23		OMNI-SPECTRA	216	SMA ADAPTER, PLUG TO JACK	2
24		OMNI-SPECTRA	201-2A	SMA PLUG .085 CABLE	10
25			#2-56 x 3/8 LG	SS SHCS	8
26			#2-56 x 1/2 LG	SS SHCS	2
27			#4-40 x 3/16 LG	SS PHS	4
28			#4-40 x 5/16 LG	SS SHCS	18
29			#4-40	SS FLAT WASHER	10
30		NRAO		RCP OUTPUT LINE	1
31		NRAO		LCP OUTPUT CABLE	1
32		NRAO		CAL INPUT CABLE	1
33		NRAO		CAL AMP INPUT CABLE	1

A53206B010-RF CARD

BILL OF MATERIALS
National Radio Astromomy Observatory
VLBA

ITEM NUM.	REF. DES.	MANUFACTURER	MANUFACTURER'S PART NUMBER	DESCRIPTION	QUAN. REQ.
34		NRAO		CAL COUPLER CABLE	1
35		NRAO		.085 CABLE	0