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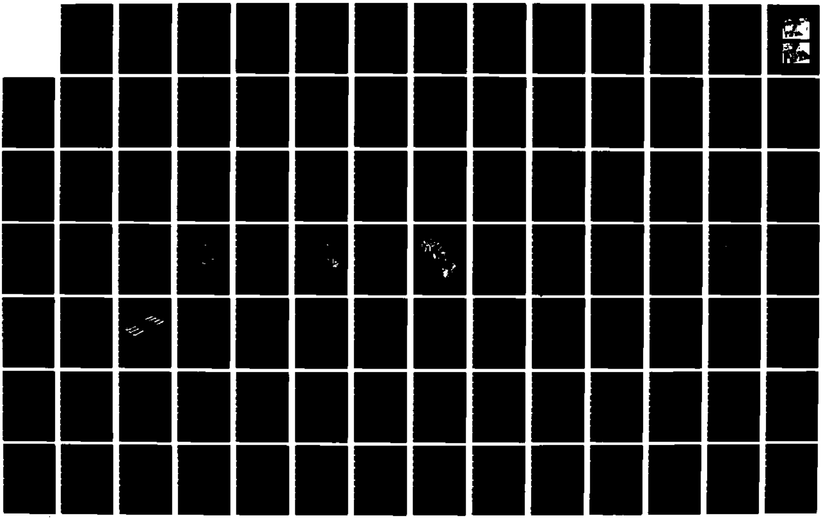

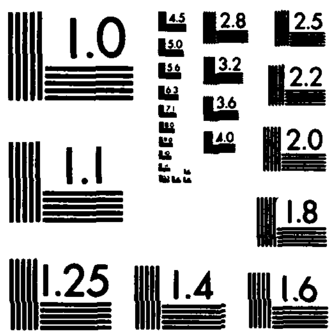

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PULSED HETERODYNE CO_2 LASER/SCANNER SYSTEM
Volume I - Assembly Report

G. B. Jacobs

General Electric Co.
Electronics Laboratory
Syracuse, New York 13221

Final Report
September 1980 - June 1983

June 1983

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
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This report has been reviewed by the ESD Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS).

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Ten-micron heterodyne laser radar offers a new type of remote sensor that can add significantly to our characterization and understanding of the atmosphere. For example, accurate range-resolved measurements of air velocity via the Doppler of aerosol backscatter -- to distances of tens of kilometers -- will yield a better understanding of wind shear. This report is the assembly volume of a two-volume report intended to aid the government in assembling and operating the long pulse laser radar built and

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20. ABSTRACT (Continued)

cont delivered on this contract. The equipment is intended for assembly in a trailer to be supplied by the government. It incorporates a high pulse repetition frequency, high power electron beam injection CO_2 laser developed earlier by the General Electric Co. and a hemispherical scanner with a laser beam of less than 2×10^{-3} degrees beamwidth.

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VOLUME I

1 INTRODUCTION

Ten-micron heterodyne laser radar offers a new type of remote sensor that can add significantly to our characterization and understanding of the atmosphere. For example, accurate range-resolved measurements of air velocity via the Doppler of aerosol backscatter -- to distances of tens of kilometers -- will yield a better understanding of wind shear. The General Electric Company, on Contract F19628-80-C-0184 has built a heterodyne laser radar for AFGL to be installed in a Government Trailer Facility in Sudbury, Massachusetts. This equipment, disassembled and carefully packed to prevent damage to the various precision optical components, will be shipped to the Air Force in June 1983. This report, one of a two-volume series, is to aid government technical personnel to unpack and reassemble this equipment in the new location.

The laser radar being delivered was tested as a breadboard in the GE laser radar facility in Syracuse, New York. A complete prototype for trailer use was designed and partially assembled and tested. Figure 2 shows the partially assembled system and Figure 1 shows the basic functional diagram. The TEA laser is in the center right of Figure 1. The scanner in the upper left transmits the beam to the target area and receives the target signal which is carried to the heterodyne receiver in the lower left. The TEA laser is shown on the upper right of the optical bench of Figure 2 and the scanner is shown in the upper portion of the upper photo. Almost all of the equipment is either on the optical bench, under the optical bench, or in one of the three electrical racks shown in the two photos.

In the next section, "Assembly Summary," we explain the numbering system and provide an overview of the planned sorting, set-up and cabling process. The component identification system is built around two categories, "Optical", and "Electrical". These two categories cover all the components involved but are not mutually exclusive since many components have both electrical and optical functions.

Sections 3 and 4 describe the assembly process in detail for the "Optical" and "Electrical" subsystems respectively.

CAUTION

The electrical system is the source of a number of high voltage hazards. The sustainer capacitor box is particularly dangerous. In setting up and operating this system all possible safety precautions should be observed with diligence. All metal parts that may be touched should be solidly and permanently grounded with heavy copper braid. Permanent grounds should be provided for cable connectors that may be unlatched during operation (such as oscilloscope leads). A grounding stick should be handy and always used whenever a high voltage circuit box is opened.

Section 5 discusses this and other safety hazards, such as x-rays, ozone and laser emission. Anyone who contemplates working on or operating the system should first become thoroughly familiar with the precautions delineated in this section.

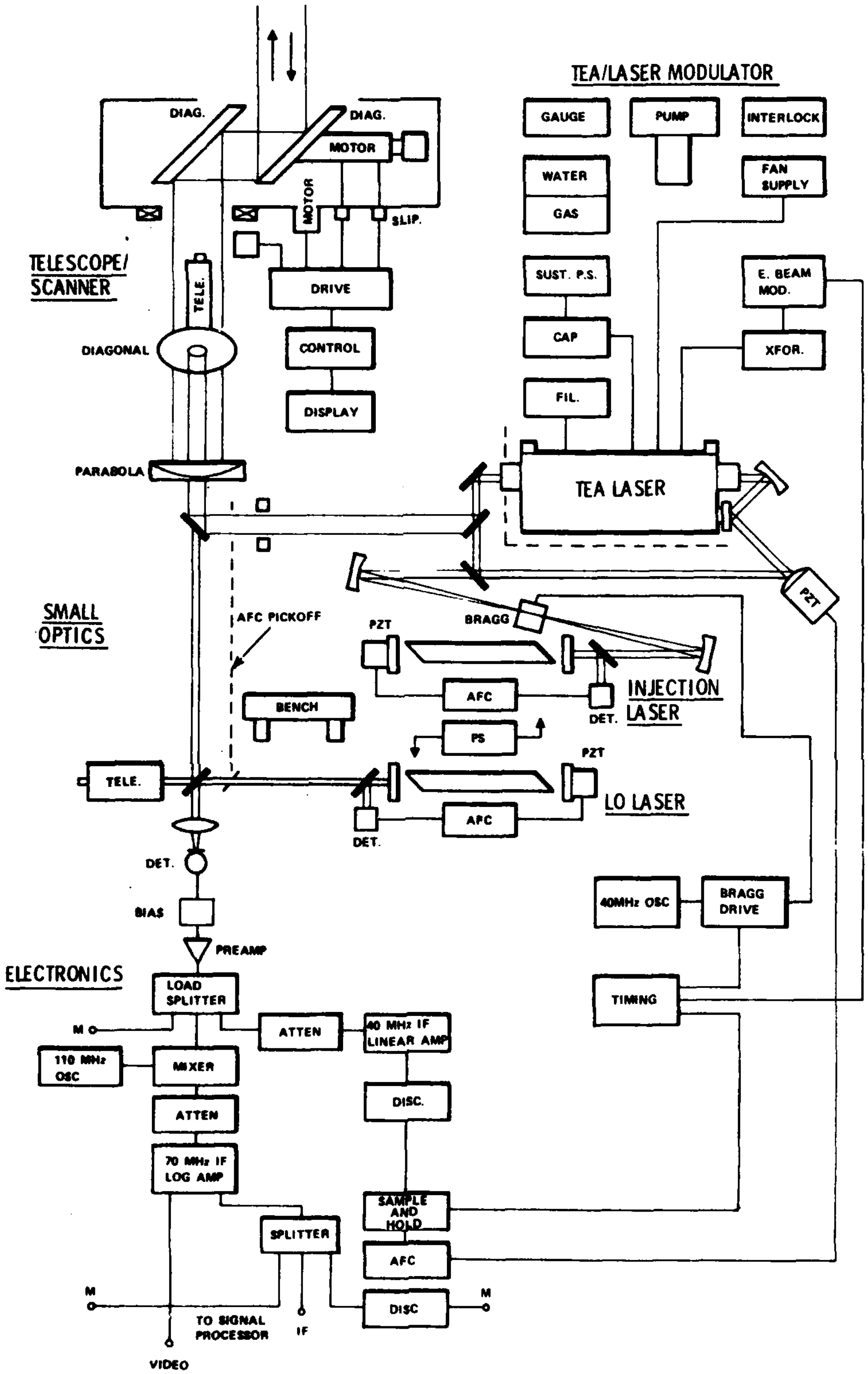


Figure 1. Basic Laser Heterodyne Radar System

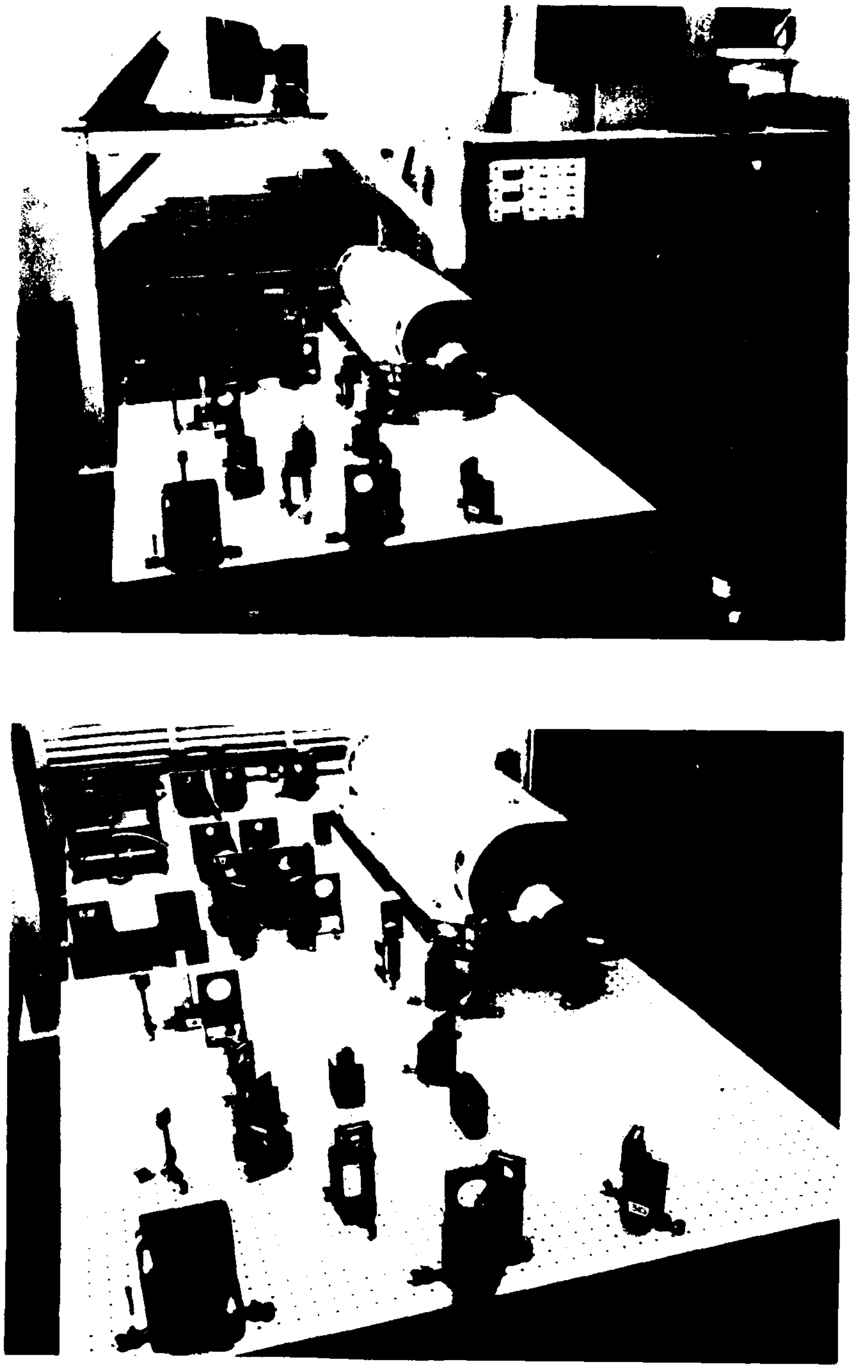


Figure 2. Penthouse System Test, Partial Installation

2 SUMMARY OF ASSEMBLY PROCEDURE

The optical bench is shown in plan in Figure 3. Assembly and alignment of the optical system must be such as to sustain the optical paths shown in this diagram. Each number or optical station shown consists of a mirror or optical component, a gimbal mount, a support block for the mount and perhaps an electrical or electronic component. Sometimes the optical component is a laser or detector or attenuator but in each case the "SO" number represents a significant optical function.

The "electrical" system is shown in Figures 5a and 5b. Although some of the components may hardly be electrical at all, such as the CO_2 gas supply system, the point is that every component is now either on the optical system diagram or the electrical system diagram or both. Figure 5a shows the contents of the three electronic racks. Racks #1 and #2 are primarily power supplies and their controls. Rack #3 is primarily signal generation control and display. In Figure 5b we show the electrical categories on, under, or beside the optical bench; and again in their approximate physical juxtaposition.

Our numbering system to identify the many components and systems to be labeled, shipped, and reassembled is based on the two master system diagrams of Figure 3 and Figure 5. These diagrams provide at once the identification number and relative location for each component. Since most parts serve both functions, optical and electrical, the two numbering systems overlap. To prevent confusion the optical identification uses the letters "SO" as a prefix and the electrical system uses the letters "EL" as a prefix.

Figure 1 shows the basic overall functional diagram showing the paths of the optical beams and the flow of electrical signals. The diagram is useful to help understand the basic principles and physical function of each part.

In Figure 1 a single frequency, low pressure CO_2 laser, the injection laser, provides a seed pulse of 10μ light to the TEA laser which amplifies this to about a megawatt. The resulting transmitter beam is expanded to 12" diameter by the telescope parabola and aimed in the direction of the target by the scanner. The return signal is heterodyned with the beam from the other low pressure CO_2 laser, the local oscillator laser. Signal and local oscillator waves are heterodyned in the cryogenic detector and the resulting difference intermediate frequency (IF) processed in two separate receivers. On the left the signal is converted to 70 MHz, amplified and sent to the user's doppler signal processing computer. On the right the IF is applied to a frequency discriminator which generates an automatic frequency control (AFC) signal. The AFC is used to control the transmitter frequency to conform to the injection laser energy. Both injection and LO laser signals have their own AFC system holding them to the center of the 10.6μ CO_2 lasing wavelength.

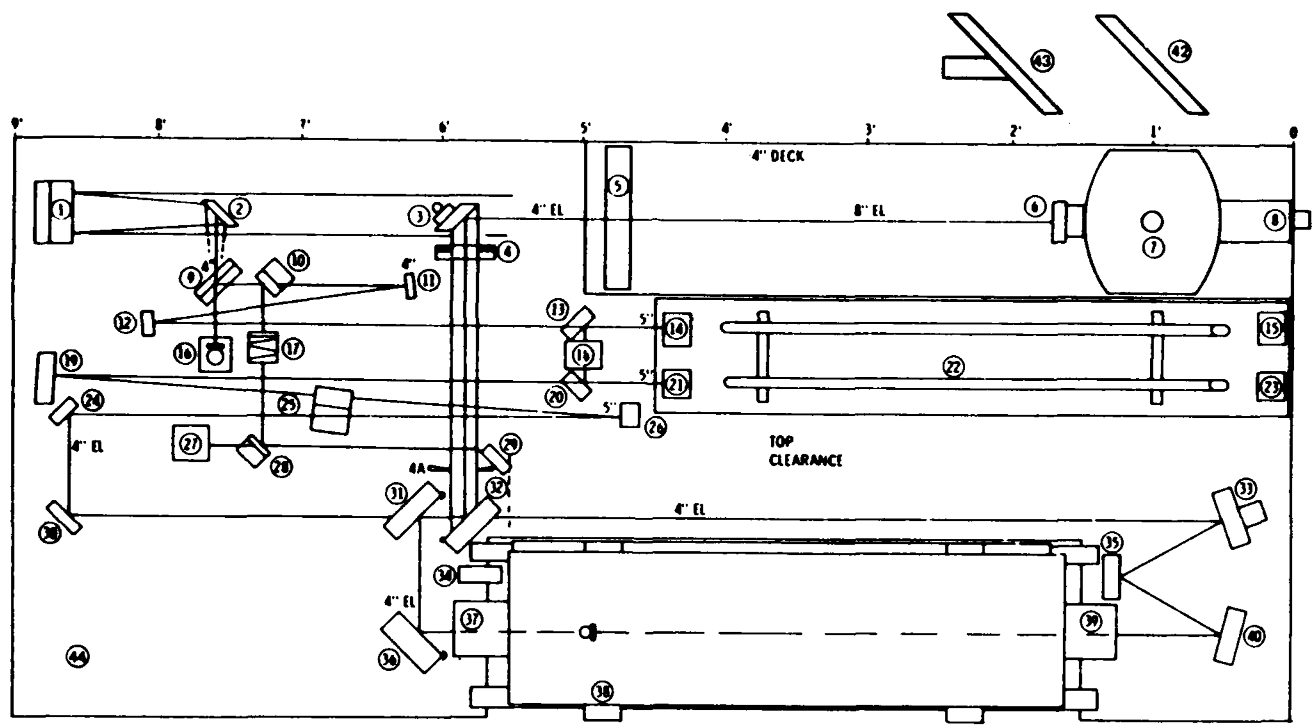


Figure 3. Optical System.

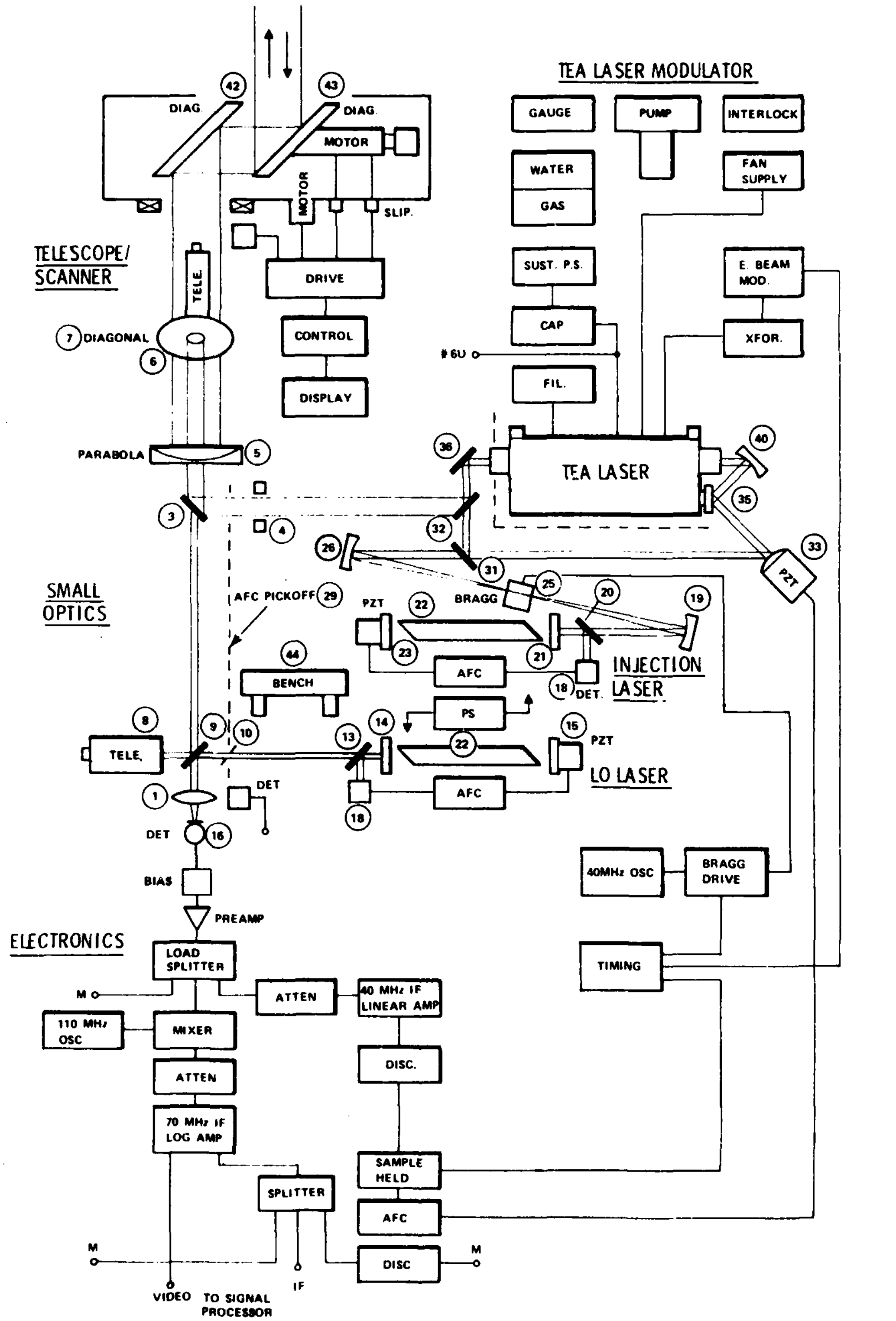


Figure 4. Functional Location of Numbers (SO) Optical Components

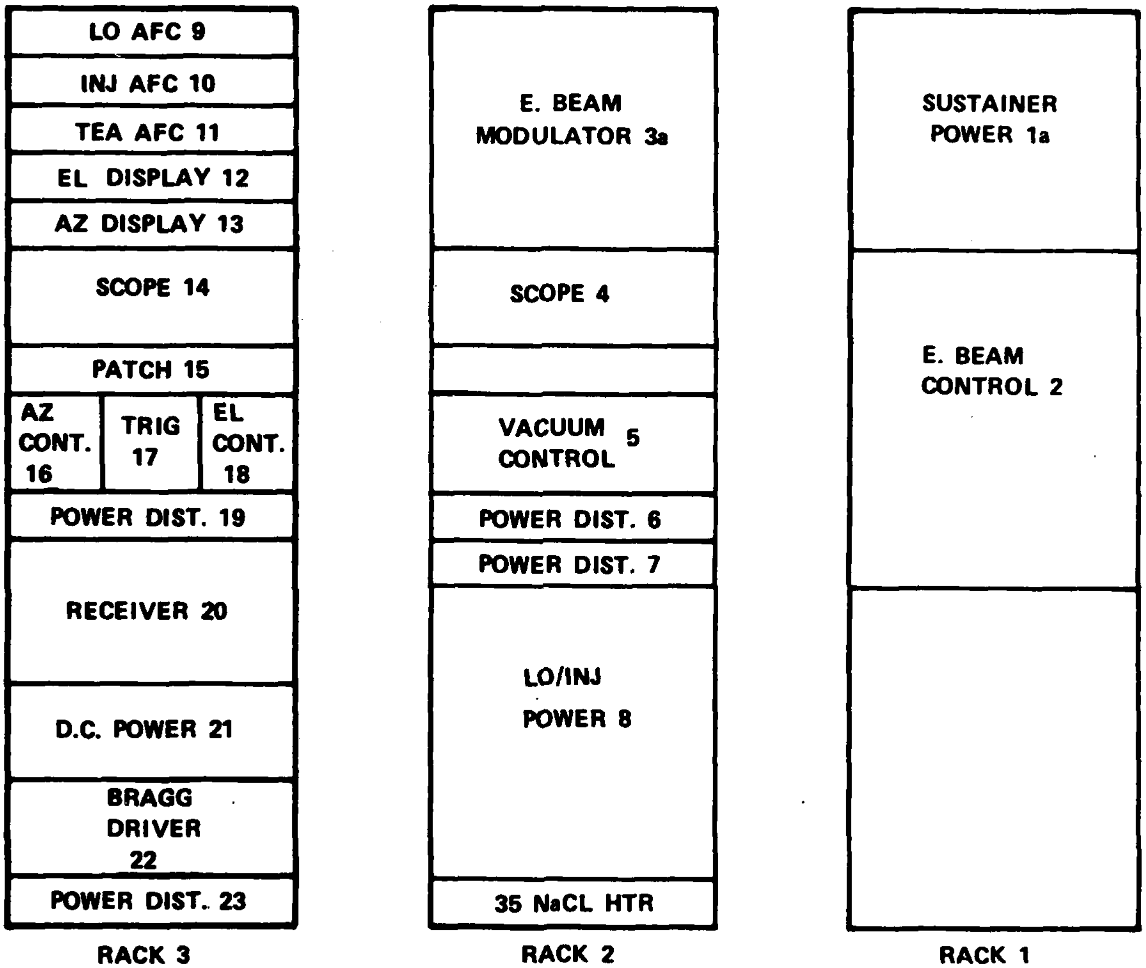


Figure 5a. Electrical System Located in Racks

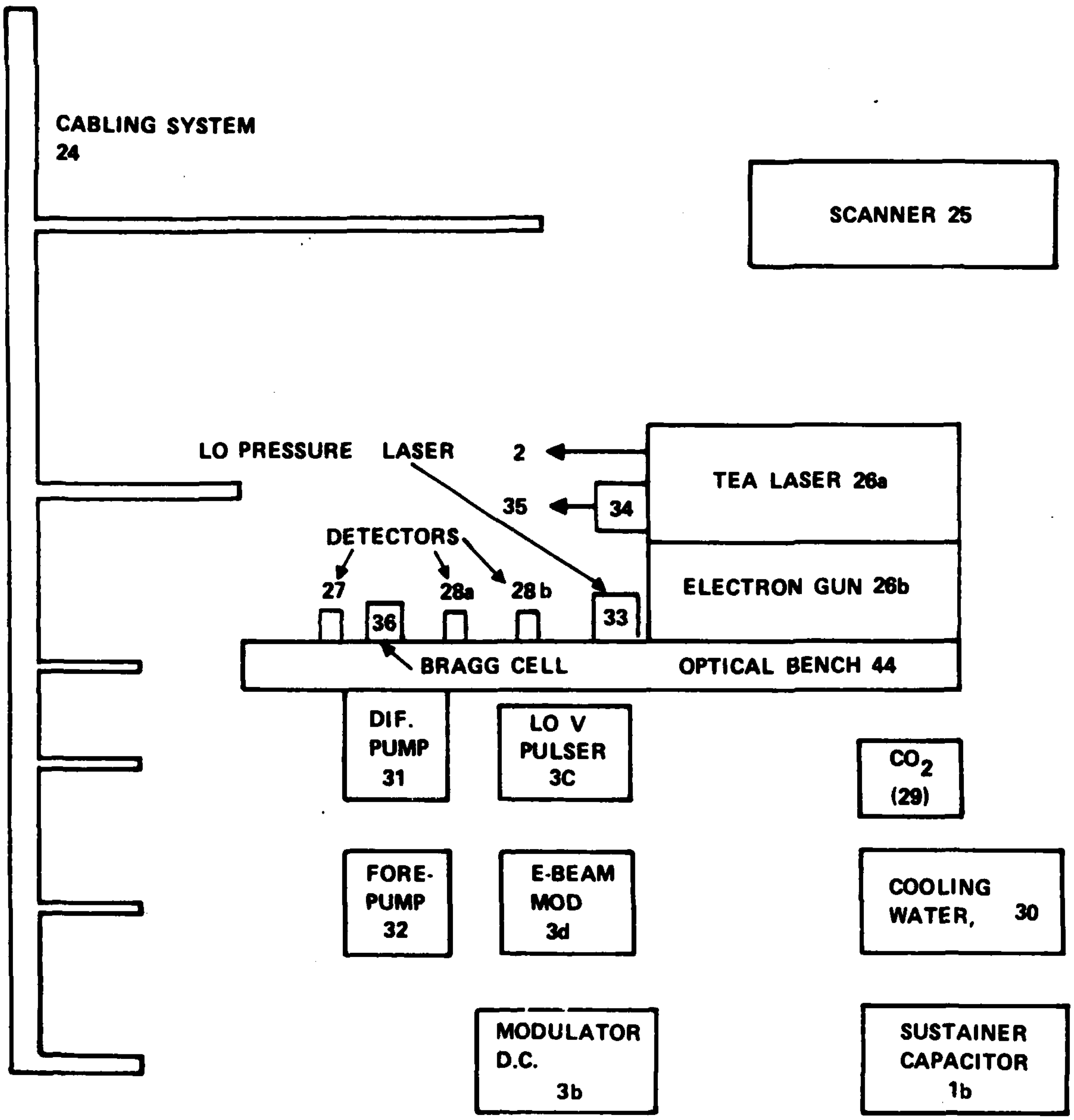


Figure 5b. Electrical System Located at Optical Bench

The TEA laser transmitter uses an electron beam modulator which sends a 120 KV 15 ampere beam of electrons into the atmospheric pressure CO_2 lasing gas volume. These electrons ionize the CO_2 gas which is further excited, in a controlled avalanche, by the 20 KV DC on sustainer electrodes in the gas. (See Figure 18.) The resulting CO_2 plasma has an optical gain which regeneratively amplifies the injection laser signal to the 1 joule 5 μs transmitter output. A primary goal of the system is to maintain sufficient temporal and spectral coherence of these lasers to allow a sensitive doppler measurement of the target velocity.

It is helpful, in reassembly, to understand the function of each of the components shown in Figures 3 and 5 relative to these operating principles and the functional diagram of Figure 1. Figure 4 shows Figure 1 repeated with many of the numbers of the optical components ("SO" numbers) superimposed. Figure 6 shows Figure 1 repeated with many of the electrical components ("EL" numbers) superimposed. Note again that many components have two ID or station numbers. For example, the local oscillator laser is SO #22 and EL #33.

The laser radar being delivered includes three subsystems which required considerable mechanical drafting, shop work and shop assembly by GE. These were the TEA laser, the scanner, and the optical bench support system. For each of these, we provide a formal set of mechanical drawings and parts lists even though the systems are delivered assembled. The positions of the parts on the parts list are shown on the assembly drawings.

Most of the electronics is made up of purchased standard commercial equipment. Thus the assembly and operation of much of the system is provided by the technical manuals supplied by the vendors. The technical manuals and the formal GE mechanical drawings are packaged separate from this report.

Figure 3 shows, approximately to scale, the relative position of the 44 optical equipments. The positions have been marked in ink on the top of the optical bench itself to help in system reassembly. The ink marks can be removed with trichloroethylene. Final precise location of these parts will have to be done with the use of a Helium Neon laser (as described in Volume Two, System Operation). Figure 3 shows the optical beams as they progress through the various transformations. Note that all of the beams are either at 4" above the table, 5" above the table, or 8" above the sub-deck. The function of the supports provided with each mount is to hold each optical gimbal mount at the required height. Coarse angle adjustment is by turning the mounts in their bench clamps. Final adjustment is by gimbal micrometer. The machine shop drawing (SK) numbers itemized with each component on the master parts list gives the part and number dimensions. Each part is either stamped with this SK number or tagged with the optical system "SO" number or both. Each gimbal mount (made mostly by NRC Company) has its own NRC number also listed on the master parts list. Each optical element is identified in the master parts list by a technical description, (such as 90% partial reflector, 2 meters radius concave). For the most part these fragile

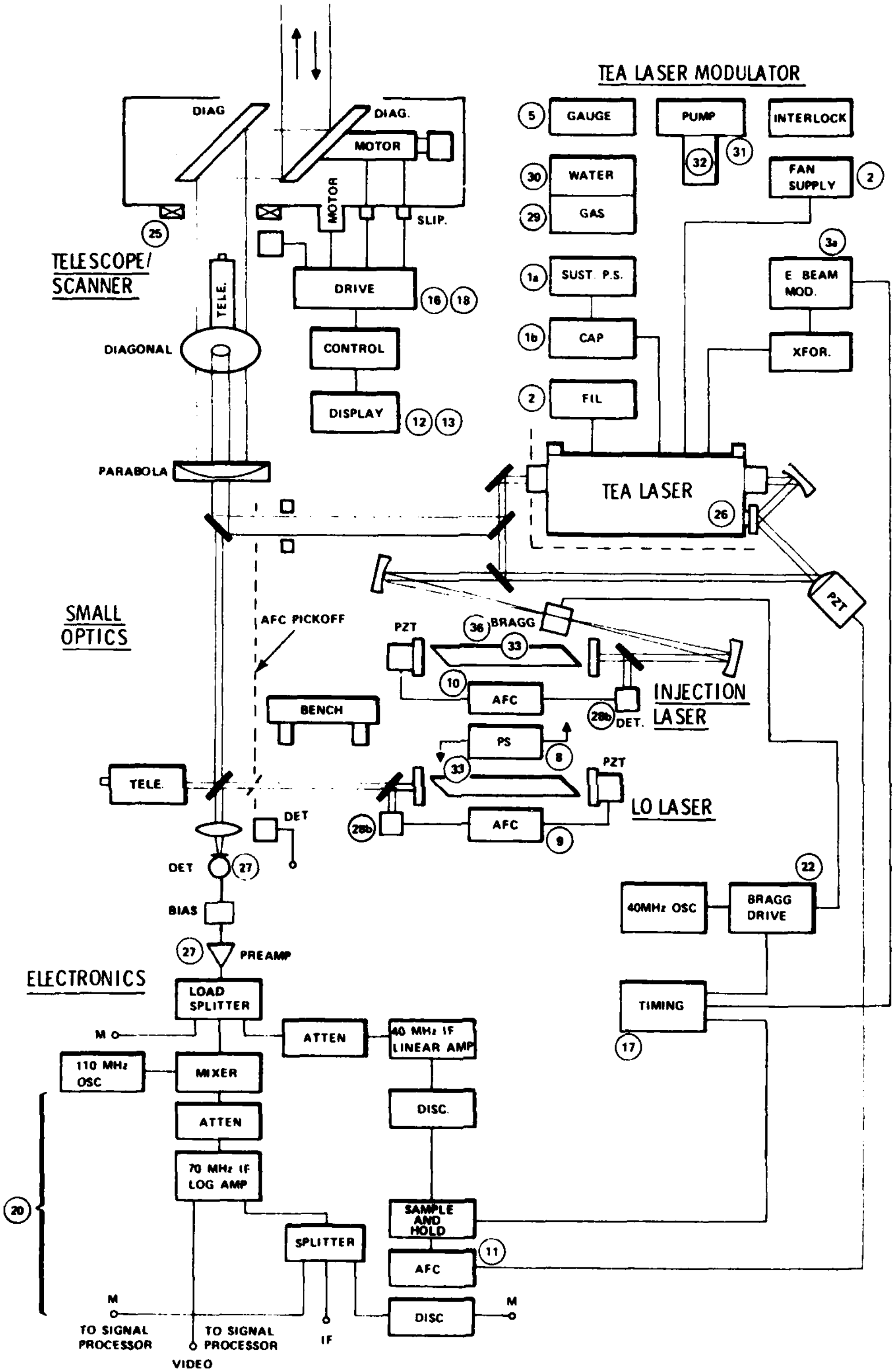


Figure 6. Functional Location of Numbered (EL) Electrical Components

optical components have been left in their original manufacturer package* marked "To be opened only by qualified technician." These packages are tagged with the optical system number as well as the manufacturer's number and specification. For each optical station (usually one SO number) all three items; optical element (O), gimbal mount (M) and hardware (H) are packed in one box, to aid the reassembly process. Large items are packed separately. All boxes are labeled according to the optical system (SO) number or the electrical system (EL) number. Since most of the electrical units are being shipped assembled and mounted, in the three racks, rather than boxed, there are only a few "electrical" system boxes.

Figure 5 identifies the rest of the subsystems being shipped, the electrical group. These charts correlate identification (EL) number, equipment location and equipment titles. The charts are then used as the basis for overall wiring and cabling diagrams to supplement interchassis wiring and cabling instructions supplied with each component. Figure 5a shows those equipments located in the three 19" control and electronics racks. Figure 5b shows the electrical equipments (and other functions such as CO_2 and water supply) located in the optical bench area. The two usage areas; optical bench and rack, and the two functional groups; optical and electrical cover all of the equipments being supplied. In Figure 6 we show how the electrical system components serve in the functional system, Figure 1.

Figures 1-5 are used again in the operational report, Volume II, when system operation and component functions are discussed in greater detail.

Tables I and II summarize the shipping and completion status of the overall system, by SO and EL number. It shows that all optical system components (except SO #8) are complete in the sense that all the needed pieces have been obtained, by purchase or construction or whatever. It also shows that all parts have been boxed for shipment at this writing and about 20% of the 45 subsystems are packed fully assembled. We note again that unassembled parts are boxed according to their SO number and where possible, in one box. Table II shows the status of the electrical system components. Most of the units are complete electronic chassis which are not "packed" as such but simply shipped in-place in their racks. Most of the remainder are rugged components, such as the roughing pumps which are not boxed by engineering but are simply suitably packed on the truck by the shipper. Since the shipment will be by exclusive air-ride van this is adequate.

Table II shows the completion status of the 36 electrical system (EL) components. Note that all the major part inventories (a resistor or small capacitor is not a major part) for each item are complete. Eleven systems need to be wired. Of these, two are either composed of completed subassemblies which have only to be interconnected (such as the receiver) or a commercial unit which requires some modification (rewiring and retesting) to be used in its present capacity, such as the TEA laser AFC system. The

*The TEA laser was tested at GE using identical GE optical components

TABLE I. COMPLETION STATUS OPTICAL SYSTEM COMPONENTS

Optical System (SO) Part Number	Inventory Complete	Fully Assembled	Boxed
1	x	x	x
2	x	-	x
3	x	-	x
4	x	x	x
5	x	-	x
6	x	-	x
7	x	-	x
8	-	-	x
9	x	-	x
10	x	-	x
11	x	x	x
12	x	x	x
13	x	-	x
14	x	-	x
15	x	-	x
16	x	x	x
17	x	-	x
18	x	-	x
19	x	x	x
20	x	-	x
21	x	-	x
22	x	-	x
23	x	-	x
24	x	x	x
25	x	x	x
26	x	x	x
27	x	-	x
28	x	-	x
29	x	-	x
30	x	x	x
31	x	-	x
32	x	-	x
33	x	-	x
34	x	x	x
35	x	-	x
36	x	-	x
37	x	-	x
38	x	-	x
39	x	-	x
40	x	-	x
41	x	-	x
42	x	-	x
43	x	-	x
44	x	-	x
45	NA		

TABLE II. COMPLETION STATUS ELECTRICAL SYSTEM COMPONENTS

Electrical System (EL) Part Number	Title	Major Parts Inventory Complete	Mechanically Assembled	Electrically Complete and Tested	Ready for Shipper
(1a)	Sustainer Power Supply	x	x	x	x
(1b)	Sustainer Capacitor Box	x	x	x	x
(2)	E Beam Control Panel	x	x	x	x
(3a)	E Beam Modulator Control Panel	x	x	x	x
(3b)	E Beam Modulator D.C. Power	x	x	x	x
(3c)	E Beam Modulator Low Voltage Pulser	x	x	x	x
(3d)	E Beam Modulator High Voltage Pulser	x	x	x	x
(4)	Oscilloscope (Rack 2)	x	x	x	x
(5)	Vacuum Gauges	x	x	x	x
(6)	Power Distribution (Upper), (Rack 2)	x	x	x	x
(7)	Power Distribution (Lower), (Rack 2)	x	x	x	x
(8)	Lo Laser, Inj. Laser D.C. Power Supply w/Ballast	x	x	x	x
(9)	LO Laser AFC	x	x	x	x
(10)	Inj. Laser AFC	x	x	x	x
(11)	TEA Laser AFC	x	x	-	x
(12)	Elevation Display	x	x	x	x
(13)	Azimuth Display	x	x	x	x
(14)	Oscilloscope Rack 3	x	x	x	x
(15)	Patch Panel	x	x	x	x
(16)	Azimuth Control	x	-	-	x
(17)	Trigger	x	x	-	x
(18)	Elevation Control	x	-	-	x
(19)	Power Distribution Upper (Rack 3)	x	x	x	x
(20)	Receiver	x	x	-	x
(21)	D.C. Power (Low Voltage)	x	x	x	x
(22)	Bragg Driver	x	x	x	x
(23)	Power Distribution Lower (Rack 3)	x	x	x	x

TABLE II. COMPLETION STATUS ELECTRICAL SYSTEM COMPONENTS (Continued)

Electrical System (EL) Part Number	Title	Major Parts Inventory Complete	Mechanically Assembled	Electrically Complete and Tested	Ready for Shipper
(24)	Cabling System	-	-	-	-
(25)	Scanner	x	-	-	x
(26a)	Electron Gun	x	x	x	x
(27)	Heterodyne Detector	x	x	-	x
(28a)	Power Detector	x	-	-	x
(28b)	AFC Detectors	x	-	-	x
(29)	CO_2 Gas	x	x	N/A	x
(30)	Cooling Controls	x	x	x	x
(31)	Diffusion Pump	x	x	x	x
(32)	Fore Pump	x	x	x	x
(33)	Low Pressure CO_2 Lasers	x	-	-	x
(34)	NaCL Heaters (TEA Laser)	x	x	x	x
(35)	NaCL Heater Control	x	x	x	x
(36)	Bragg Cell	x	x	x	x

rest are simple circuits such as the pyroelectric detectors. The engineering design of all units is complete and complete circuit drawings are provided later in this report.

The design of the present system is such that the equipment can be assembled in the AFGL Trailer and be mechanically adequate for use in geophysical measurements around the world. GE has provided AFGL with the set of requirements (such as power, cooling water, weight loads) and the van necessary to accommodate the system, (see Scientific Report #1 on this contract). The van space requirements are shown in Figure 7.

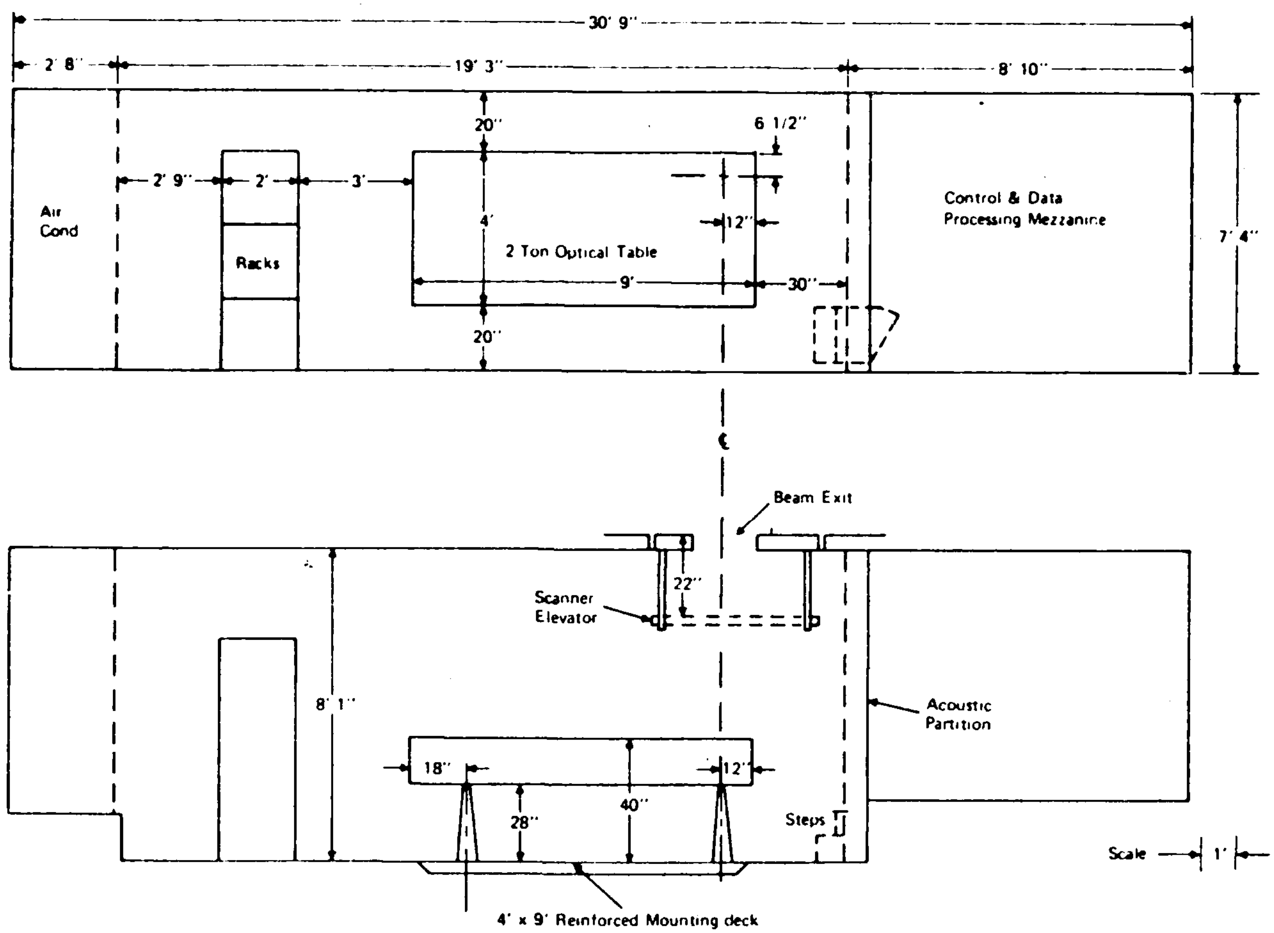


Figure 7. Inside Dimension Requirements.

3 ASSEMBLY, OPTICAL SYSTEM

3.1 INTRODUCTION

In this section we discuss the procedures for unpacking and reassembling the optical system, particularly those technical details not obvious from the supplied drawings. One of the problems of optical systems is that many optical items such as beam splitters cannot be easily tagged. We have attempted to solve this problem by "SO" components as fully assembled or at least wrapping, tagging, and then putting all the pieces of one unit in the same box. When parts are lost or need to be replaced we have a system of parts lists and parts specifications which is presented in the next section. This is followed by an item by item discussion of the location and assembly process itself.

3.2 PARTS LISTS AND AVAILABLE DRAWINGS

The optical components, shown in Figures 3 and 4, are for the most part built around 26 standard NRC mounts, listed in Table III.

TABLE III. LISTING OF STANDARD NRC MOUNTS

Part	Quantity
NRC 600A-4R	1
NRC MM-0	3
NRC MM-2A	5
NRC GM-2	5
NRC MM2-1A	5
NRC 600A2	4
NRC 600A-3	3

At each station however additional GE fabricated components are needed to complete the function. Table IV lists the shop drawings associated with each mount. In general all of the components for each optical station are complete and collected together in one box.

The most critical unpacking process of course, is the optical component (O) itself. Once unpacked it is difficult to identify except when mounted in the tagged optical mount as hardware and/or located in the proper station on the optical bench. The optical characteristics of the optical component required at each site are noted in Table IV. We recommend that each unwrapped optical component always be kept in its assigned place. The packing status, assembled or unassembled is noted, in the list, for each station.

TABLE IV. OPTICAL COMPONENTS - PARTS LIST

PACKING SUMMARY OF THE SMALL OPTICS SYMBOLS:

(O)	Optical Component
(M)	Angle Mount
(H)	Parts for Mounting
(SS)	Shipping Status
(BCA)	Boxed Complete, Assembled
(BCU)	Boxed Complete but Unassembled

Station		
1	(O)	101 mm dia. 1st surface reflector, 1296 mm radius of curvature, coated aluminum with monoxide overcoat oriel part no. 4475.
	(M)	Optical mount NRC Part No. 600A-4R
	(H)	SK56157-C194-97P9 (4" centerline)
	(SS)	BCA
2	(O)	Elliptical Pyrex mirror 46.7 mm minor axis, 66.04 mm major axis, ER-1 coating, NRC Part No. 18E20
	(M)	Optical Mount NRC Part No. MM-1
	(H)	SK56157-B194-99P1 and SK56157-B194-98P1 (4" center line)
	(SS)	BCU
3	(O)	Copper Diagonal
	(M)	Optical Mount NRC Part No. MM-1
	(H)	SK56157-B174-99P and SK56157-B194-98P1 (4" center line)
	(SS)	BCU
4,4A	(O)	Sharp edge carbon ring, two
	(M)	41 mm ID fixed shroud (two)
	(H)	SK56157-B194-103P1, SK56157-B194-101P1 and SK56157-B194-102P1 (4" centerline), two sets.
	(SS)	BCA
5	(O)	Fixed mirror 60 CM
	(H)	SK56157-E1[illegible]-89P1 (8" center line)
	(SS)	5(O) and 5(H) boxed separately
6	(O)	Convex copper spherical 30 cm FL, 60 CM R.
	(M)	NRC part no. MM-2A
	(H)	SK56157-B194-99P2 and SK56152-B194-98P2 (8" centerline)
	(SS)	BCU

TABLE IV. OPTICAL COMPONENTS - PARTS LIST
(Continued)

Station		
7	(O)	12" × 17" perforated diagonal and 2.6" minor axis diagonal
	(M)	Both 45° fixed
	(H)	SK56157-E194-87P1
	(SS)	7(O) and 7(H) boxed separately
8	(O)	Alignment accessories (a) Temporary inverted telescope (b) Temporary rifle scope (c) 10μ corner reflector
	(M)	Temporary scope mount
	(H)	Incomplete 8" centerline
	(SS)	Incomplete
9	(O)	25/75 beam splitter, 1" × 2" ZnSe .12" thick, x/40 flat, AR coated one side for < .5% R with perpendicular polarization at 45° E vector parallel to short side II-VI.
	(M)	Gimbal mount NRC Part No. GM-2
	(H)	SK56157-C194-97P1 and SK56157-B194-100P (4" centerline)
	(SS)	BCU
10	(O)	25/75 beam splitter, .8" × 1.2" × .12 thick ZnSe x/40 AR coated one side for < .5% R with polarization perpendicular to plane of incidence and parallel to short side II-VI
	(M)	NRC Part No. MM-2A 1.25" aperture
	(H)	SK56157-C194-97P2 (4" centerline)
	(SS)	BCU
11	(O)	2" diameter first surface concave mirror, 50 cm focal length, aluminum with SiO coated, Oriel Part No. 4447.
	(M)	NRC Part No. GM-2
	(H)	SK56157-C194-97P1 and SK56157-B194-100P1 (4" centerline)
	(SS)	BCA
12	(O)	1" diameter Pyrex flat 10R08 coated, NRC Part No. ER-1
	(M)	Gimbal mount, NRC Part No. MM2-1A
	(H)	SK56157-C194-97P3 (5" centerline)
	(SS)	BCA

TABLE IV. OPTICAL COMPONENTS - PARTS LIST
(Continued)

Station		
13	(O)	Same as 10
	(M)	Same as 10
	(H)	SK56157-C194-97P4
	(SS)	BCU
14	(O)	ZnSe partial reflector x/40 figure 85% reflectivity concave side, A/R coated on plano side, 2 meter radius, 1" diameter .12" thick II-VI
	(M)	To be used with PZT NRC Part No. 600A-2
	(H)	(5" centerline)
	(SS)	BCU
15	(O)	ML302 grating 100L/MM, blazed for 10.3μ, 25 mm diameter, PTR optics
	(M)	NRC Part No. MM2-1A
	(H)	SK56157-C194-97P5, SK56157-B194-100P2 and SK56157-B194-149P1 (5" centerline)
	(SS)	BCU (in same box as 23)
16	(O)	NERC detector (and accessories)
	(H)	-- See Figure 9 (4" centerline)
	(SS)	BCA (Electronics Box attached, empty)
17	(O)	6 Kapton film attenuator
	(H)	SK56157-B194-105P1 and SK56157-B194-104P1 (4-1/2" centerline)
	(SS)	BCU (sheet Kapton also enclosed)
18	(O)	Pyroelectric dual detector and chassis
	(H)	SK56157-194-97-3 (5" centerline)
	(SS)	BCU, electronic chassis empty, 4 pyroelectric detectors enclosed
19	(O)	Same as 11
	(M)	Same as 11
	(H)	SK56157-C194-97P6 and SK56157-B194-100P1 (5" centerline)
	(SS)	BCA
20	(O)	Same as 10 and 13
	(M)	Same as 10 and 13
	(H)	Same as 13 (5" centerline)
	(SS)	BCU

TABLE IV. OPTICAL COMPONENTS - PARTS LIST (Continued)

Station		
21	(O)	Same as 14
	(M)	Same as 14
	(H)	Same as 14 (5" centerline)
	(SS)	BCU
22	(O)	0.8" by 0.28" ZnSe Brewster window .120" thick II-VI (2 for each of 2 lasers)
	(H)	SK56157-D194-90P1(2) and SK56157-C194-96P1(4)
	(SS)	Two laser tubes boxed (as 22M), four Brewster windows boxed separately as 22(O). Two large laser chassis,(H), marked 22, unboxed.
23	(O)	Same as 15
	(M)	Same as 15
	(H)	Same as 15 (5" centerline)
	(SS)	BCU, in same box as 15
24	(O)	Same as 12
	(M)	Same as 12
	(H)	SK56157-C194-97P2
	(SS)	BCA
25	(O)	Bragg modulator made by Isomet
	(H)	-- (5" centerline)
	(SS)	BCA
26	(O)	Same as 11 and 19
	(M)	Same as 11 and 19
	(H)	Same as 19 (5" centerline)
	(SS)	BCA
27	(O)	Pyroelectric single detector chassis
	(M)	Plate
	(H)	C-194 97-6 (5" centerline)
	(SS)	Mount and empty electronic chassis boxed, 4 pyroelectric detectors enclosed in box SO #18.
28	(O)	Same as 10
	(M)	Same as 10
	(H)	SK56157-C194-97P2 (5" centerline)
	(SS)	BCU

TABLE IV. OPTICAL COMPONENTS - PARTS LIST
(Continued)

Station		
29	(O)	Glass sliver 1-1/2" × 1/8" × 1/64" gold plated
	(M)	NRC Part No. MM-1
	(H)	SK56157-C194-97P7 and SK56157-B194-100P4 (4" centerline)
	(SS)	BCU
30	(O)	Same as 12 and 24
	(M)	Same as 12 and 24
	(H)	Same as 24 (4" centerline)
	(SS)	BCA
31	(O)	3" diameter copper flat with hole
	(M)	NRC Part No. 600A-3
	(H)	SK56157-C194-97P8 and SK56157-B194-100P5 (4" centerline)
	(SS)	BCU
32	(O)	3" diameter scraper
	(M)	NRC Part No. 600A-3
	(H)	SK56157-C194-97P8 and SK56157-B194-100P5 (4" centerline)
	(SS)	BCU
33	(O)	2" diameter convex copper and 2" diameter Lansing PZT
	(M)	NRC Part No. 600A-2
	(H)	SK56157-B194-100P6 and SK56157-C194-97P8 (4" centerline)
	(SS)	BCU
34	(O)	Carbon block, SK56157-B194150
	(H)	SK56157-B194-100P7, SK56157-B94-102P1 and SK56157-B194-151P1 (4" centerline)
	(SS)	BCA
35	(O)	2" diameter copper flat
	(M)	NRC Part No. GM-2
	(H)	SK56157-C194-97P1 and SK56157-B94-100P1 (4" centerline)
	(SS)	BCU

TABLE IV. OPTICAL COMPONENTS - PARTS LIST
(Continued)

Station		
36	(O)	3" diameter copper flat
	(M)	NRC Part No. 600A-3
	(H)	SK56157-C194-97P8 and SK56157-B94-100P5
	(SS)	BCU
37	(O)	NACL window
	(SS)	NACL windows to be shipped in large glass drybox.
38	(O)	Tea laser
	(H)	SK56157-D194-106P1(2) and FABCEL 100 rubber mounts See package of drawing and parts lists of TEA laser, assembly drawing SK56157-194-86.
	(SS)	TEA laser to be shipped mounted on special support but unenclosed.
39	(O)	NACL window NACL windows in glass, dry chamber.
40	(O)	2" diameter concave mirror
	(M)	NRC Part No. 600A-2
	(H)	SK56157-B194-100P6 and SK56157-C194-97P8 (4" centerline)
	(SS)	BCU
41		80 1/4 × 20 NRC bench bolts.
42	(O)	12" × 17" diagonal
	(M)	45° azimuth coelastat mount
	(H)	See package of drawings and parts lists. Scanner assembly dwg. #SK56157-E194-153.
	(SS)	Azimuth and elevation scan optics mounted in scanner and shipped on special unenclosed table. Slip ring assembly not complete.
43	(O)	12" × 17" diagonal
	(M)	45° elevation coelastat mount
	(H)	See package of drawings and parts lists. Scanner assembly dwg. #SK56157-E194-153.
	(SS)	Azimuth and elevation scan optics mounted on scanner and shipped on special unenclosed table.

TABLE IV. OPTICAL COMPONENTS - PARTS LIST
(Continued)

Station		
44	(M) (SS)	NRC custom built 4' × 8' optical bench and legs Shipped unenclosed
45		Special test instruments 10 mW He/Ne laser, Perkin Elmer 124B 10 W laser power meter, Coherent Radiation Labs #201 CO_2 spectrum analyzer, Optical Eng'g Inc., Stanton, Cal. IR viewer (UV fluorescence), Optical Eng'g Inc., Stanton, Cal.

For the most part approximate location on the bench of each of the 44 optical stations is clear from Figure 3. Exact location can only be done by simultaneous positioning and orientation using a visible (He/Ne) alignment laser. This process is discussed in the "operation" (Volume II) manual.

3.3 ASSEMBLY PROCEDURES

Most of the mirrors to be gimbal mounted can be held in their mount with nylon screws in threaded holes already in place. For the very heavy mirrors, like #7, special clamps and bands have been provided. In all cases, of course, the forces used must be minimized. For those few cases where a cement must be used we recommend a thin layer of soft, resilient cement such as one of the sulphide based epoxies. If this is not available ordinary epoxy is adequate if a single spot of cement is used and the area of the bond is kept small, about 3/8" diameter. Epoxy is stronger than glass and differential contraction will cause the epoxy to pull out a chunk of glass and/or distort the mirror surface if a large area is used. In the case of partially obscuring mirrors such as #2, #3 and #6 the positioning must be done such as to minimize the effect of the rod support itself. That is the rods should be located such as to minimize the area of their common shadow.

Mirrors #5, 7, 42 and 43 are very large in diameter compared to their thickness and all have been precision ground and polished to correct figure within a fraction of a wavelength. Any non-uniform clamping stress will distort this figure. Our clamps have been designed to give uniform support but it will be up to the assembler to see that gasketing and tightening of clamps is sufficient for support but insufficient to distort.

Mirror #7 (Figure 8) has a 2" diameter perforation that is used for target observation via the telescope at position #8. The perforation is also useful in other configurations such as when the secondary mirror #6 is located behind #7. The drill chips around the perforation are not illuminated normally but a cardboard annulus should be put over the chipped area to prevent spurious reflections if accidentally illuminated by the laser beam. Mirrors #7, 42 and 43 are 17" long and only 1" thick. To maintain their diffraction limited figure requires that firm support be obtained primarily by means of the band around the perimeter. The clamping fingers should be little more than finger tight and any beam bending forces be minimized by using soft pads. Mirror #5 is an aspheric, Dall-Kirkham ellipse. It produces collimated in-collimated out beams only when used with the spherical secondary, #6, for which it was designed.

Optical position #8 provides a position for the operator to observe the general direction of scanner pointing. It can be used for aiding initial alignment but since its view is not perturbed either by transmitting optics (3 and 32), receiver optics (1 and 2) or collimating optics (5 and 6) it can not be used to include intermediate stages of system alignment. The views looking into beam splitters #9 and #32 are used for this.

Position eight is used to provide visual check of the target areas. The preferred optics of position #8 is a large aperture spotting telescope (with reticle and zoom eye piece providing say X5 to X20 magnification) and/or a closed circuit TV camera with monitor located in the central control room, depending upon customer applications. Initial alignment by the naked eye or low power rifle scope is adequate. We have provided a rifle scope and a wide field inverting telescope for temporary use. Final alignment should be done at the operating wavelength using the full transmitter and receiver optics and a strong point target provided by a diffraction limited retro reflector. A 2" cube reflector is supplied in package SO #8.

The beam splitters at positions 9 and 10, 13 and 20 must be mounted either with nylon screws or with a soft epoxy at their corners. In each case the long axis is horizontal and the A/R coating is on the side away from the detector.

Laser mirrors #14 and #21 are to be mounted in the PZT cavity length controller, with the concave side toward the laser.

Laser gratings 15 and 23 are to be mounted with the grating lines horizontal. It is important to construct a plastic (or hard board) shelter over the grating to keep dust out and yet allow occasional angle alignment. Note that the NERC cryogenic detector, SO #16, Figure 9, needs electronic circuitry, DC bias and high frequency preamp, mounted as close as possible to minimize distributed capacity loading of the detector and RFI pickup. There are two detectors mounted on the dewar tongue. One should be reserved for final, high sensitivity operation and used only after all danger of damage due to laser misalignment has been removed.

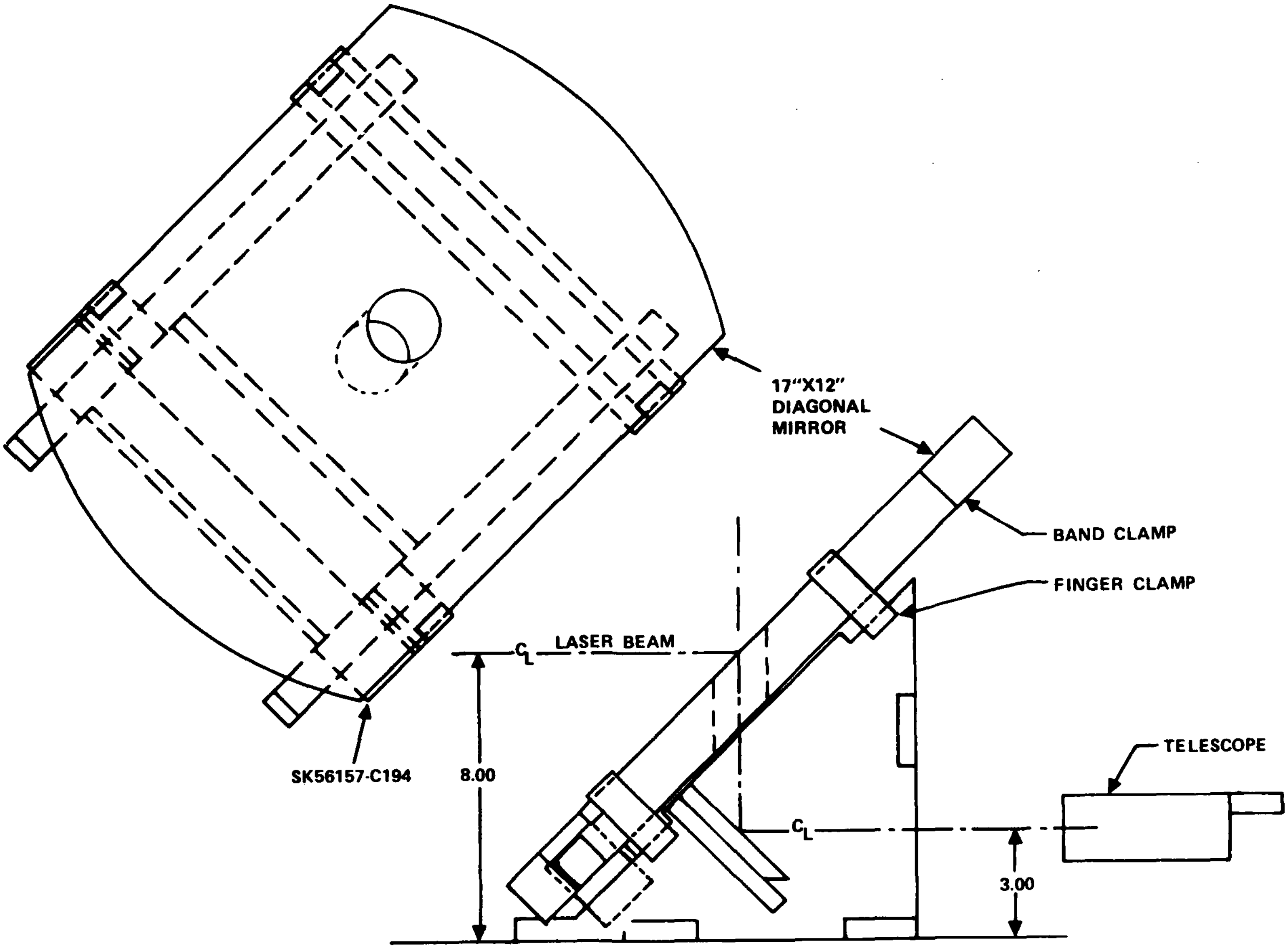


Figure 8. Twelve-inch Output-Beam Coupler (Station #7)

Figure 9 shows the detector dewar and its attached electronics chassis. These parts are all packed in box SO #16. Note that the LO and injection beams pass by quite closely. From Figure 3 it is also evident that high power 10μ energy originating in the TEA laser could find its way into the detector window via multiple scattering from surfaces involving #3, #4, and the optical table itself. To prevent this it is wise to install a series of temporary plexiglas baffles along the path leading up to the detector. These can be removed when it is necessary to get at various components.

The Kapton attenuators of #17 are used to bring the TEA AFC pickoff power down to the required signal level of the detector. They are, like any plastic, birefringent and thus not accurately calibrated (about X8 each element).

The dual pyro-electric (Molectron, P1-71) detectors (Figure 10), provide dither signals for LO and injection laser AFC from position #18. Another pyroelectric detector is used at position #27 for TEA power monitor. (Figure 11.) Four detectors (one spare) have been packed in box SO #18. Note that the detectors themselves have no window and must be handled carefully to prevent damage.

The two double chamber, plasma and cooling water, glass laser tubes have been separately packed in box SO #22. They must be unpacked very carefully to avoid damaging the ground window surfaces or electrodes. These tubes (see Figure 12), are constructed with more or less standard CO_2 laser techniques except that they are intended to have single longitudinal mode, single transverse mode output and the high degree of coherence necessary for heterodyne operation. Heterodyne operation is discussed in the operation manual. We describe here only critical mechanical considerations.

For this task GE designed its own heterodyne lasers since all commercial heterodyne-quality lasers are prefilled. Prefilled CO_2 lasers have only short shelf life, are apt to have plasma noise problems and their center frequency is not as precise as low pressure units. The Invar bases for the lasers are intended to hold the length and the frequency of the lasers constant irrespective of room temperature changes. While the dither electronic AFC will do this, aluminum or steel bases will also distort in angle or change longitudinal mode often enough to be disturbing for doppler systems. If both ends of the Invar laser chassis are clamped to the stainless steel table they will take on the table's thermal distortion. Laser bases #22 should be fastened at one end only, using clamps at the other end only to prevent overall accidental misalignment.

Mounting the Brewster windows on the ground ends of the laser tubes should be done using a neoprene elliptical annulus as a gasket and RTV as a seal (or no cement at all). The vacuum pump and gas supply can be connected with standard rubber, 1/4" × 3/4", hose. All rubber hose is packed with a talcum powder desiccant. This is an extremely effective attenuator when it collects on 10μ optics. Windows will occasionally have to be removed for cleaning. The Brewster windows must be oriented such as to propagate

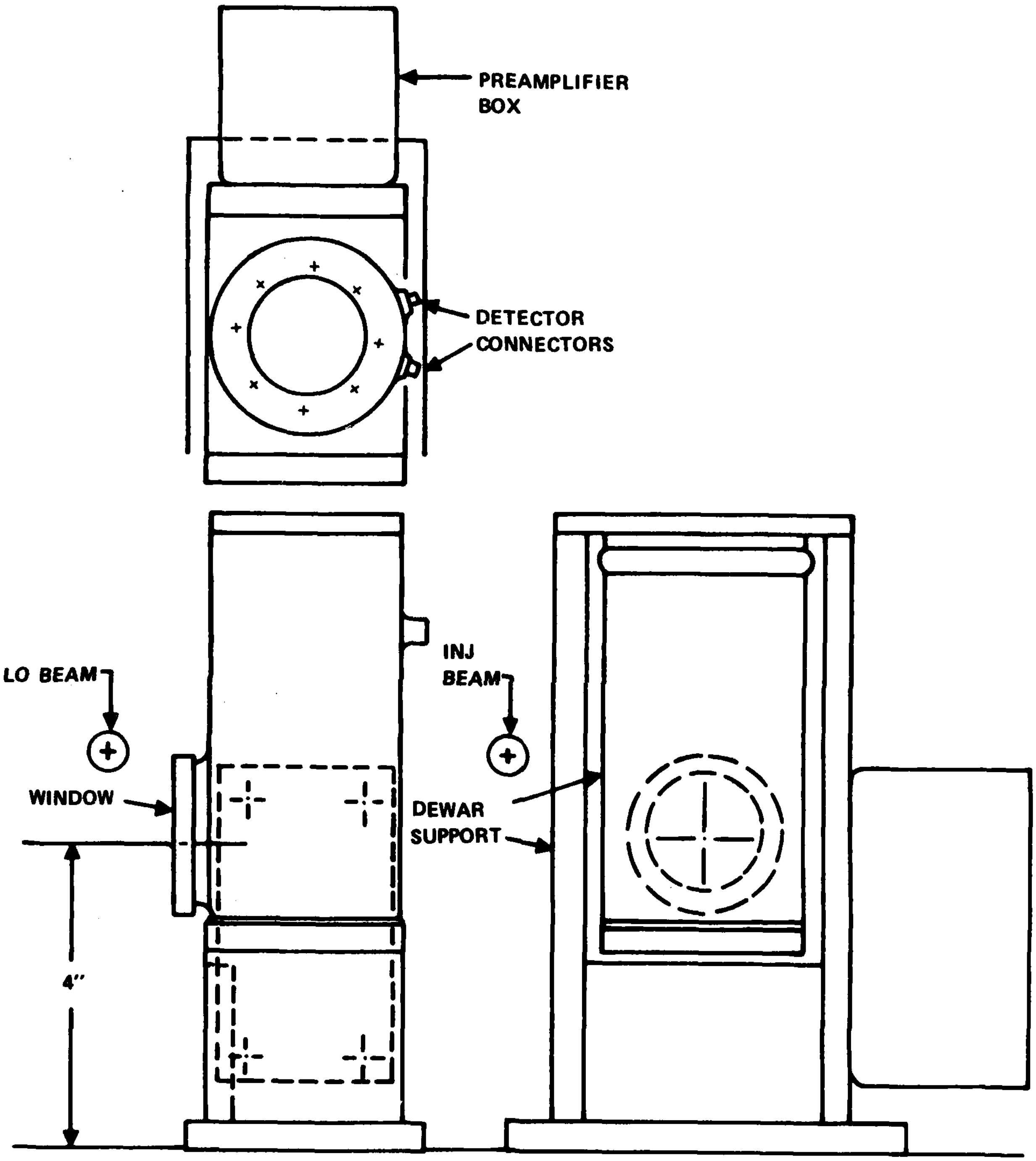


Figure 9. Cryogenic Detector, SO #16

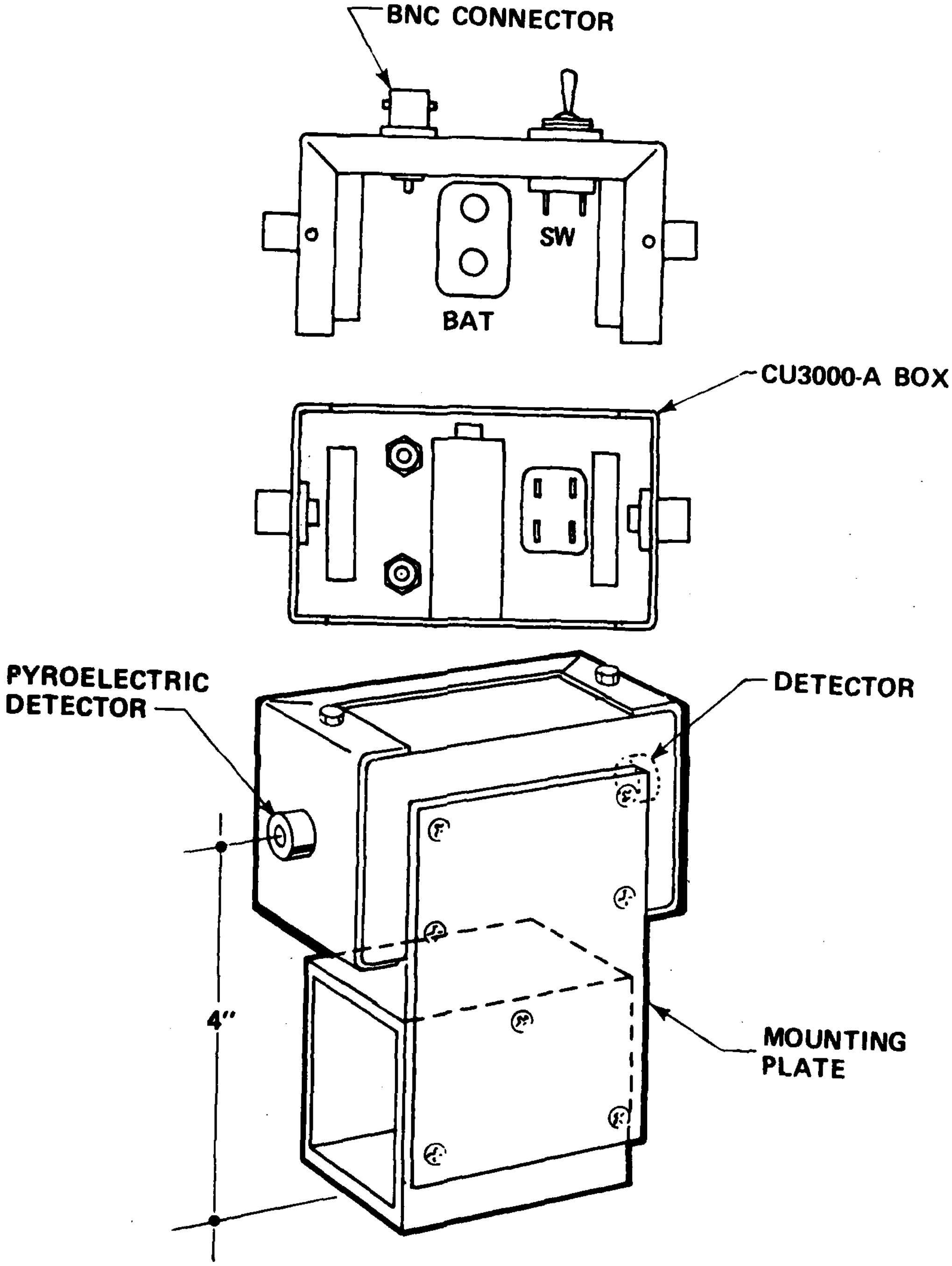


Figure 10. Dual Pyroelectric Detector Station #18

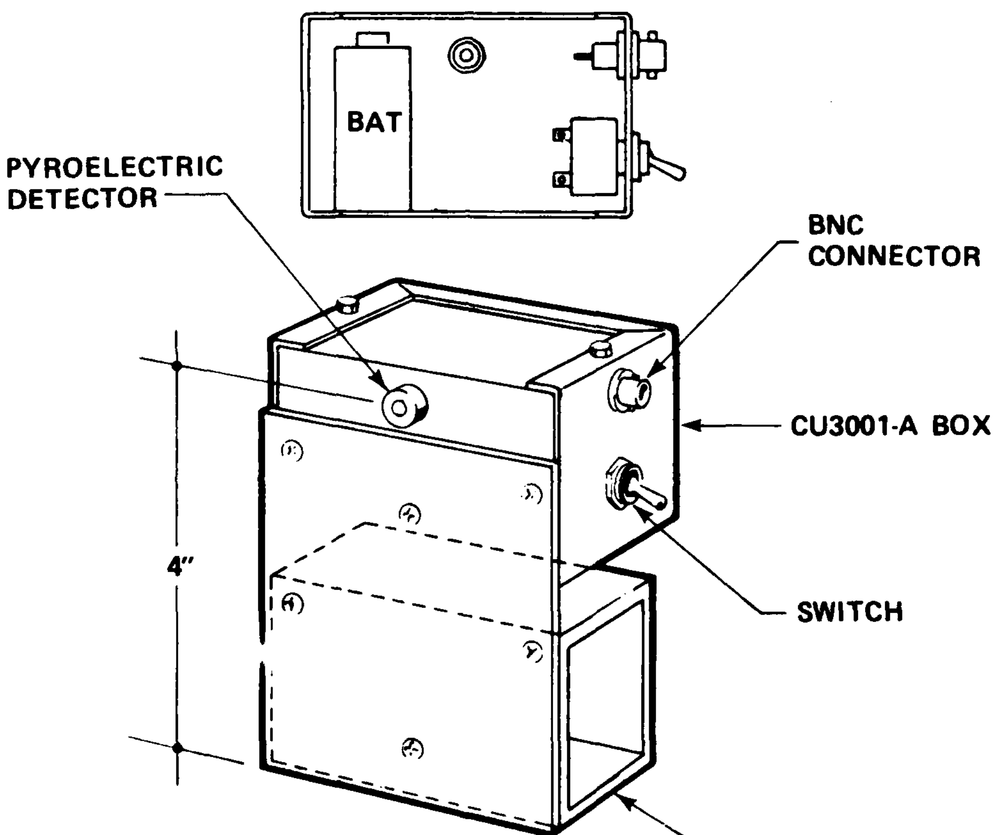


Figure 11. Single Pyroelectric Detector Station #27

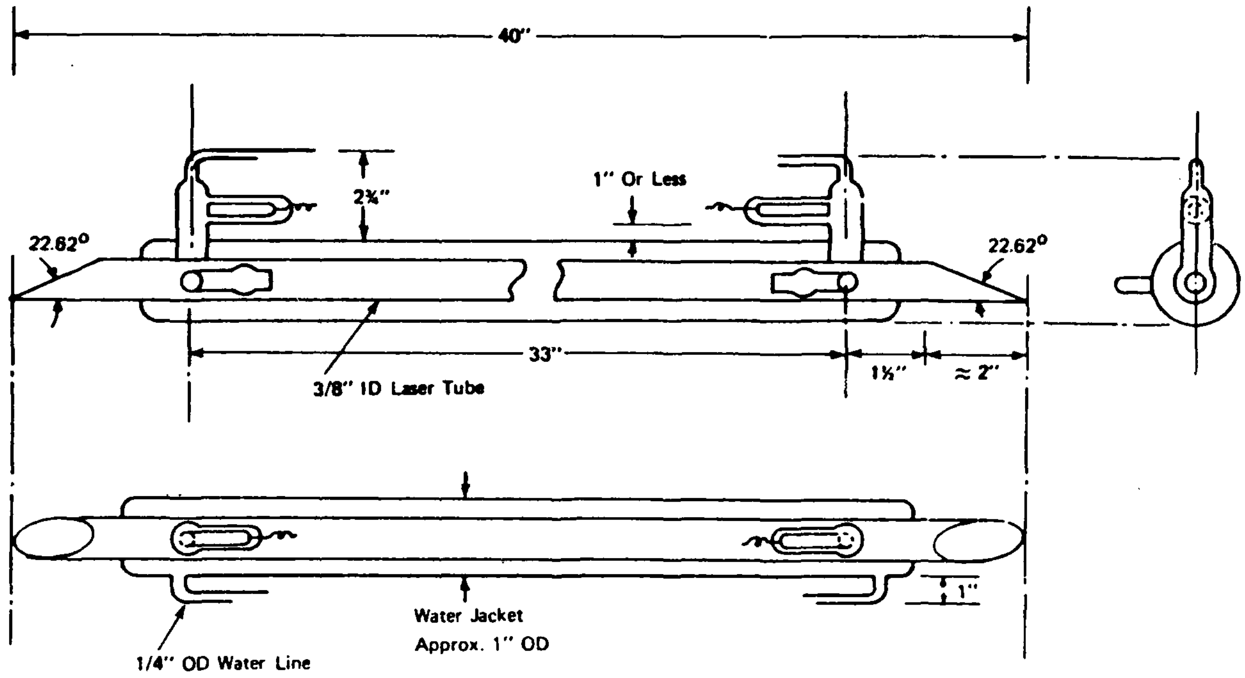


Figure 12. Flowing Gas LO/Injection Laser Tube

vertical polarization. i.e. The plane of the window plus laser beam must be vertical. The operator could get a lethal shock when touching the Brewster windows or plasma electrodes. Thus these areas should be marked conspicuously and/or covered.

Water coolant tubes should connect the two lasers and the Bragg modulator in series. The flow should be interlocked to turn off the power when the total flow is less than 0.1 gpm. The water pressure should be regulated to be less than about 30 psi (for the glass). See upper view of Figure 13. The premixed CO_2 gas supply (75% He, 15% N_2, 10% CO_2) is connected to the system through the high pressure gas regulator supplied (box # EL29). The gas is reduced to about 5 psi (above atmospheric) and reduced again with the needle value leading to the two lasers in parallel. The paralleled laser exhausts go to the low speed, belt driven, vacuum pump. The pressure is monitored by the 50 Torr vacuum gauge (packed in a box marked SO #22) connected to the inlet side of the lasers. The gauge can be mounted anywhere on the top of the optics bench. Optimum pressure is about 15 Torr. See upper view of Figure 14.

Depending upon the excitation level and alignment the output of the laser may be multiple transverse mode and/or its frequency may wander somewhat with angle disturbances of the mirrors unless two small, on-axis apertures are provided in the laser cavity at the grating and output mirrors. The optimum size of this aperture (about 1/8") will depend on the desired output power.

The process of aligning and tuning these lasers for the center of the P-20 line and setting the discrete LO and injection power levels requires (1) a laser spectrum analyzer such as that made by Optical Engineering, Stanford, CA., (2) a laser power meter like the model 201 made by Coherent Radiation Co., (3) a 10μ viewer like the thermally quenched UV fluorescence unit made by Optical Engineering, and (4) a He/Ne laser of at least 10 mW output like the Spectra Physics 124B.

The Bragg modulator (see Isomet Company, technical specification sheet in box of service manuals), station 25, splits the beam from the injection laser into a frequency shifted, pulse modulated beam and a residual beam that exits at an angle of about 5° lower. The residual beam should be absorbed in a block of carbon. The incoming beam has to be tilted downward about 2-1/2° in order to react properly with the 40 MHz acoustic wave internal to the modulator, and the modulator must be located at the focus of mirror 19. The angles and positions of the beam relative to the modulator are critical and will have to be iteratively positioned before final locking. The incoming copper or plastic water hoses need be no more than 1/8" ID but must be sufficiently flexible to allow this repeated adjustment. The cooling water is in series (see Figure 13) with the low pressure lasers. Flow should be interlocked to turn off the 40 MHz driver if water supply should fail as discussed under electrical unit EL #22.

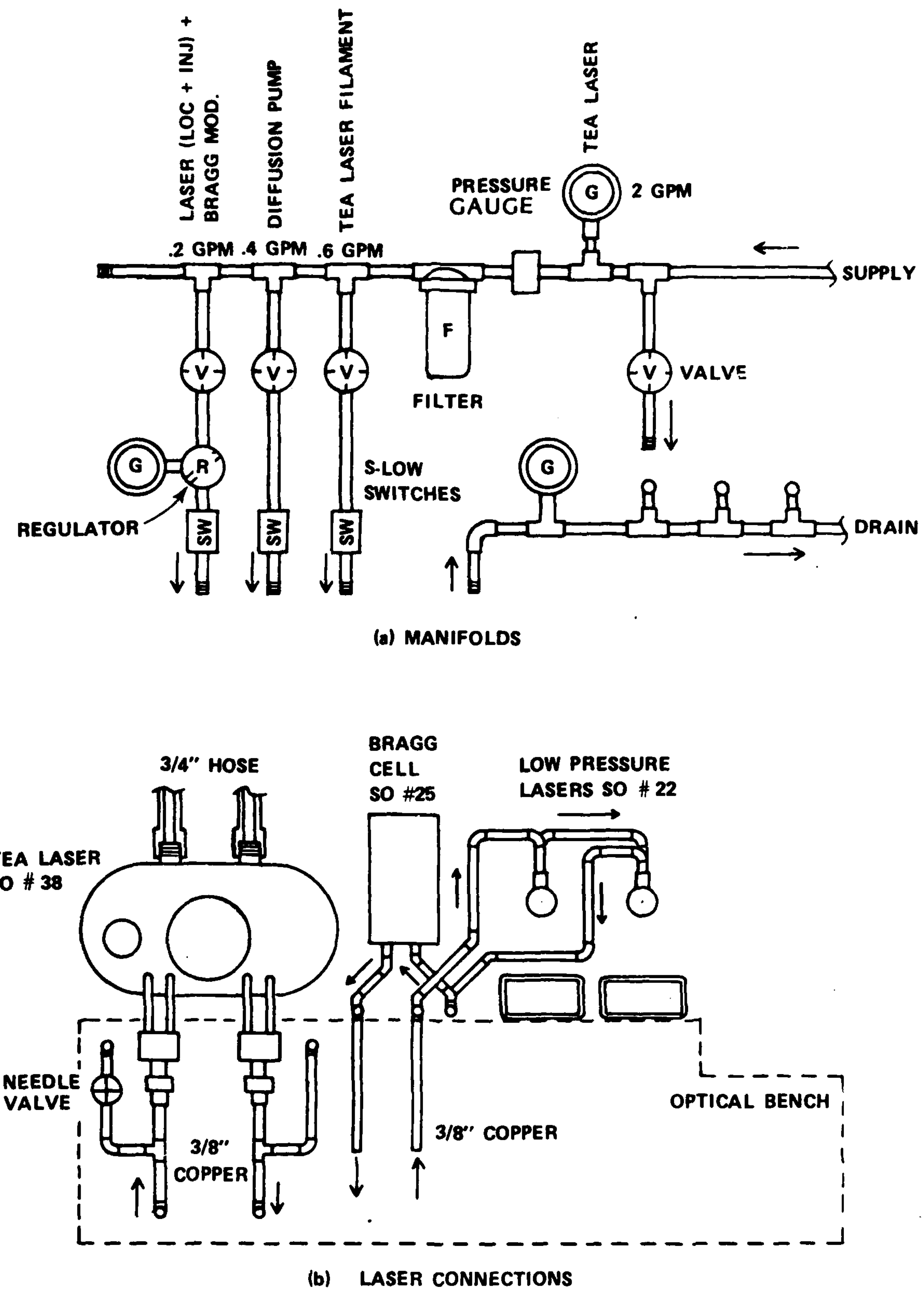


Figure 13. Water Flow

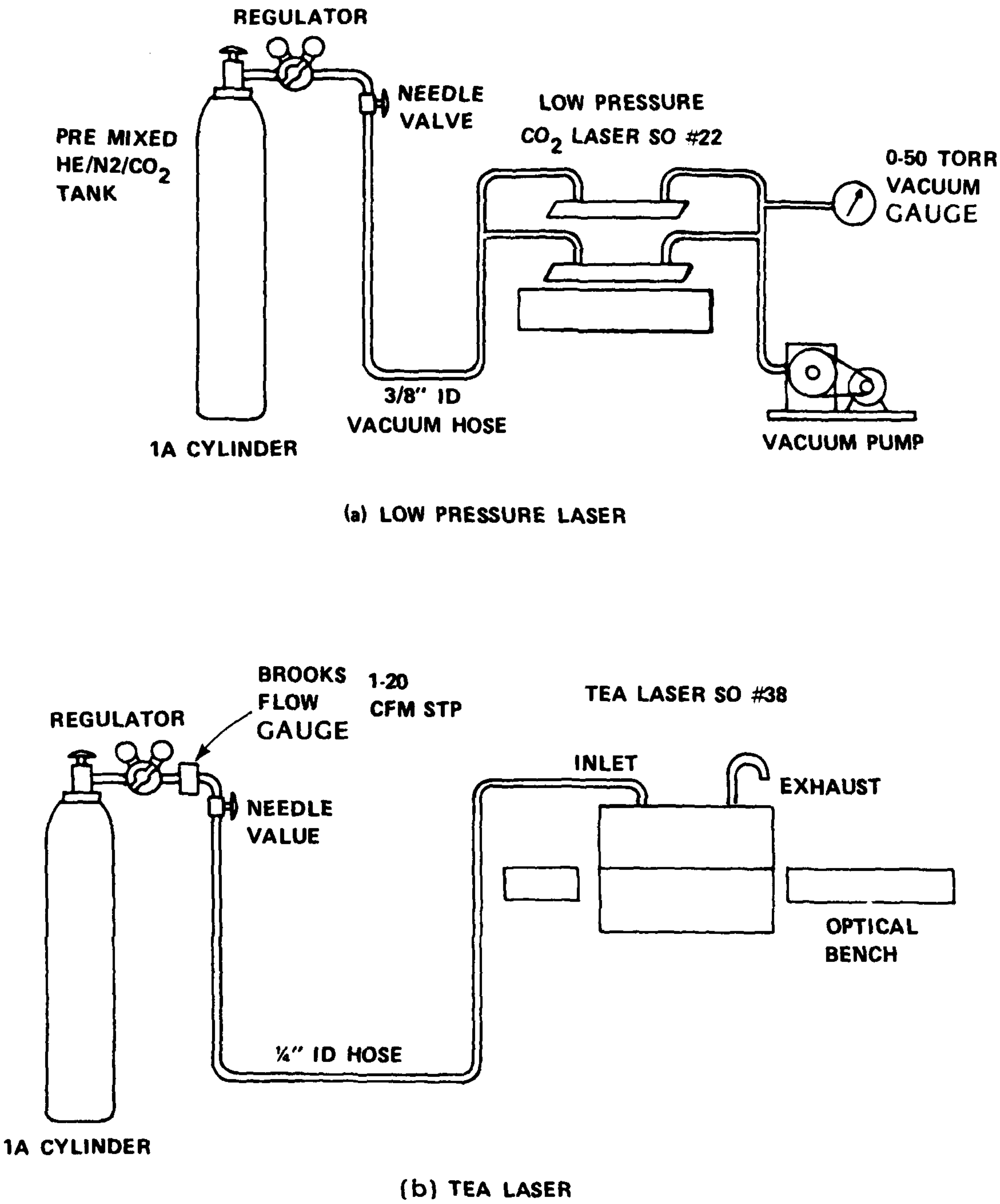


Figure 14. CO_2 Laser Gas System (EL #29)

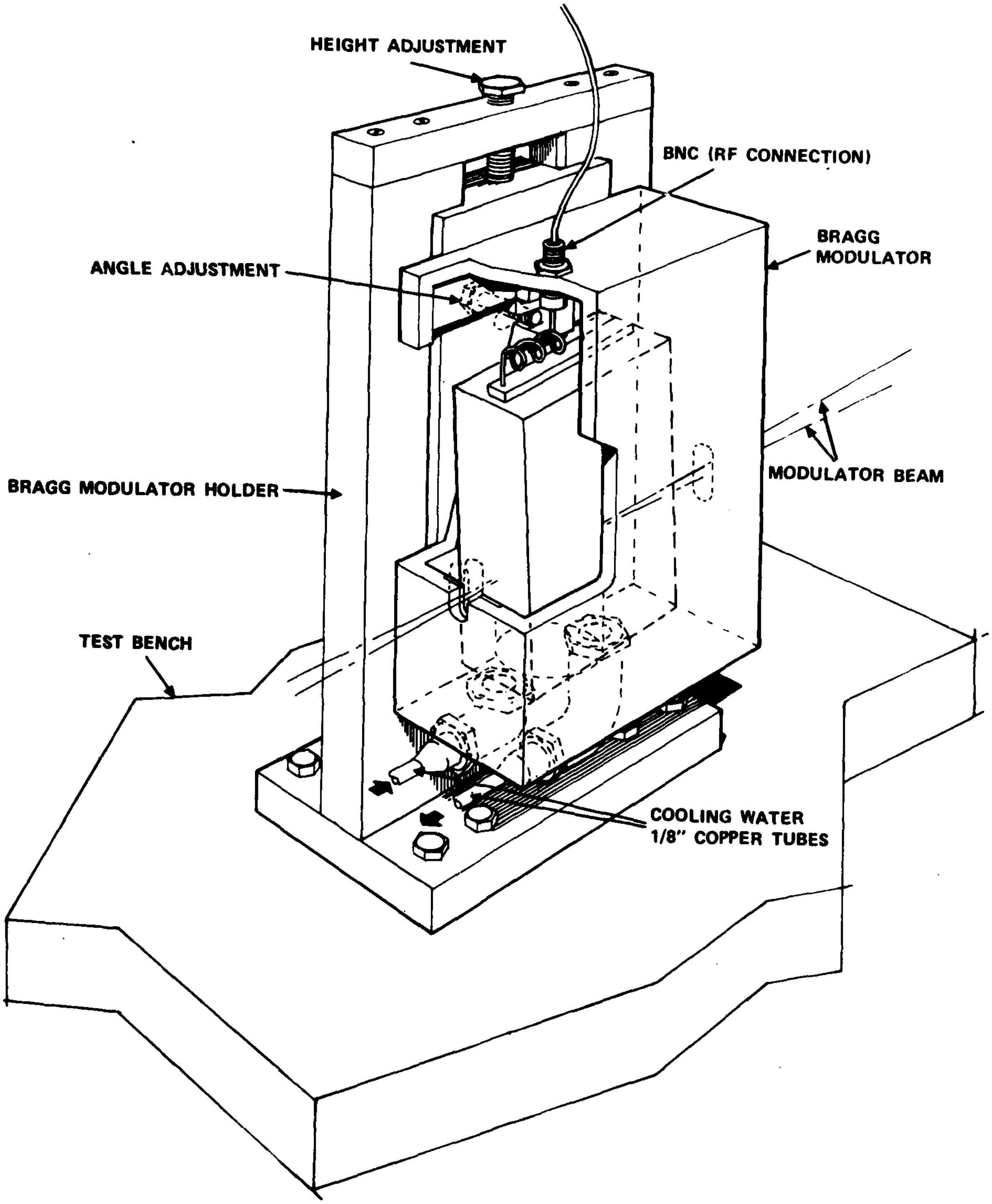


Figure 15. Bragg Modulator, Station 25

At position #29 there is a gold plated "sliver" mirror intended to pick off a small, coherent sample of the TEA laser output for the TEA AFC and power monitor #27. The mirror and mount are packed, unassembled, in box SO #29. Assembly of the group relative to the TEA laser beam is shown in Figure 16.

The high power laser windows at positions 37 and 39 are made of polished single crystal sodium chloride. Since this material absorbs moisture and deteriorates rapidly at relative humidities above about 10% it is important not to remove them from the sealed desiccant chamber until ready to mount and hold continuously at an elevated temperature of about 110°F. Windows should only be handled when wearing rubber gloves. The windows must be mounted with rubber gasket and compressed sufficiently to maintain a hermetic seal. The gaskets must not be allowed to protrude into the laser beam as they will smoke up the windows. The window heaters are connected to the NACL heater control panel EL #35 as discussed in the electrical section. The windows are shipped in a large, fragile, glass dry box — marked SO #37/39.

The copper mirrors, #3, 6, 31, 32, 33, 35, 36, and 40 and absorbers 4A, 4B and 34 get quite warm in operation and should be mounted to minimize heating by the wings of the laser beam, i.e. centered.

The optical bench, #44, was custom made, by NRC, to accommodate the large optics on a subdeck and the TEA laser in a special reinforced cutout, (see Figure 17).

The TEA laser is to be mounted, at the reinforced mounting holes marked on the table, on the 1/4" thick isolation pads provided. The bolts are to be loose except during travel. The three table legs are located so as to balance its load when fully assembled but heavy loads should be confined to the support area. The legs are to be bolted to the floor. Rubber pads lie between the table and the legs. The bolts between the table and its legs are to be left finger tight except while travelling. Three legs and the 1/4" rubber pads should allow sufficient kinematic isolation to prevent floor deflections from misaligning the laser optics. If not, thicker rubber pads may be required.

The table top is drilled and tapped every 1" with 1/4-20 mounting holes. These holes open into the aluminum honeycomb between the quarter-inch stainless steel deck and bottom plates. If a water connection breaks or rain comes in the elevator hatch and floods the table top there is no easy way the table can be dried out. In about a year the honeycomb will corrode and damage the table structural integrity. It is imperative that the TEA laser clear the floor beneath it by at least 28 inches (preferably 29 inches) since the E-beam modulator (EL #3d) and sustainer capacitor box (EL #1b) fit closely.

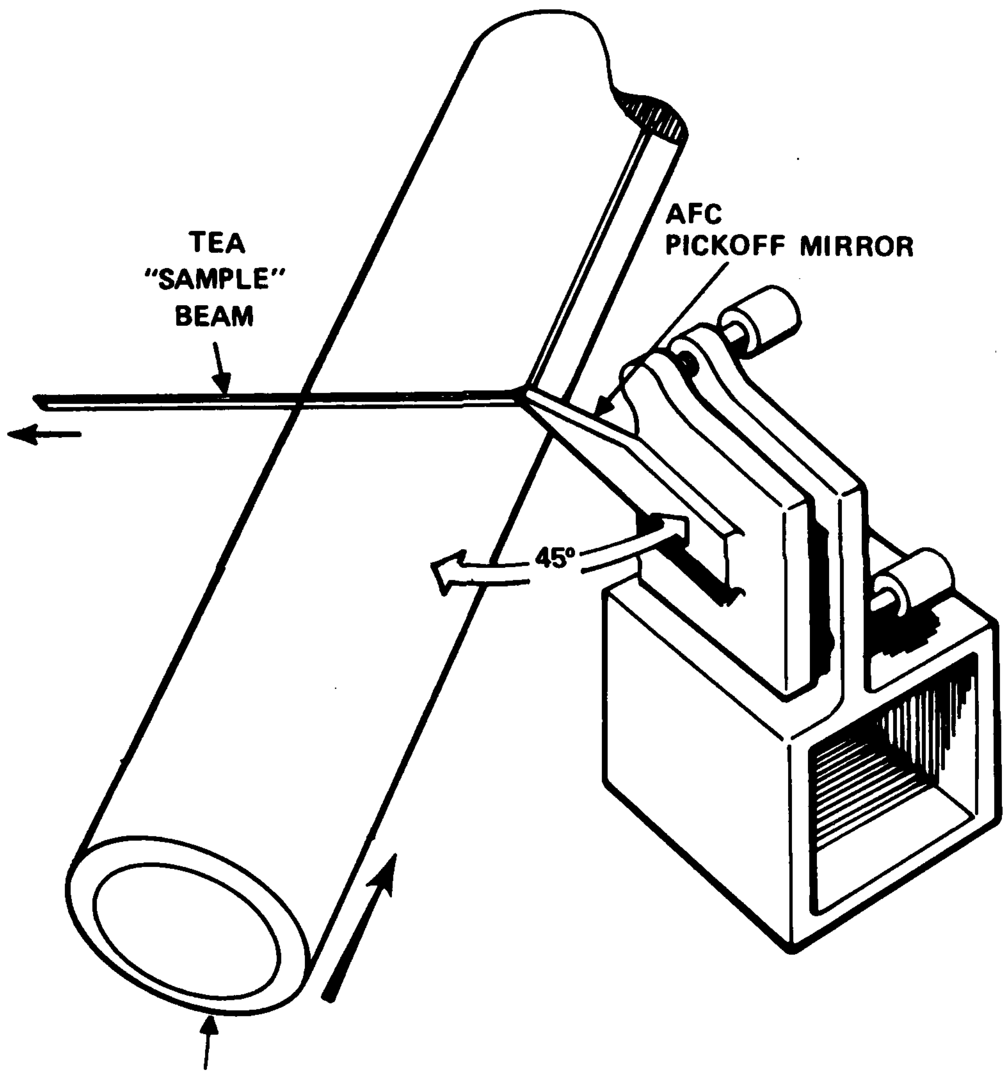


Figure 16. AFC Optical Pickoff, SO #29

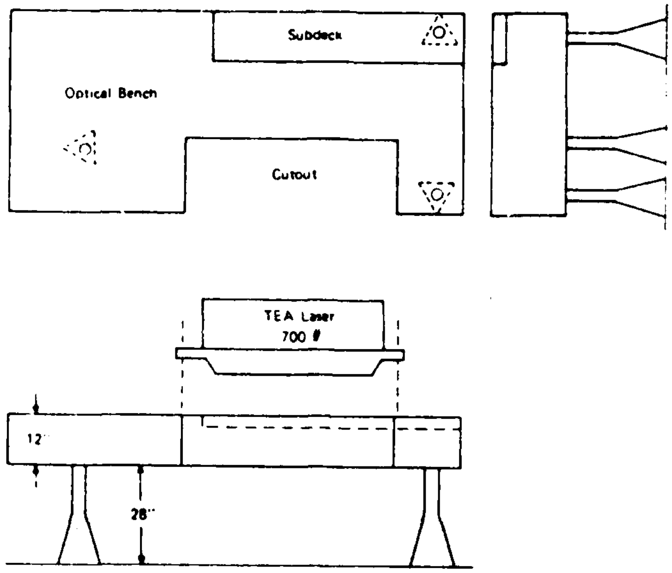


Figure 17. Optical Bench

The TEA laser, station #38, is a complex electro-mechanical system. As with the 44 element optical mount array just described and the scanner to be discussed later, a full set of mechanical drawings, cataloged by parts list and SK number, are supplied in separate folders. However, since the laser has been tested and is shipped fully assembled it will not require a major assembly effort.

Figure 18 shows TEA laser internally. The upper portion is the TEA laser proper with its cooling fans, heat exchanger, sustainer anode, sustainer cathode and electron window operating with premixed He/Ne/CO_2 at atmospheric pressure. The lower portion is the water cooled electron gun with a 1 kW tungsten filament in the vacuum. The gun uses 120 kV pulses at 1 kW average power, and the sustainer uses 20 kV at 5 kW. Under these circumstances arc-over prevention and water cooling are part of the mechanical problem. Figure 13, lower, shows the water cooling connections. The heat exchanger in the top of the laser requires 2 gpm. The vacuum box of the electron gun is cooled by feeding water into the bottom left (low) and out at the top right (high) to prevent air pockets. The two additional cooling lines, for the foil/top plate, are connected in parallel through a quick-disconnect used when replacing the filament. The needle, apportioning, valve should be set to divide the flow about equally between the electron gun box and the foil/top plate.

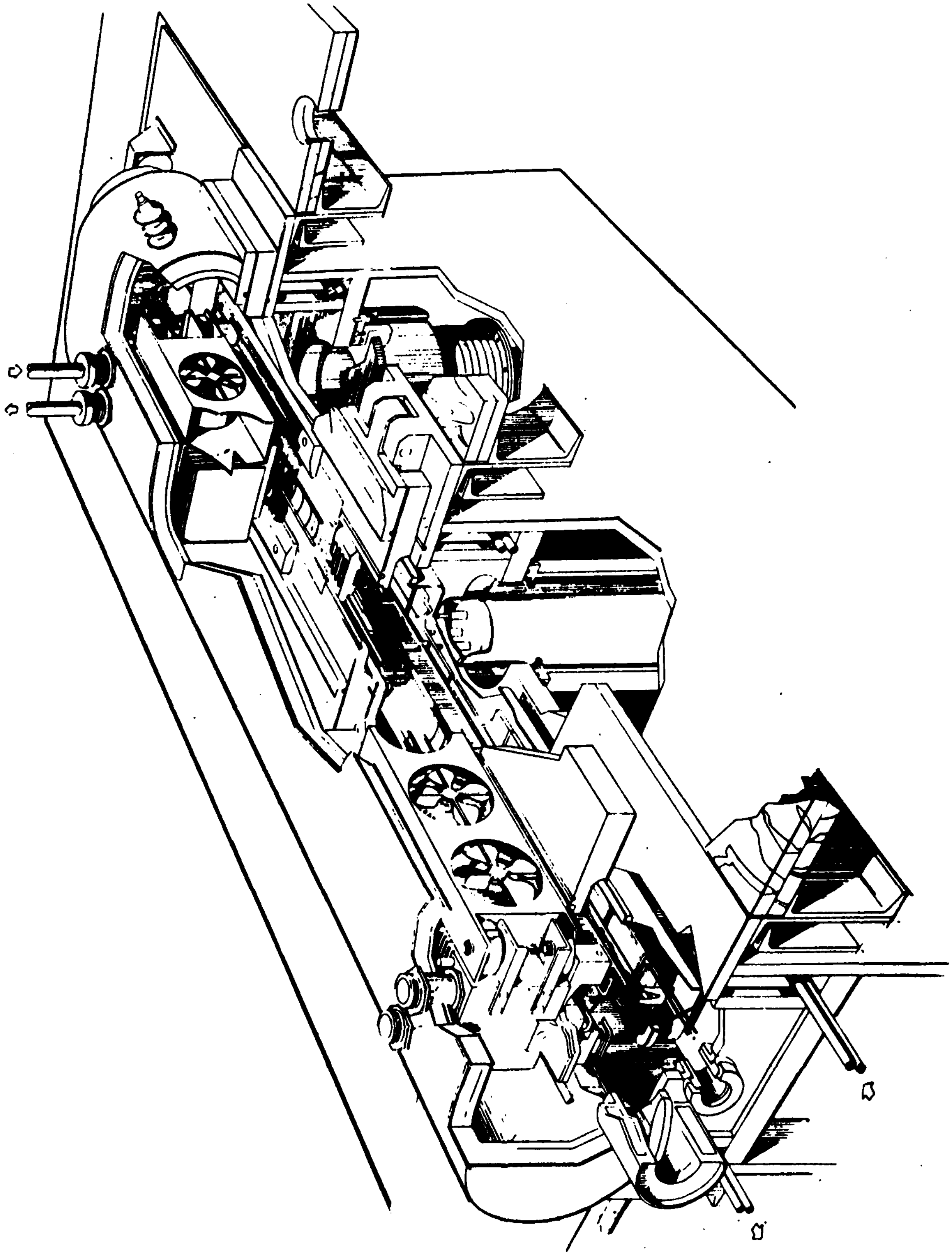


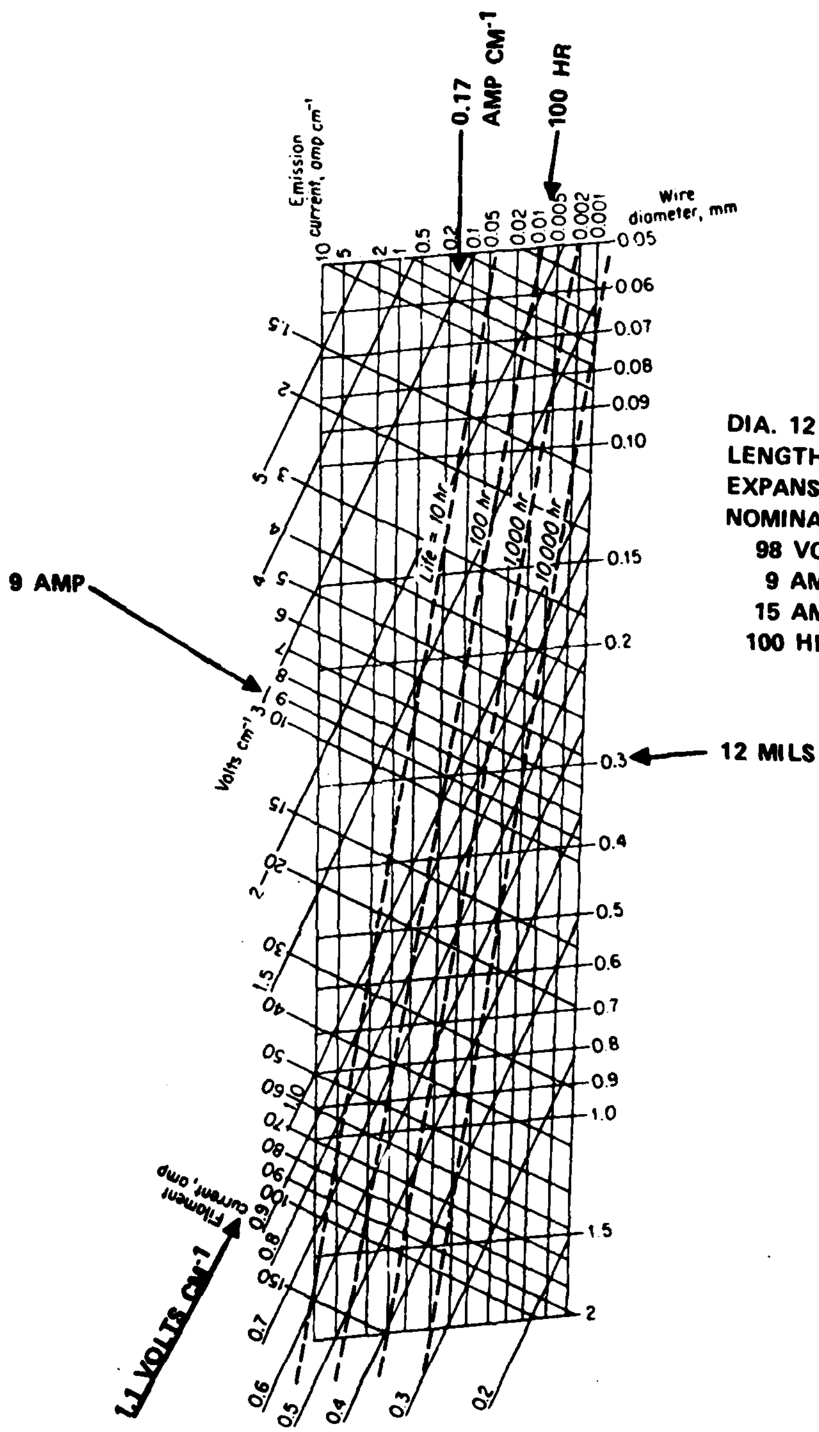
Figure 18. EBI/TEA Laser

The vacuum pump system consists of a direct drive, vane roughing pump, a 4 L/S diffusion pump (see Varian Tech manuals), and water-cooled baffle. After a new filament and/or foil is installed it will take about an hour to pump down to 10^{-5} or 10^{-6} Torr. Bringing the filament up to temperature for the first time will require about 1/2 hour while keeping the vacuum better than 10^{-4}. After operation at full power for a few minutes the system will be degassed to about 5×10^{-6} without E-beam power and 10^{-5} to 5×10^{-5} with E-beam power on. If the pressure approaches 10^{-4} it is time to stop and look for a leak. At this pressure the vacuum gauges can still be used to find the leak quite quickly by painting with acetone and watching for the sudden increase in apparent pressure. Foil leaks can be repaired with RTV.

The filament is 12 mil pure tungsten wire operating at about 9 amperes as shown in Figure 19. The filament expansion (0.9 cm) is taken up by molybdenum springs at each end. The filament is electrically isolated from the cathode tray by ceramic pads. The gun is designed to be used either as a diode or triode. As a triode the tray is biased to cut-off (15 kV) between pulses. In the present case the tray is tied to one side of the filament. Proper electron beam shape, to uniformly illuminate the foil and CO_2 plasma, requires the filament to be located rather exactly in the center of the pan and at the set depth below the beam forming wings (0.3 cm). The filament position is held by three pierced molybdenum plates at the ends and center. The moly plates shield the springs from the intense heat and moly foil in the bottom of the tray keeps it cool and prevents warping. The wings are fastened by screws, tightly only at the center and finger tight elsewhere.

It is important that the E-beam window, titanium foil, be cleaned of grease (rolling mill lard) before using (by overnight soaking in trichloroethylene), and that pump back-streaming be minimized. Otherwise carburization will seriously reduce filament life. The filament is supplied by approximately 100 volts, 9 amperes DC. Control of the filament power determines the (emission limited) beam current and thus the laser output. DC filament heating power is used to prevent excessive 60 Hz "violin string" vibration which can destroy the beam uniformity. The filament power supply can provide a variety of combinations of current and voltage (if different size filament wire is desired), as shown in the Elemek modulator circuit diagram.

Either 0.5 or 0.4 mil titanium foil is used for the electron gun window. Foil failure is by three mechanisms: plasma etch, arc-over or other mechanical piercing and bending-fatigue caused by two stresses. These are (1) the foil sliding over the support edges each time the vacuum is relieved and (2) the pressure change of the shock waves in the pulsed plasma. Plasma etch is reduced by good foil cleaning so it is electrically at the same potential as the foil support plate even during maximum pulse current. Bending-fatigue is minimized by leaving the roughing pump on all the time. Arc-over is eliminated by "floating" the sustainer cathode relative to the foil as much as possible.



DIA. 12 MILS
LENGTH 89 CM
EXPANSION 0.9 CM
NOMINAL OPERATION
98 VOLTS DC
9 AMPERES DC
15 AMPERES PULSE
100 HR. LIFE

FROM SPANGENBURG, "FUNDAMENTALS OF ELECTRON DEVICES" McGRAW HILL p.145

Figure 19. Electron Gun Filament

The procedure for replacing the foil is to unbolt the laser head and tip it back. Then unbolt the foil clamp plate uniformly (1 turn at a time until the O-Ring pressure is relieved). Lay in a new foil. Reclamping the foil requires that one force the clamp plate straight down first with the two auxiliary clamps then successively tighten the several dozen bolts. The use of the clamp plates helps reduce wrinkling caused by the clamp plate and/or foil rolling around on the partially compressed O-ring.

To replace the filament it is necessary to remove the cathode tray. The foil need not be unclamped. First disconnect the water "quick-disconnect" to the foil plate. Then unscrew the foil plate and bolt on the two foil-plate lifting handles provided. Once the foil support plate is lifted back the cathode tray can be disconnected from the leads at the Allen head terminals and the tray disconnected from the insulator bushing tongue by the four screws at the tray flange. When the tray is on the bench a new filament is inserted (after the beam forming wings are removed) by attaching the filament to the moly tension springs. This must be done while the latter are, of course, extended.

Rolls of about 200 feet each of 0.5 mil and .4 mil pin-hole free titanium foil for the E-beam window is enclosed in box marked SO #38. A one pound roll of 12 mil pure tungsten filament is packed in the same box.

Before tilting the laser head back, using the 1-1/4" pipe lifting handles, it is esential to

(1) adjust heat exchanger hose supports

(2) move mirrors 34 and 35

(3) be sure bumpers are in place.

The TEA laser cavity must be hermetically sealed from the atmosphere using the 1/4-20 bolt on the laser head flange to pull the head tight against its O-ring. The laser is provided with about 5 cubic feet per hour at STP of fresh CO_2 in a mixture about 48% He, 40% N_2 and 12% CO_2. It takes about 1 hour to purge the laser volume at this rate after the top has been rebolted.

There are 9, 60 Hz muffin fans used to circulate the CO_2 gas fast enough to remove the ionization (and heat) after each pulse. Cooling the gas with the heat exchanger also cools the foil. We have provided an additional fan assembly equipped with 400 Hz fans that require a 400 Hz power supply. These fans give unity clearing ratio up to 300 pulses per second. The fans are specially lubricated by the manufacturer, to resist the high ozone content in the laser gas.

The x-ray hazard measurements, at the time of this writing, are not complete. We have data on a similar laser taken in 1975 that can be extrapolated, as below, to show the approximate safe exposure rates based on the Federal and NYS safe limits of 5000 millirems/year.

The primary x-ray protection was the 1/2-inch permanent lead shielding incorporated over the top and sides of the laser (see Figure 20). There were however five areas that were not leaded except for temporary shields that must be put in place by the operator.

These uncovered areas were:

(1) The bottom of the gun which exposes the floor area

(2) The laser output beam windows, two

(3) The viewing windows, two in the laser area and two in the gun area

(4) The two cutouts in the side area next to the high voltage electron gun bushing. (During the tests quoted below this cutout area was partly covered by the high voltage pulse transformer.)

(5) The joint between the upper, laser, section and the lower, gun, section.

Without any of the temporary shields in place the worst x-ray radiation hazard was 55 mr/hour at the sides 15" from the joint area, (marked X in Figure 20). This was with 100 kV 20 ampere 8 μs pulses at 300 pulses per second. At 120 kV 15 ampere pulses of 10 μs length and 50 pulses per second, the present system specifications, the dosage would be

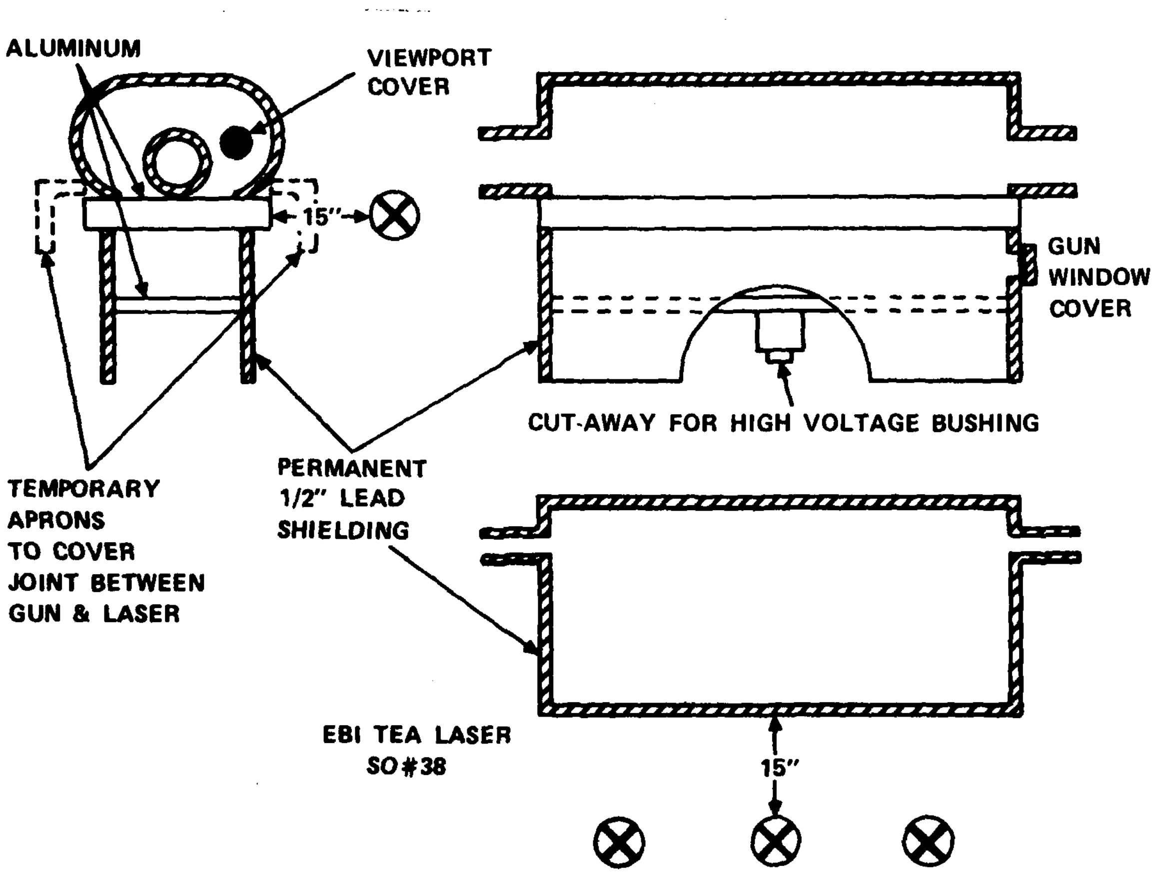
$$\frac{(120)^2}{(100)^2} \times \frac{15}{20} \times \frac{10}{8} \times \frac{50}{300} \times 55 = 12 \text{ mr/hour.}$$

Thus an operator could stand 15" from the laser for 5000/12 = 416 hours per year without endangering himself. If he moves to the other side of the table 45" away the dosage would decrease by 1/9 to 1.3 mr/hour. The federal limit is well above this, 2.5 mr/hour, for a full time 40 hour/week operating position. It is doubtful that the equipment will be used this much.

The "half-level" thickness for monochromatic 100 kV radiation is 0.1 inches. Thus if temporary 0.3" thick lead shields are hung over the critical joint areas, in the plane of the chief source of radiation (which is the titanium foil), the radiation level would have been reduced, for 100 kV monochromatic radiation, to

$$55 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = 6.9 \text{ mr/hour}$$

Since the heavy aluminum base plates have already removed most of the high energy emission this extrapolation is very conservative. It is <u>estimated</u> that for our new laser, at 15", with 0.3" temporary aprons as shown, actual radiation would be well within the 2-1/2 mr/hour federal standard for a full time operator. Additional lead plates have been supplied with the laser. A separate report documents the x-ray hazard of the new laser.



X RADIATION HAZARD SUMMARY

MOST INTENSE RADIATION AT $\otimes$, 15" FROM ALUMINUM BASE PLATE WITH TEMPORARY APRONS REMOVED WAS 55 MILLIROENTGENS/HOUR AT 100KV 20 a, 8 μs 300 PULSES PER SECOND. MEASURED AUG 29 1975.

Figure 20. X-Ray Emission Safety Summary

Mounting of the TEA laser is not critical. The fans are mounted on an internal vibration isolator support on the heat exchanger. The laser vibration itself is isolated from the optical bench by 1/4" pads under the laser support yoke. The yokes are bolted to the optical bench by 4 1/4-20 bolts which are only tightened when the laser radar trailer is to be moved.

The axes of the hinges holding the 500 pound laser head to its base plate are not perfectly coaxial and thus may be excessively stressed as the top is lifted back. We recommend that one of the two outer hinge bolts on each hinge be left only finger tight to avoid possible fatigue failure.

When ready to assemble, lifting the laser and gun onto the optical bench, from the shipping table, must be done very carefully to avoid damage to the high voltage bushing. Chains under the support yoke slung from a chain hoist on a dolly or overhead rail will work well.

The TEA laser scanner is to be placed over the output mirror, #7, on the scanner elevator in the GFE trailer. The scanner should be accurately positioned since the azimuth bearing throat diameter is only 12-1/2" to accommodate the 12" diameter receive beam. Figure 21 shows the nominal dimensions of the scanner and how it might be mounted on the elevator. We have provided a large roll of 0.1 mil mylar film which can be stretched and taped over the exit port or throat of the scanner to keep out the cold. This film is so thin that it has negligible effect on visual boresighting of the system. We believe it will also have negligible effect on the coherence of the beam input and output beams. The transparency is adequate to prevent thermal damage to the film at full laser power. Of course, the film will deteriorate in the presence of sunlight in a relatively short time but it could be useful for operating at high elevation angles in the presence of rain.

Figure 21 shows the key points of the assembled scanner. An assembly drawing, parts drawings and parts lists are supplied in the scanner envelope. The elevation and azimuth axes are driven by gear motors through a chain-belt drive direct to sprockets on the two axes. The gear motors are of such high gear ratios that they cannot be turned by external torque. To prevent in-transit damage to the chain-belts we have removed them from their sprockets but left them hung to their motor mounts for easy locating. The angle sensor belts are separate from the drive belts to avoid angle error under load. All four belts are held to their proper tension by springs that can simply be stretched when a belt is to be wound onto its sprocket. (See Figure 22.) The motor springs are sufficiently tight to handle the specified wind loading. The azimuth drive motor belt, Berg Type 25CCF-250-E and elevation drive motor, 25CCF-90-E have a quarter-inch pitch and are rated at 200 pounds maximum. The encoder belts are 0.13" pitch.

The power to the elevator motor and the signals from the elevator angle encoder is to be carried across the azimuth axis by a set of 7 slip rings contacted by two sets of 7 or 14 brushes. The two brush assemblies, Figure 23, are to be bolted to support angle brackets already in place under the scanner base. Note in Figure 23 that adjacent brushes are to be mounted at

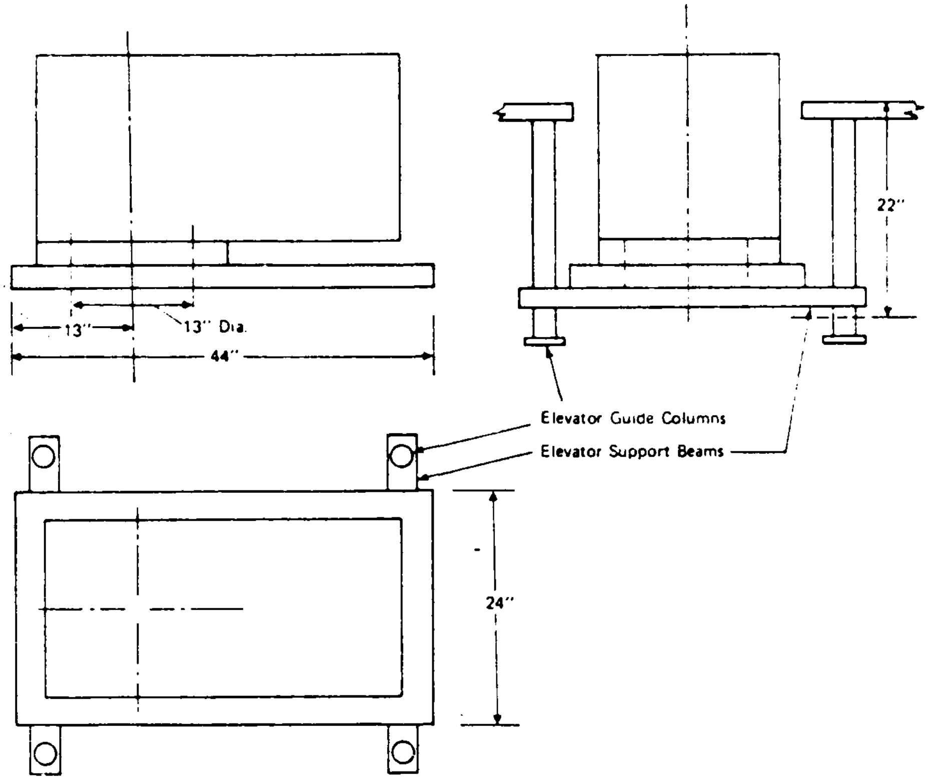


Figure 21a. Scanner Elevator

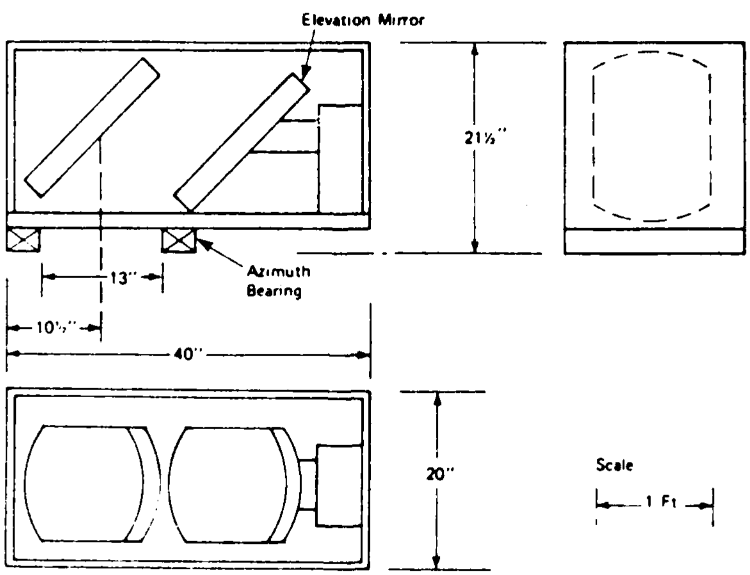


Figure 21b. Scanner Cross Section

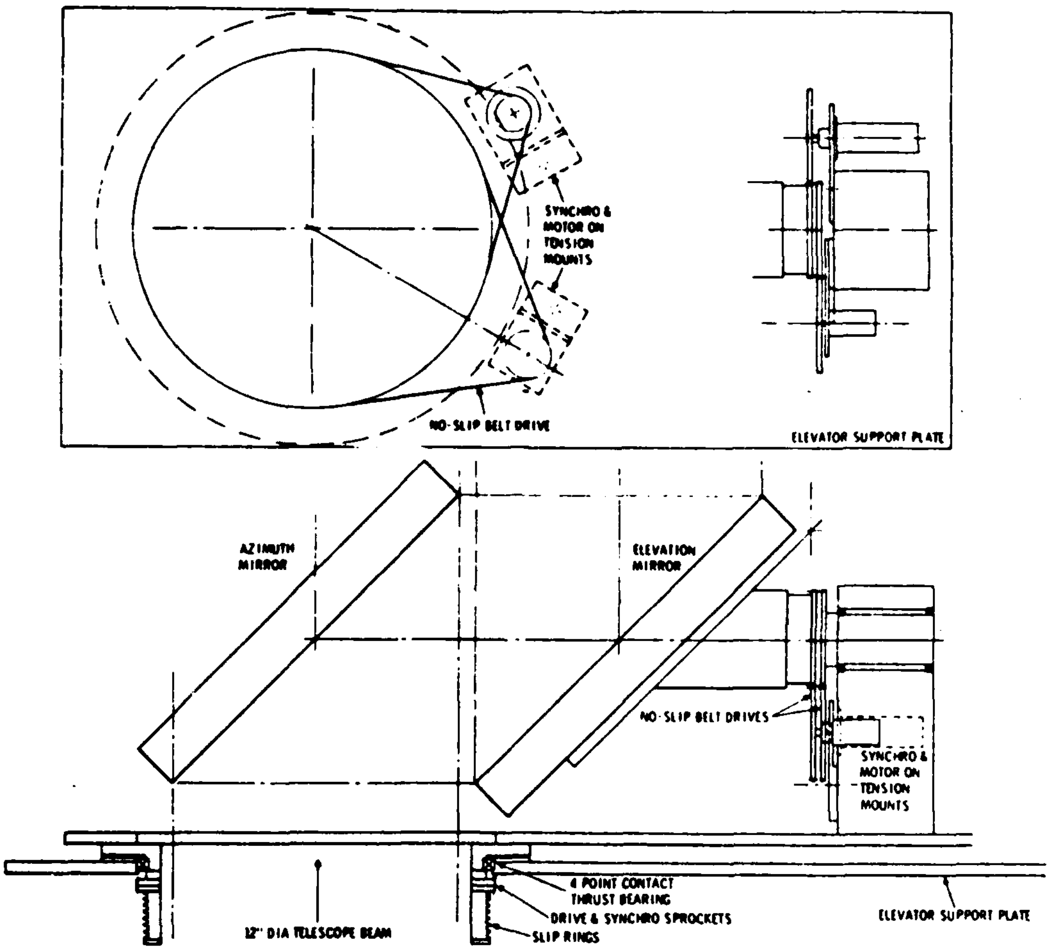


Figure 22. Scanner Bearing Detail

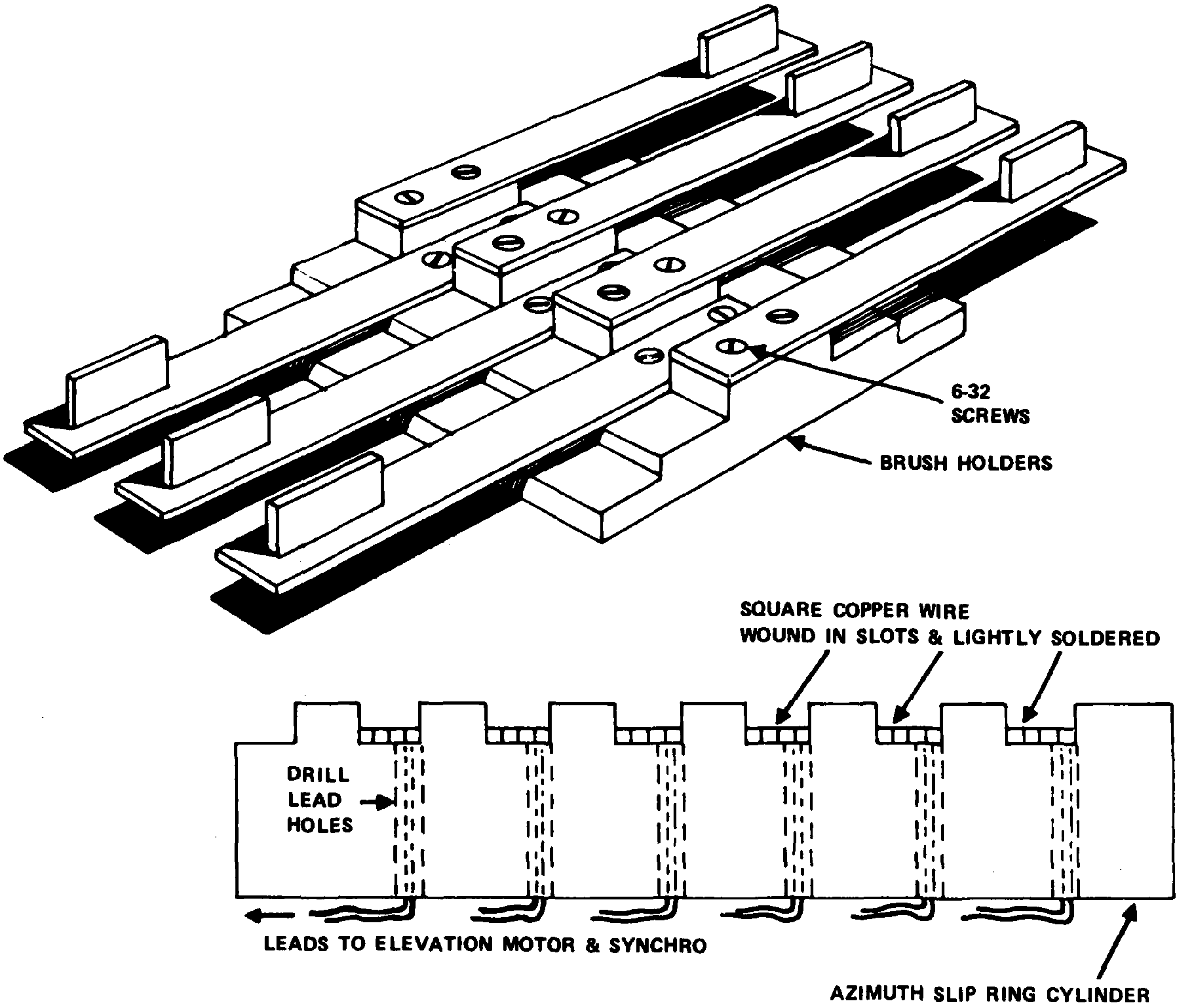


Figure 23. Azimuth Shaft Slip Ring Assembly

different levels to prevent them from touching each other at their support ends. If 14 brushes are to be used on each block, it will be necessary to grind the brush springs into a taper to prevent their touching. However, 7 brushes on each block, as shown, should be adequate. Since the angle readout is by synchro output phase, not a digital counter, occasional current drop out will have no effect on signal readout accuracy.

Two ways of laying slip rings into the 7 textolite grooves are available. We suggest simply winding 3 or 4 turns of square bare copper wire in the grooves and continuing the wire through a hole in the cylinder. From there it goes up the inner diameter of the azimuth throat and to the motor or synchro. The 3 or 4 turns can be lightly soldered (and sanded) to prevent their unraveling. Alternatively 1/4" copper ribbon can be wound in the grooves. Since the shaft speed is only 1/30 rps there is no brush wear or bounce problem. The manufacturers of the azimuth and elevation drive motors, encoders, belts and other parts are noted in the parts list in the scanner envelope. The main bearing, a Kaydon KD140XPO with a 14 inch throat is a single-row torque bearing shimmed to provide sufficient residual longitudinal loading to handle any wind or weight load (rated 21000 pounds dynamic moment) without backlash. For shipping the scanner has been mounted on a shipping table. It is important when unpacking to not strike the azimuth drive assemblies mounted under the elevator plate or to allow the azimuth mount to swing unrestrained on its bearing.

4 ASSEMBLY, ELECTRICAL SYSTEM

4.1 INTRODUCTION

In this section we summarize the procedure for unpacking, reassembly and cabling the electrical system, in particular those technical details that might not be clear in the many drawings and blueprints. We have aided the process somewhat by shipping all the electrical assemblies to be used in the three main racks, still mounted in those racks and in the locations they will be used. The remaining electrical equipments like the scanner drives, sustainer capacitor, water and gas systems, E-beam modulator and vacuum pumps are located near, over or under the optical bench. These units are large, easily identified and essentially completed except for cabling.

The master electrical assembly drawing, Figures 5a and 5b, supply the basic number system by which we catalog each component and call-out wiring cables between components. As noted in Section 2 various components of the laser radar in the functional diagram of Figure 1 have been marked with the EL (electrical system) number of Figure 5, as shown in Figure 6, to correlate the function with the electrical and mechanical location. The function diagram, Figure 1, is discussed in more detail in the operational report, Volume II. This second volume is devoted to the technical details of debugging and using the system as an instrument.

4.2 ELECTRICAL ASSEMBLY DETAIL

EL #24

Having summarized the delivery status of the 36 electrical subsystems in Table II we continue here to detail the functions and assembly process of each item. Since the cabling system EL #24 tends to give the "big picture" we describe it first then resume in the numerical sequence with EL #1.

The 36 electrical subsystems of Figures 5a and 5b are repeated in Figures 24, 25 and 26, 27 modified to show master AC and DC cabling connections. The symbols for the connections, shown on the charts, are used throughout the report. Figure 24 shows, for example, that the TEA laser sustainer power supply, item EL #1a, requires only one power line and this should come from a 6 kW 3 phase 208 volt outlet on the wall near the racks. E-beam control panel, EL #2 on the other hand, has 8 lines. Two 120 volt 2 kW power supply cables, three power output cables to the TEA laser and vacuum pumps and three interlock cables. Almost all of the AC power cables shown in Figures 24 and 25 are wired in and ready to use.

The DC power cabling charts are much simpler but not complete. For example, the DC power to the various detectors and receiver chassis are not in place.

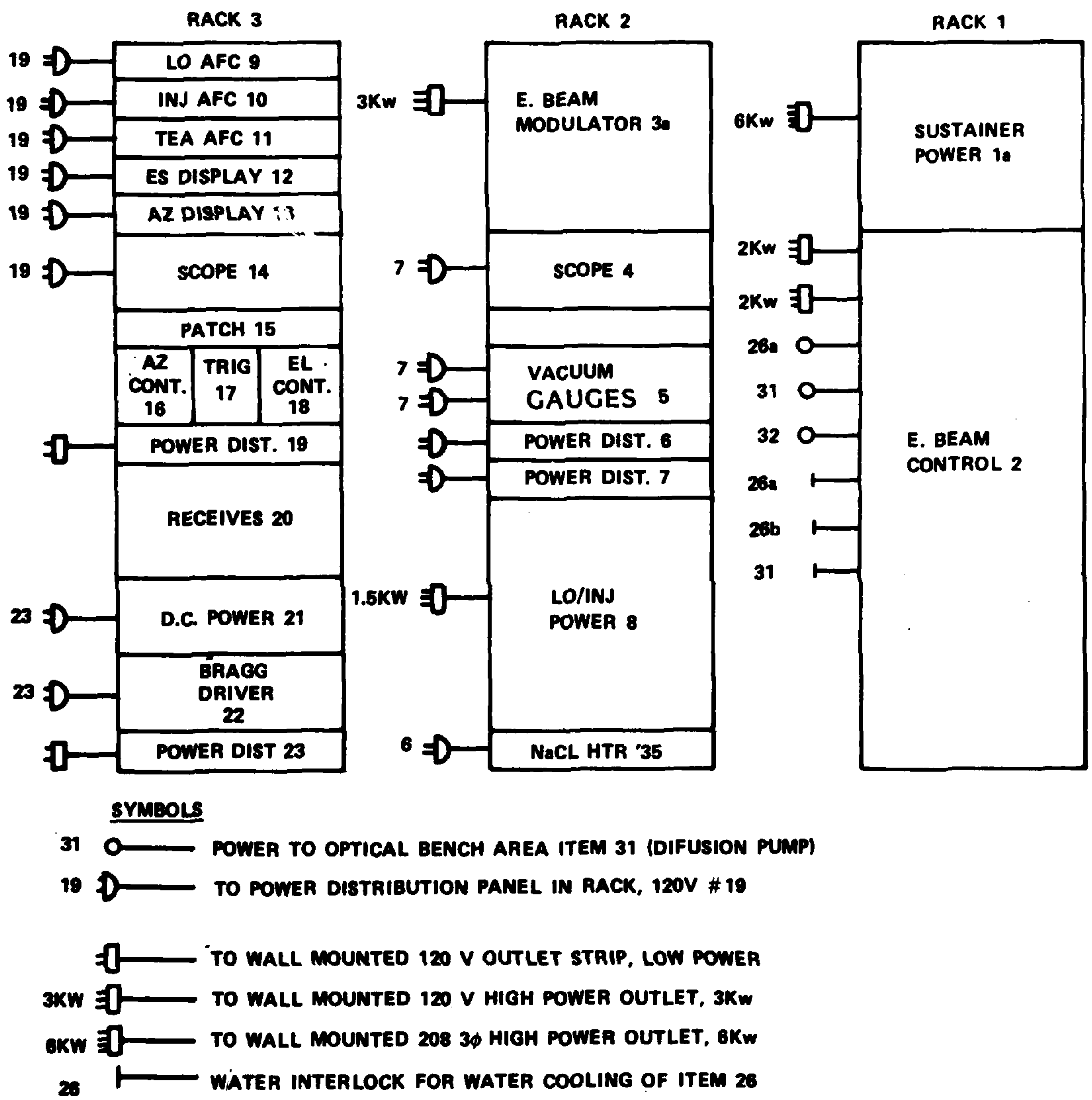


Figure 24. A.C. Cabling

AC POWER/INTERLOCK CABLING, OPTICAL BENCH

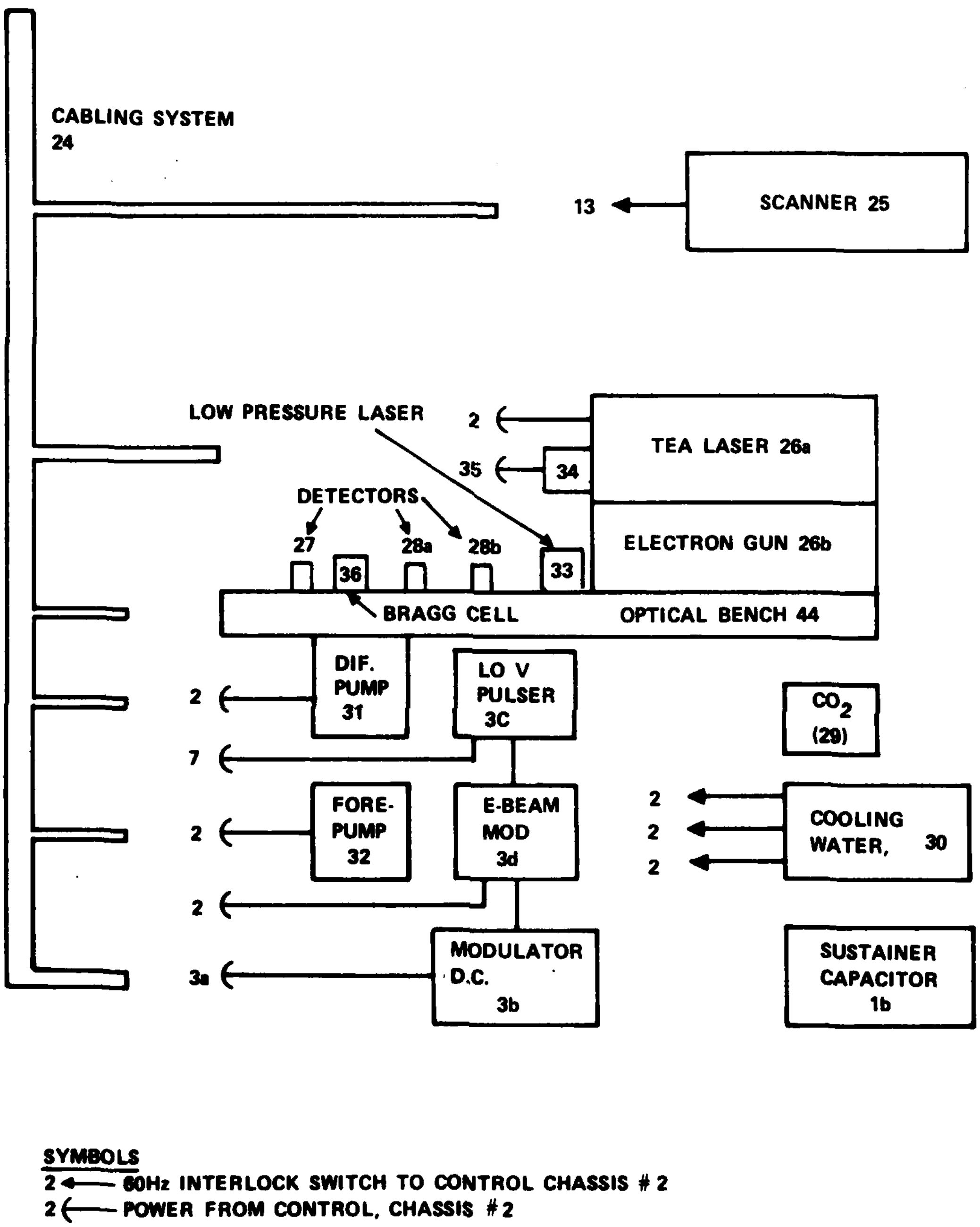


Figure 25. A.C. Cabling

D.C. POWER/CONTROL CABLING, RACK

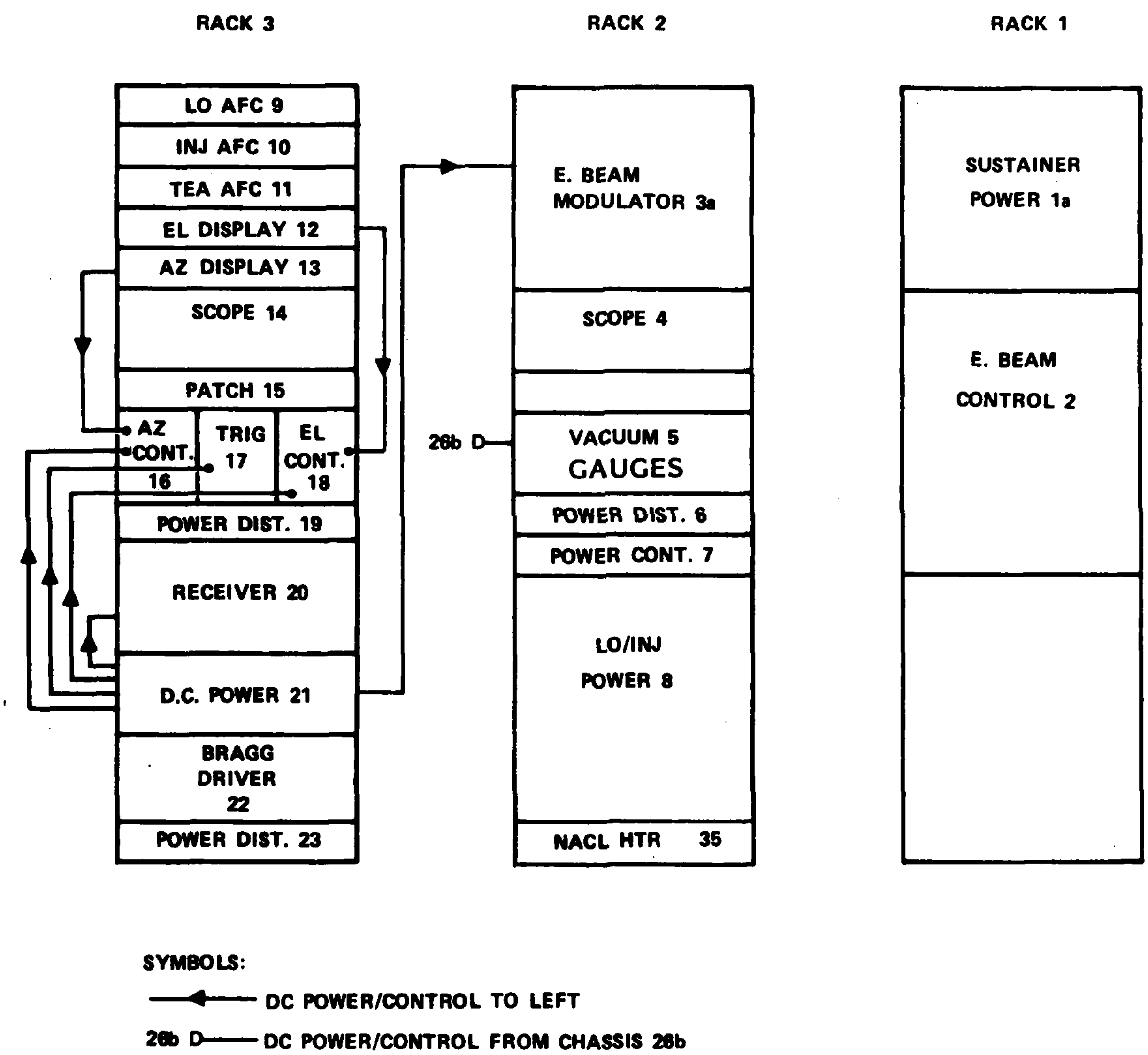


Figure 26. D.C. Cabling

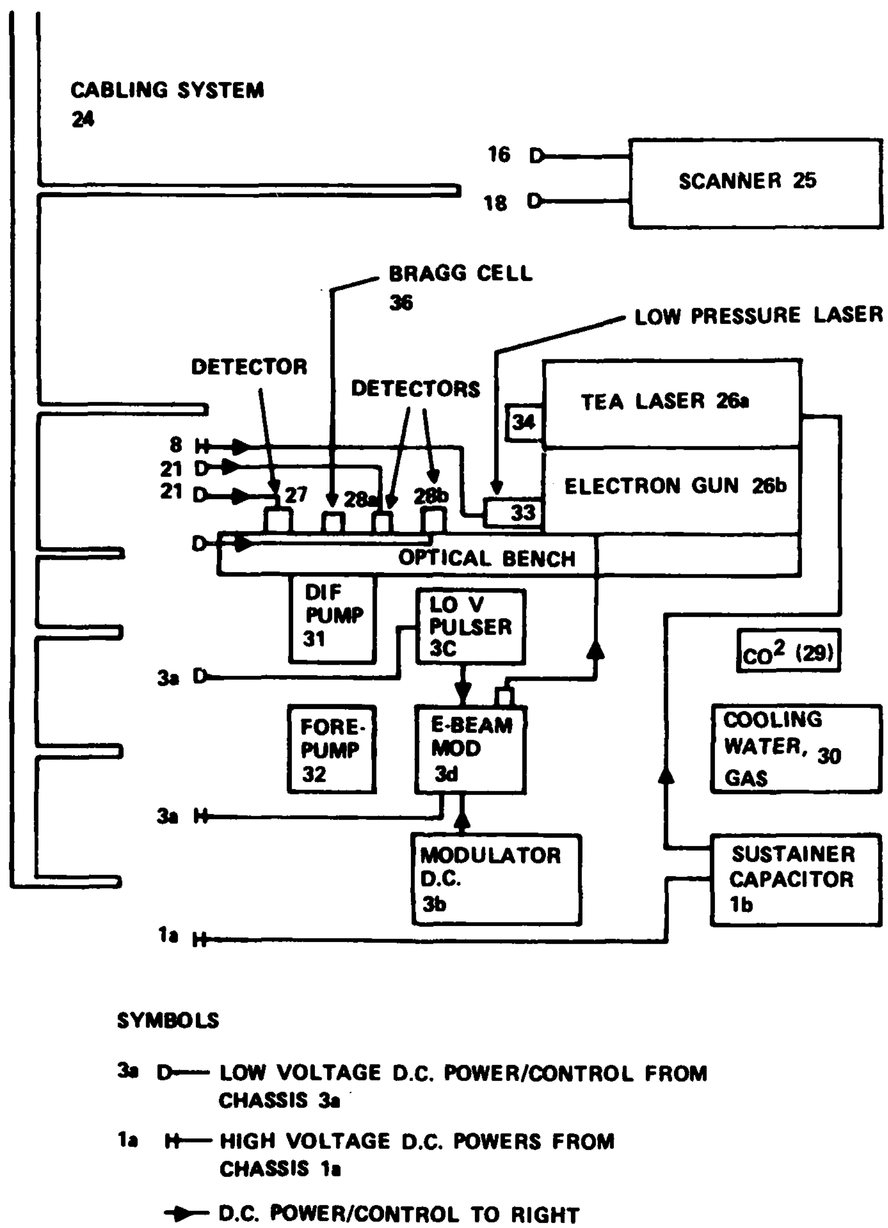


Figure 27. D.C. Cabling

The signal cabling is too complex for a single master chart like this since each chassis may use several HF coaxial and multi-lead cables to the control system, the oscilloscope patch panel and the several signal processing areas. Interconnection data is provided case by case and for the circuits diagram of each unit. We have not tried to cut and tag each signal cable in the racks. We have supplied a box with a large variety of precut cables (fitted with the various connectors, mostly BNC) and a box of adaptors and fittings such as TEE's, elbows and 50 ohm terminations.

EL #1a

Sustainer power supply, EL #1a, (Hipotronics Inc., model #820-250) is used unmodified to supply up to 20 kV 250 ma DC to the sustainer capacitor, EL #1b. Since no TEA laser heat exchanger water flow switch has been provided we have labeled the power control panel with a warning to the operator to check the flow of cooling water (to the heat exchanger of the TEA laser) before he turns on the power. However we recommend that the external interlock circuit (Terminals 5 and 6 or the manufacturer's schematic) be connected to a flow switch set at about 2 GPM.

EL #1b

All the power from #1a is transmitted to the sustainer capacitor, ballast and limiter EL #16. (Schematic shown in Figure 28.) The relatively steady charging of this sustainer capacitor is used to supply the 500 ampere pulses demanded by the discharge across the sustainer electrodes in the TEA laser. It is extremely important that the high voltage cabling from #1a to #16 to #26a be reassembled in such a way as to avoid any shock hazard. All exposed metal should be separately grounded. To reduce the tendency for arcing to the foil in the TEA laser the sustainer cathode is returned only to the capacitor negative. The capacitor negative is grounded only to the power supply cable sheath, not to the heavy common ground braid.

The cable from the capacitor to the laser should be lightly laced and hung to maintain flexibility when the top is lifted back. The impedance (spacing) of this line is not intended to match the load. The line reactance is used to help limit the capacitor current in case of arc-over of the electrodes.

The Pearson current transformer is used to monitor the sustainer current pulses via patch panel EL #15. The calibration is twenty amperes per volt when a 50 ohm termination is used. Of course when the laser head is lifted back the sustainer electrodes should always be grounded with the grounding hook supplied. A bleeder should be installed internal to the capacitor box to discharge the capacitor in the event the external bleeder fails.

EL #2

The TEA laser optical beam power is controlled by the TEA laser electron gun filament temperature. The gun must be protected from thermal damage by loss of vacuum or cooling water. Thus E-beam control panel, EL

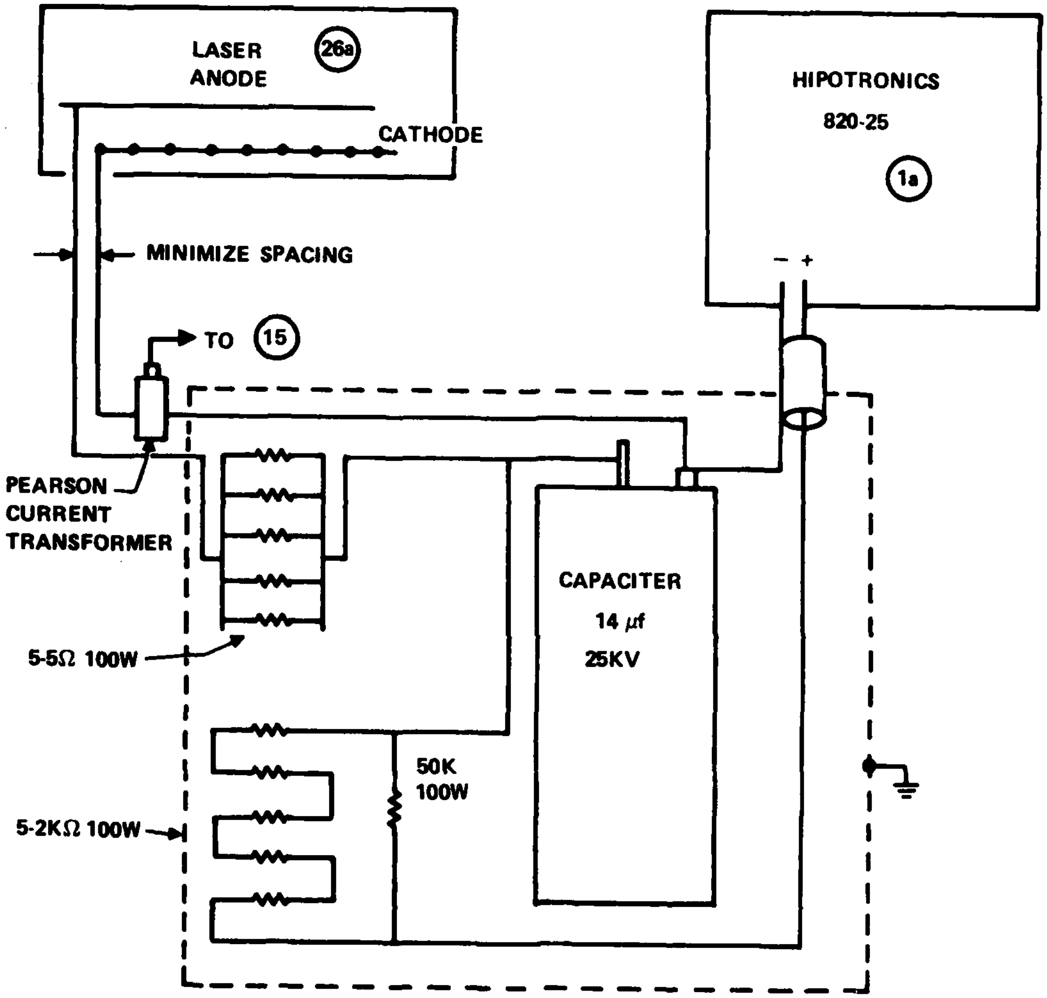


Figure 28. Sustainer Capacitor Ballast and Limiter, EL #1b

#2 becomes a major center for both system operation and automatic interlocks. The circuit and physical layout of EL #2 are shown in Figures 29 and 30.

The system uses 3 solid state relays, an electromagnetic relay and a manual switch to control four loads, roughing pump (8 amperes), diffusion pump (10 amperes), E-gun filament (17 amperes), and TEA laser fans (1 ampere). The total current of 36 amperes is inconveniently large for one power line phase. Since two phases cannot be interlocked simultaneously with a solid state relay one of the circuits uses a mechanical relay. The four terminal boards are already cabled inside rack #1 to their external leads. This internal cabling is rigidly supported inside the rack. Since this internal cabling however is in some proximity to high voltage wiring also inside rack #1, it is important that these cables be regularly inspected to see that they are mechanically supported very securely.

As shown by the circuit, the roughing pump can only be energized at start-up by shorting out the thermocouple vacuum sensor switch until the vacuum gets below the interlock level (set at about 100 microns). The warning light is intended to warn the operator to remove the bypass as soon as possible. The control logic will shut off the various circuits under several conditions as noted in the operational manual. The external flexible cabling to the various supply points is completed and the plugs tagged according to terminal board numbers and EL #5 shown in Figures 24, 25, 29 and 34. The capacitors shown in circuit of EL #2 supply the split phase power to three groups of three, split-phase fans in the TEA laser. (See EL #26a).

The main function of EL #2 is to control the filament current to the electron gun. The normal current is about 9 amperes DC, 98 volts DC. The calibration between this and the AC meter of panel #2 is provided in the operations manual. It should be noted that the filament is operated at temperatures that limit its life to about 100 hours. (See Figure 19.) Thus the variac should not only be adjusted very slowly at the high current levels, but it should be returned to zero after an automatic shutdown — such as that due to loss of water. To implement this automatically it may be desirable to add a latching switch interlock on the variac — such as that used on the high voltage power supplies.

EL #3

Construction of the E-beam modulator was subcontracted, fixed price, to Elemek Corp., Syracuse, N.Y. The electron beam modulator has not been received from the vendor, at this writing. The technical manual to be supplied by the vendor has not been received at this writing. The discussion here assumes final delivery will be achieved shortly, after acceptance tests by GE at the original specification. The writer has been in close contact with the vendor and observing the results of their initial system tests. So far the system has delivered 100 kV pulse 12 amperes pulses of 10 μs pulse length. Both measurements were at 50 pulses per second with acceptable waveform. The unit also delivered full filament DC power while pulsing. Discussions of tests so far are in Volume II.

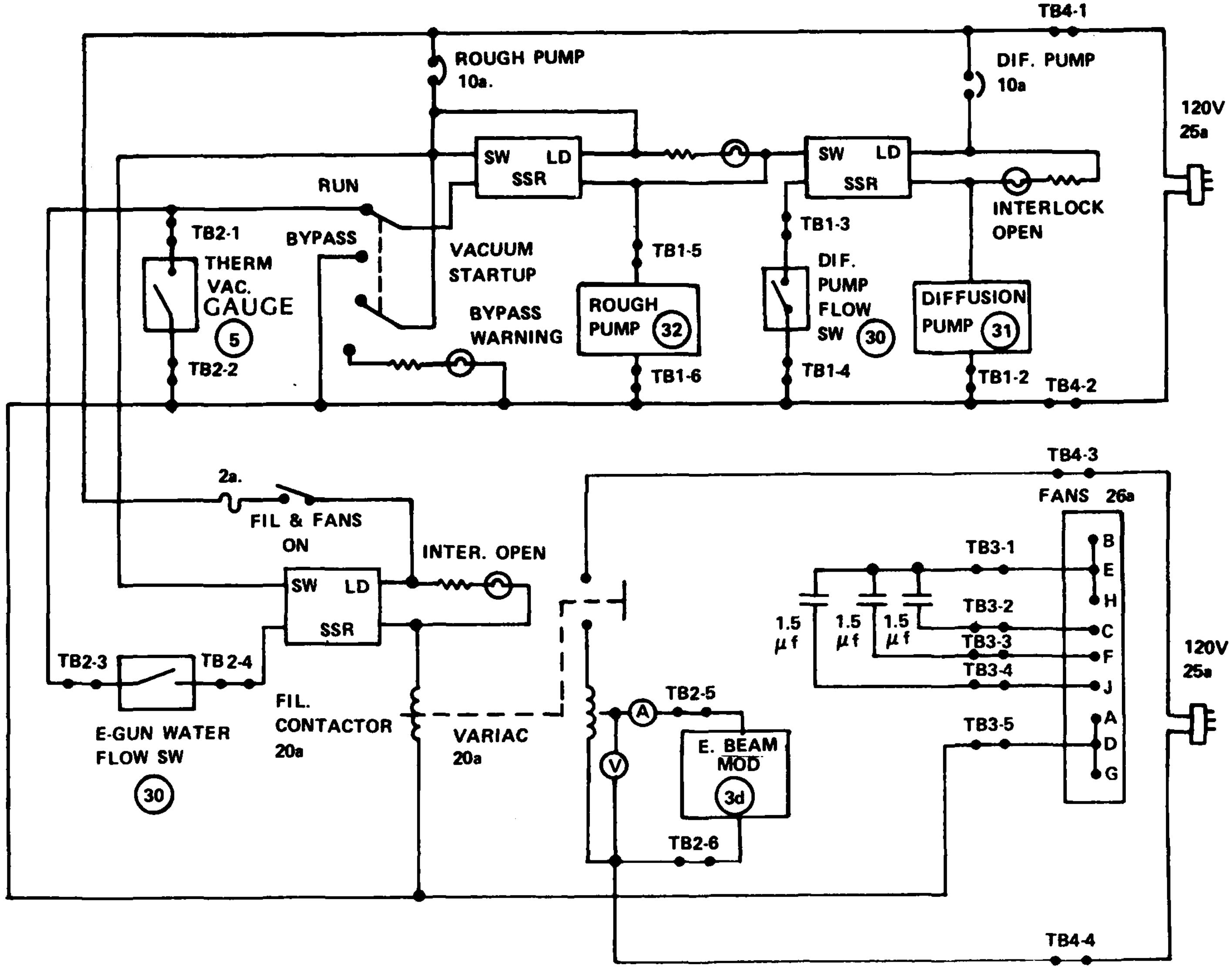


Figure 29. E-Beam Control Panel, EL #2

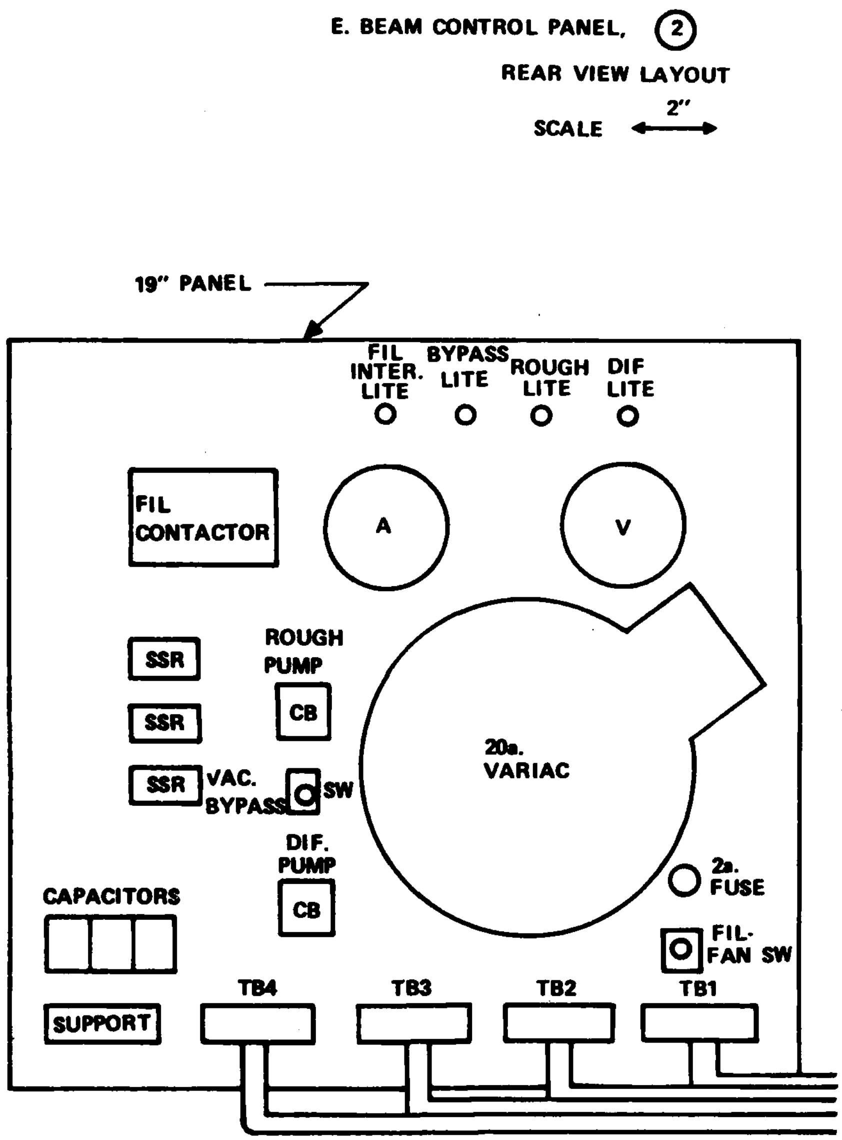


Figure 30. E-Beam Control Panel EL #2

The electron beam modulator supplies 100 volts, 9 amperes DC and 120,000 volts 15 amperes pulsed to the filament of the TEA laser electron gun. Two pulse lengths are used 5 μs and 10 μs. As shown in Figure 31 the system consists of four separate chassis. The control panel, EL #3a, located in rack #2 houses the switches and variacs controlling the DC power rectifier, which is in an oil tank under the optical bench. These two units are manufactured by Hipotronics, as model #825-100. It supplies 25 kV 100 ma. The circuits and operation of the Hipotronics power supply are described in the technical manual. The only modification to this is the insertion of a pulse length interlock relay in control panel EL #3a (as shown in Figures 32 and 33).

The electron beam modulator, itself, consists of two additional chassis both located under the optical bench, the low voltage pulses EL #3c and the high voltage pulse EL #3d. Control pulses from EL #17 are amplified to 3 kV in EL #3c and then to 120 kV in EL #3d. Figure 31 shows the filament power cable from EL #2 and the 120v AC from distribution panel EL #7. Labeling of the cabling and switch of EL #7 are provided. The low voltage pulser has three test point pickoffs on BNC connectors that are to be cabled to the patch panel EL #15 for observing pulse waveforms. These and other waveforms are described in the operational manual. The heater variac T9 is preset by the manufacturer to provide the optimum thyratron heater voltage (3.8V normally). The heavy pulse and control cable between 3c and 3d is short. These are to be located side by side under the optical bench. The high voltage pulser can be raised on self-contained casters when it is to be moved. The high voltage bushings are ceramic and relatively fragile. The spacing in the region of the high voltage electron gun bushing is very tight and movement of the heavy modulator (800#) must be controlled very carefully. Normally the unit rests directly on the floor. The modulator must, of course, be securely bolted to the deck before the system is trailed.

The high voltage pulser is a source of corona and RFI. After the filament is connected, using the 5/8" flexible connectors provided, sharp edges should be eliminated and the corona shielding arranged to shadow those remaining.

The pulse length interlock cable shown (in all three figures), prevents the operator from switching the high power PFN, between the position required for long and short laser pulses, with the PFN charged. The interlock connects to the interlock terminals 4 and 5 provided by Hipotronics for this purpose. If it is desired to further interlock the power supply (for example for safety access to the area) the same pair can be used.

The high voltage pulser generates voltage that can arc several inches in air. The lead x-ray apron of the E-beam laser has bulges and mylar sheet insulation to prevent arcing to it. A corona shield is provided to reduce corona around the filament wiring where it enters the high voltage bushing.

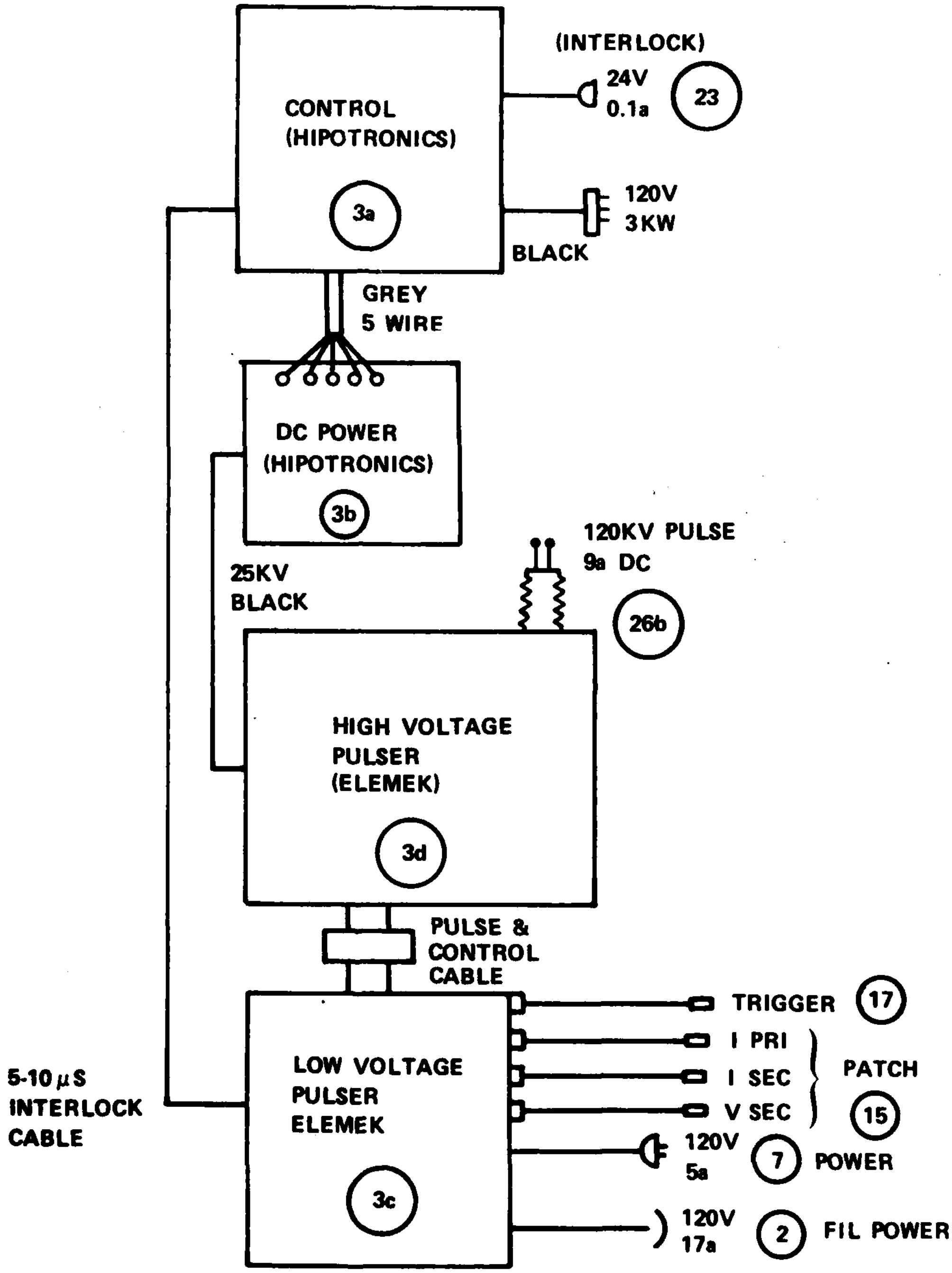


Figure 31. E-Beam Modulator Cabling

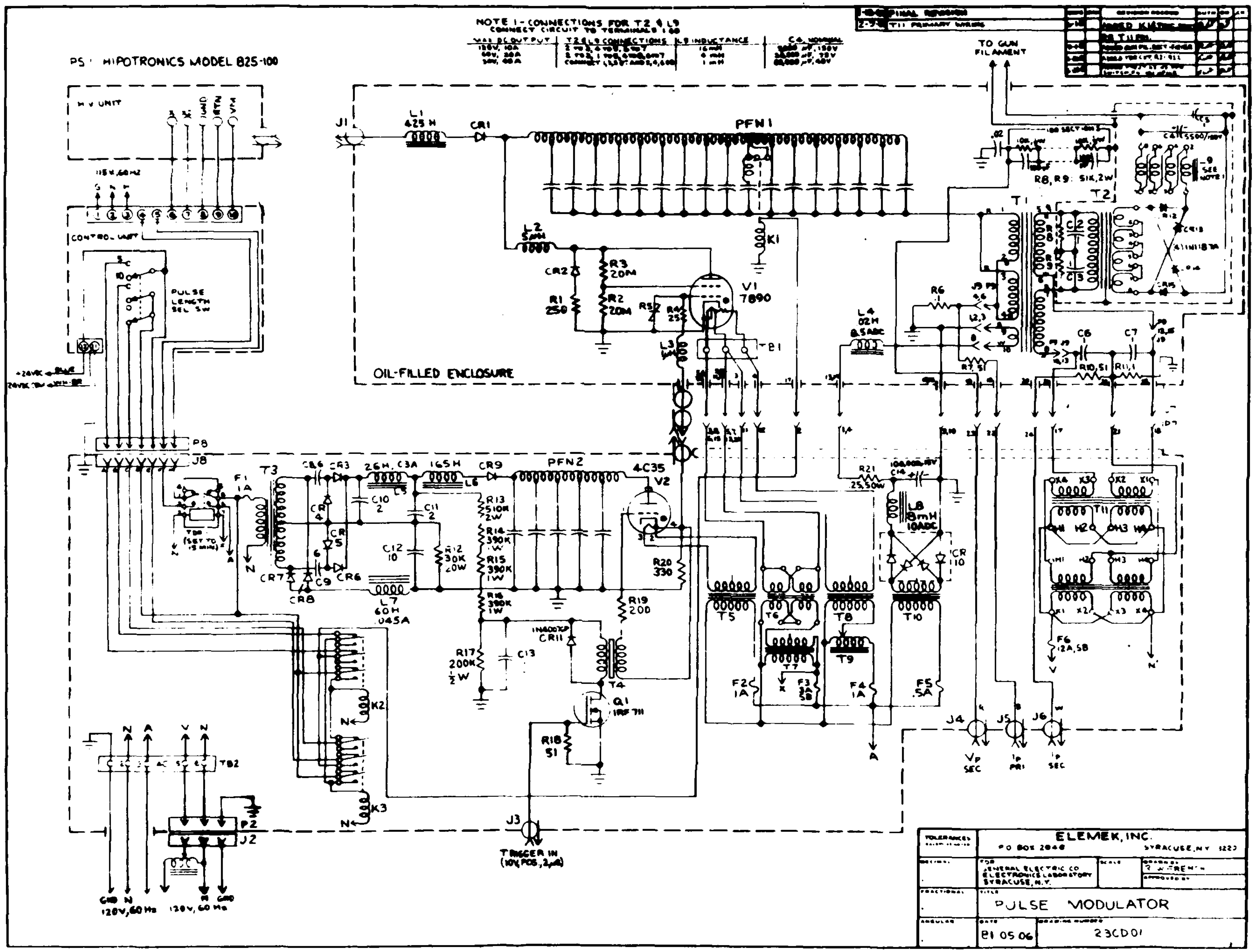


Figure 32. E-Beam Modulator

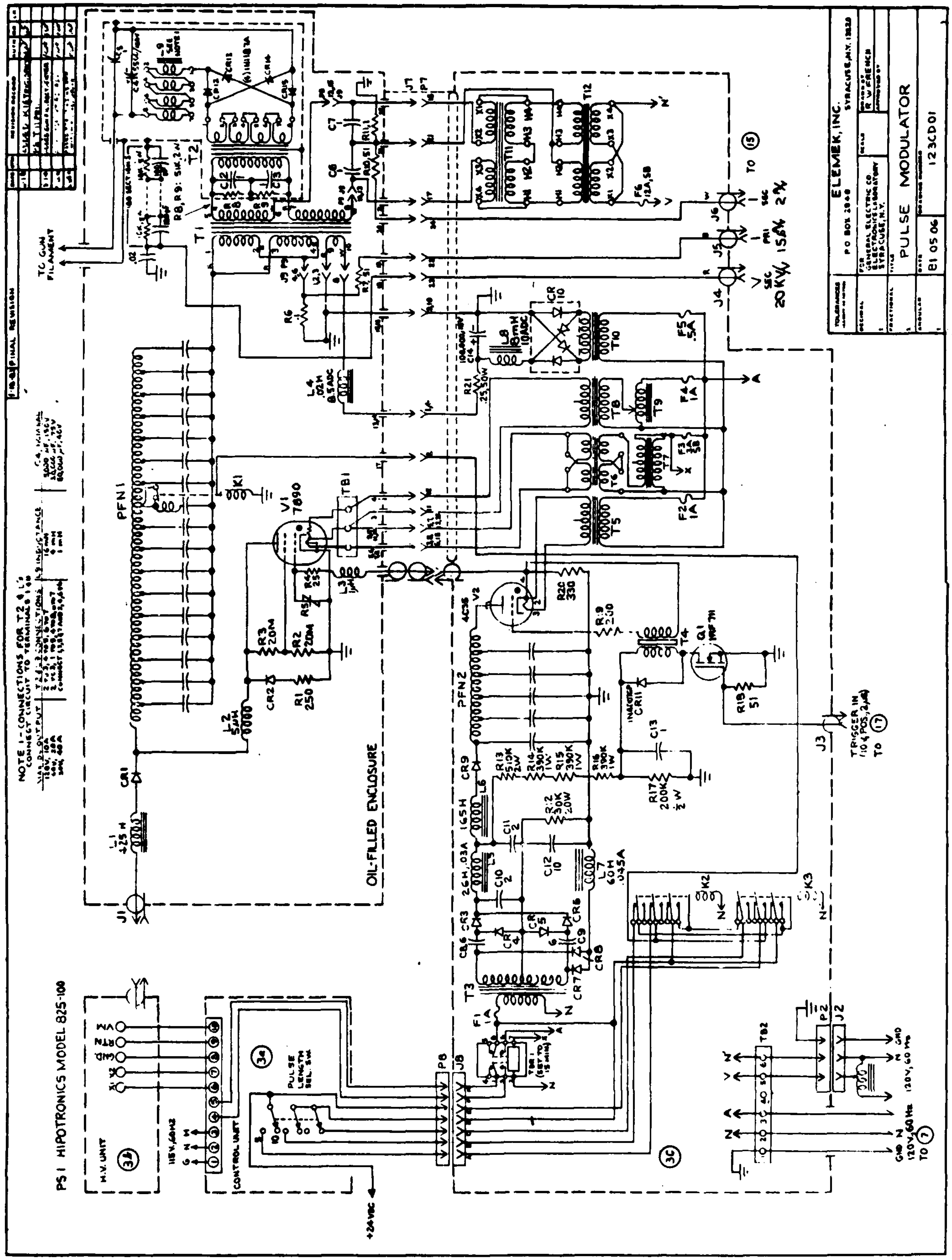


Figure 33. Test Points of the E-Beam Modulator

EL #4

During normal operation it is desirable to optimize adjustment of various units by oscilloscope waveform and further to monitor their performance during operation as a confidence check of AFC locking for example. We have provided two Tektronix 2213 oscilloscopes. These units have adequate bandwidth (50 MHz) to show all waveforms necessary to operate this system. However at 50 pulses per second the trace brightness may not be adequate for photography, bright-room, or across-the-room observation.

The three oscilloscope signal inputs are simply channel #1, channel #2 and trigger. Most signals to be observed are taken from patch panel EL #15, used in common with oscilloscope #4 and #14. This allows quick connection to any of about 20 signals including scope trigger. (See EL #15.) To monitor the LO and Inj AFC the scope inputs are connected direct to the BNC "monitor" and "sync" output on the front of EL #9 and #10.

Two copies of the Tektronix manuals are provided.

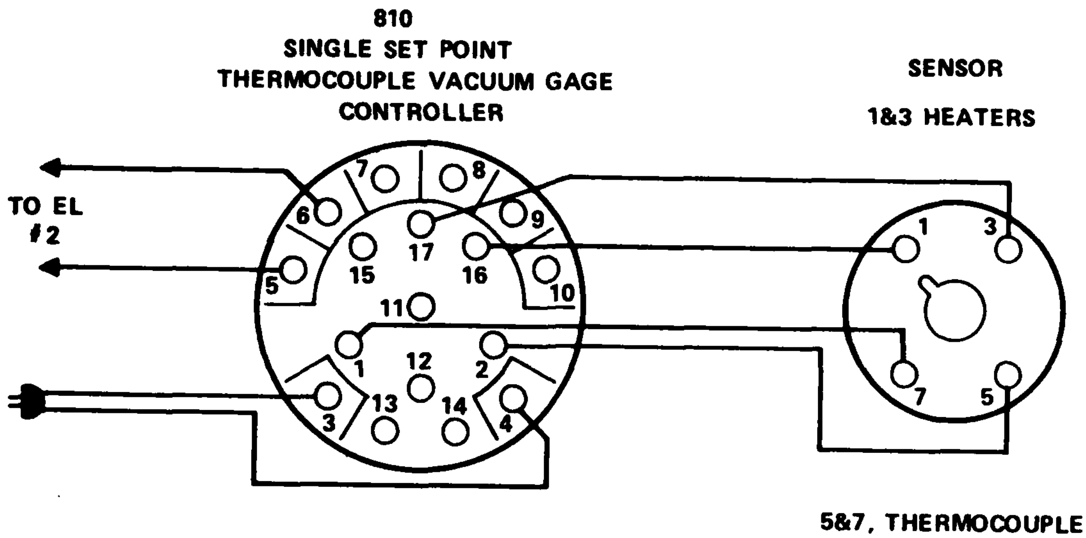
EL #5

The filament of the electron gun should not be turned on when the vacuum in the electron gun is poorer than 100 microns and the electron gun high voltage should not be on when the pressure is above 10^{-4} Torr. These conditions are indicated by the thermocouple gauge and the cold cathode gauge, respectively, located at Electrical Station #5.

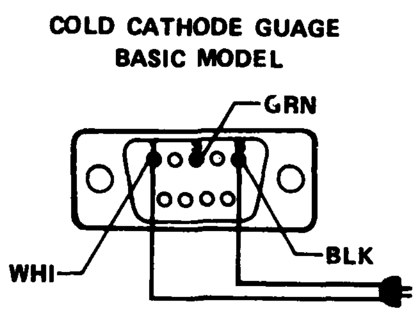
The thermocouple gauge is connected to EL #2 as shown in Figure 29 so as to shut off the pumps and filament, automatically, if the pressure gets above the set level. Figure 34 shows the cabling connection for these two gauges. The cabling is already in place. Varian manuals for maintenance and repair of the gauges, and their sensors located in the electron gun, are provided.

EL #6 and #7

Two 120V AC distribution panels are provided to power the equipment housed in rack #2. The upper has only a single master switch which we suggest be reserved for items that must be powered continuously -- such as the NACL heater control panel, EL #35. The lower panel has individual switches as well as the master. Some of the circuits have already been connected and are so labeled. These distribution centers themselves are already provided with cables (with labels) that are to be connected to the power service.



1. TC + (GREEN)
2. TC – (RED)
3. 115 V.A.C. POWER
4. COMMON A.C. POWER
5. NC } LOAD RELAY POLE 1
6. C
7. NO
8. NC } LOAD RELAY POLE 2
9. C
10. NO
11. } LATCH
12.
13. } SPARES
14.
15. 230 V.A.C. POWER
16. TC FIL. (BLACK)
17. TC FIL (WHITE)



1	PWR COM	6	
2		7	REC +
3	GROUND	8	REC –
4		9	
5	PWR		

Figure 34. Vacuum Gauge, EL #5, Connections

EL #8

The power supply, for the two low pressure CO_2 lasers, injection laser and local oscillator laser, made by Hipotronics (Model 825-40), delivers up to 40 ma at 25 kilovolts. The manufacturer's manual, supplied, provides technical data. The ballast resistors to limit laser excitation current are mounted on the back of this power supply in rack #2. The connections are shown in Figure 35. A variety of high voltage connectors, cable and panel feed-throughs are provided. The AC power is provided by a separate cable as shown in Figure 24.

Two parameters should be interlocked, water flow and vacuum pressure. If the gas flow drops to where the vacuum is less than a few Torr (normal 15 Torr) the plasma current may get high enough to damage the laser electrodes. To prevent this the power supply overload should be set only slightly above the normal operating current, (about 10 ma). These are particularly long tubes and require unusually high voltage. If the tubes fail to fire at maximum voltage (25 kV) the pressure can be dropped briefly by pinching the gas hose momentarily.

Loss of water flow will also damage the lasers. The flow switch, provided, should be connected to the external interlock terminals (4 and 5) of the EL #8 power supply. Ideally a second flow interlock should be connected to the Bragg modulator driver since the Bragg modulator, SO #25, uses the same water. (See discussion of EL #22, interlocks.)

EL #9, #10

There are three CO_2 lasers whose frequency must be controlled accurately to permit heterodyne reception in the laser radar receiver. Thus there are three optical cavities whose lengths are controlled by automatic frequency control (AFC) circuits. These are the local oscillator laser mirrors #14, 15, the injection laser mirrors #21 and #23 and the TEA laser mirrors 31, 33, 35, 40 and 36. The frequency of all three lasers is varied by a Lansing piezo-electric mirror translator on mirrors #14, 21 and 33 respectively. To drive these mirrors we use three Lansing model 80.215 lock-in stabilizers, EL #9, #10, and #11. The AFC for the LO and Inj lasers, EL #9 and #10 use the standard dither technique built into these commercial stabilizers (see Figure 7) in which the dither detectors EL #28b supply an error signal when the laser frequency is off of the laser line linecenter. The AFC for the TEA laser uses a different concept which is discussed in the next section.

The LO and Inj AFC techniques are described in the Lansing technical manuals. We show their block diagram, Figure 36, modified to show signal cabling connection to our system. The required connectors to the laser mirror translators and detector are on the rear panel. Connections for the oscilloscope monitor, are on the front panel.

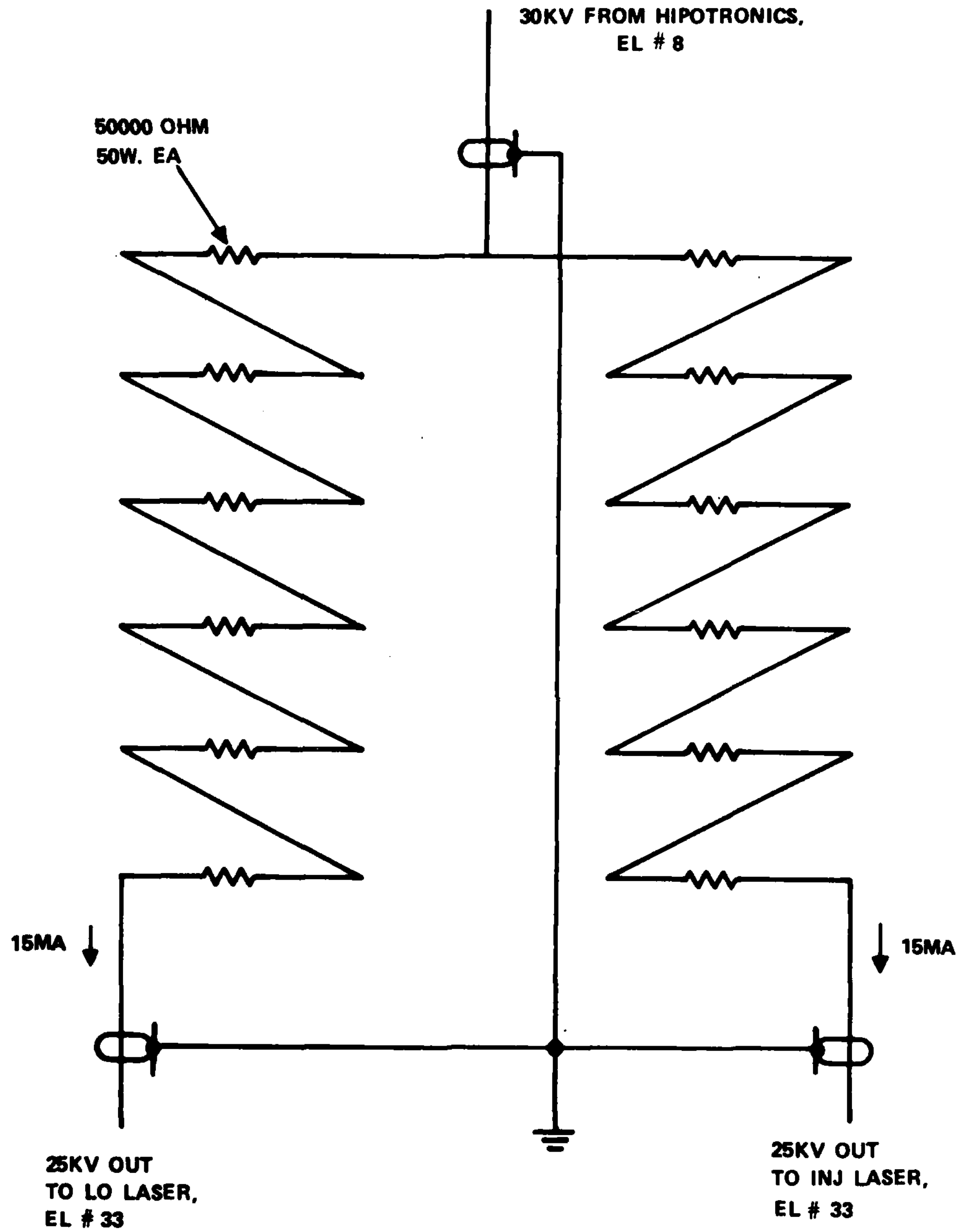


Figure 35. Ballast for Low Pressure CO_2 Lasers, EL #8

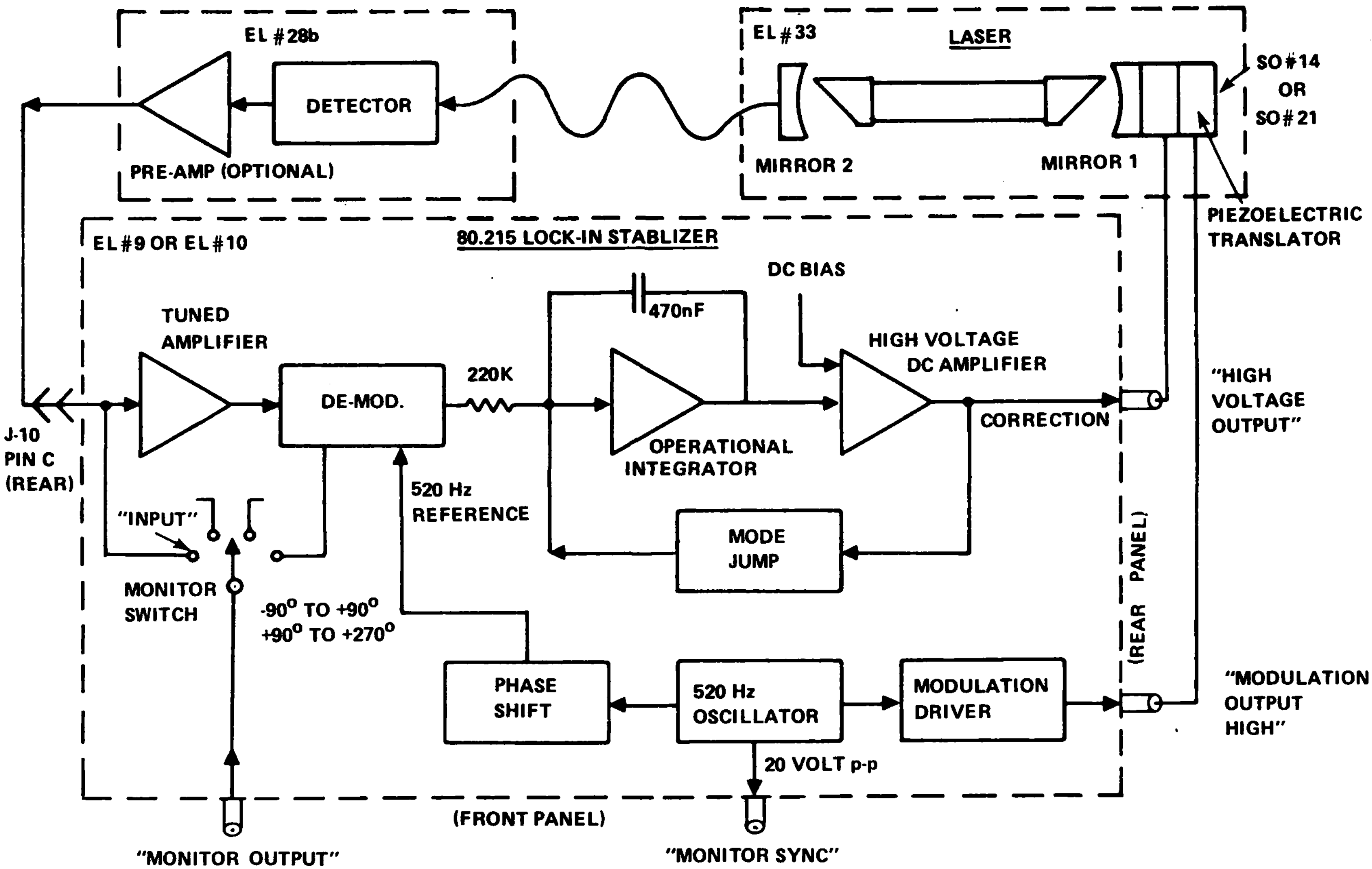


Figure 36. Block Diagram: Stabilized Laser System, Employing 80.215 Lock-in Stabilizer for EL #9 and EL #10

In the event it is desired to reduce AFC system noise due to the independent dither of the LO and injection laser AFCs a common dither source for all three AFC systems can be used.

EL #11

The two low pressure CO_2 lasers are stabilized to line center using a small 520 Hz cavity dither. However the TEA laser cavity is stabilized (relative to these two) using the heterodyne beat between the local oscillator and the output of the TEA laser. The TEA laser pickoff, SO #29, deflects a a small signal into the HgCdTe detector, SO #16, to provide a reliable heterodyned pulse at the 50 pps TEA laser output rate. This is amplified in the 40 MHz linear IF and used to generate an AFC error signal in the 40 MHz discriminator both located in Receiver, EL #20. The discriminator output is gated (to eliminate FM and RFI noise) and converted to a narrowband bipolar CW error signal by the sample and hold circuit, also of EL #20. This DC error is then applied to the input of the operational integrator of the third Lansing stabilizer EL #11. The effect of this modification to the basic block diagram of the third Lansing unit, and its interconnection to the other chassis, is shown in Figure 37. Note that with the removal of the dither stabilization the tuned amplifier and demodulator are not used and unless a common dither signal is used to remove dither FM in the doppler output, dither circuits are not used either. The mode jump, DC bias, monitor taps and other features of the Lansing unit are still available for use exactly as in EL #9 and #10.

Figure 38 shows the modifications in detail. Simply lift one wire and add another -- as shown on the manufacturer's schematic. It is not even necessary to physically add a BNC since any of the several dither related BNC's on the rear panel are now available.

At the time of this writing these changes had not been made in this chassis.

Note that the gain, and therefore the stability of the TEA AFC servo is controlled by the pot. in the sample and hold circuit located in the receiver chassis, EL #20.

EL #12, EL #13

The electronics for the scanner elevation and azimuth drive and angle readout/display are contained in a commercial (Computer Conversion Corp., CCC) difference encoder chassis EL #12 and #13 and the servo op. amp. drive chassis EL #16 and #18. The scanner motors and synchros are located in EL #25. Thus electrical assembly involves cabling among these five units. Figures 39a and 39b show the azimuth and elevation systems respectively which are identical except for slip rings on the latter and 10:1 gearing on the former.

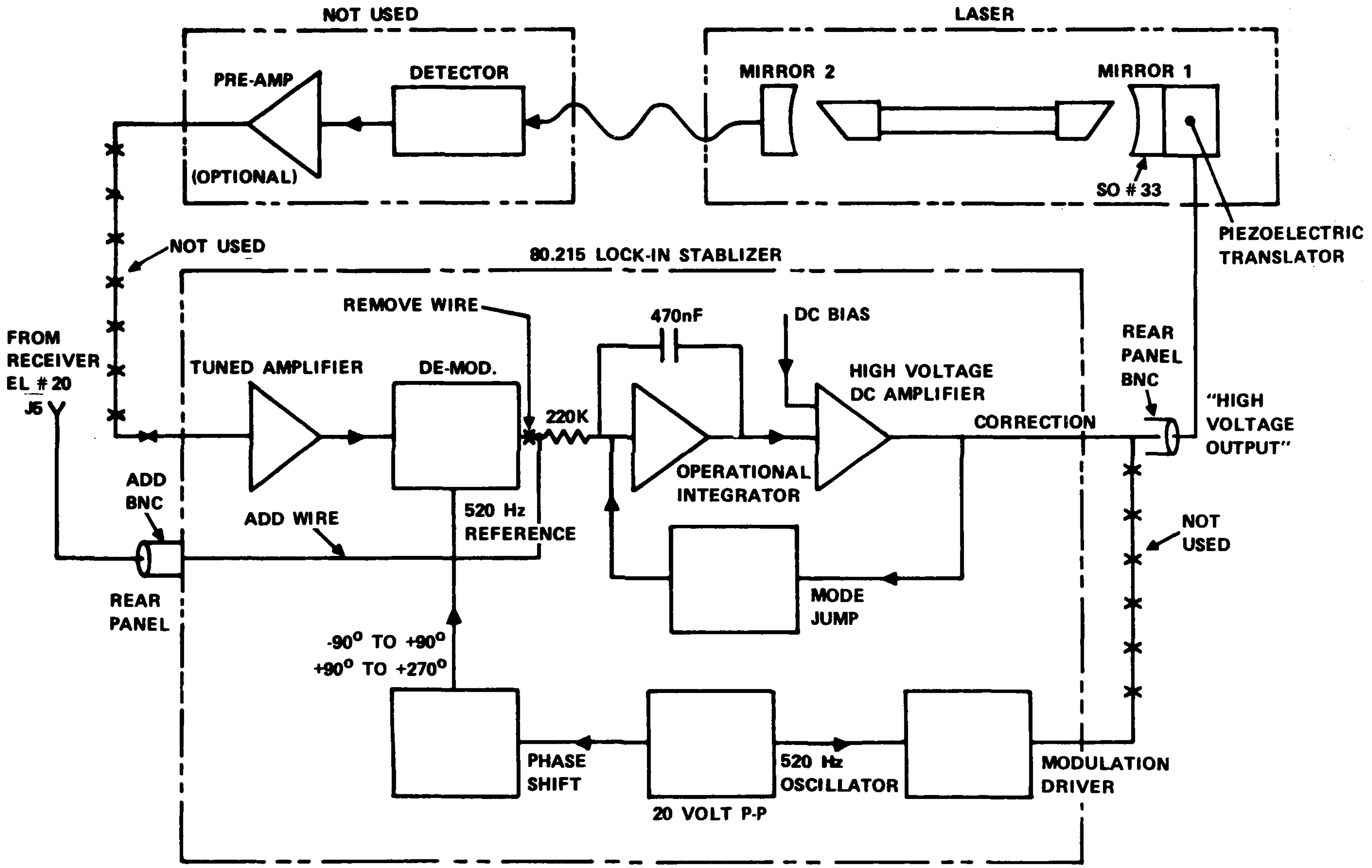


Figure 37. Changes to 80.215 Lansing Stabilizer for EL #11

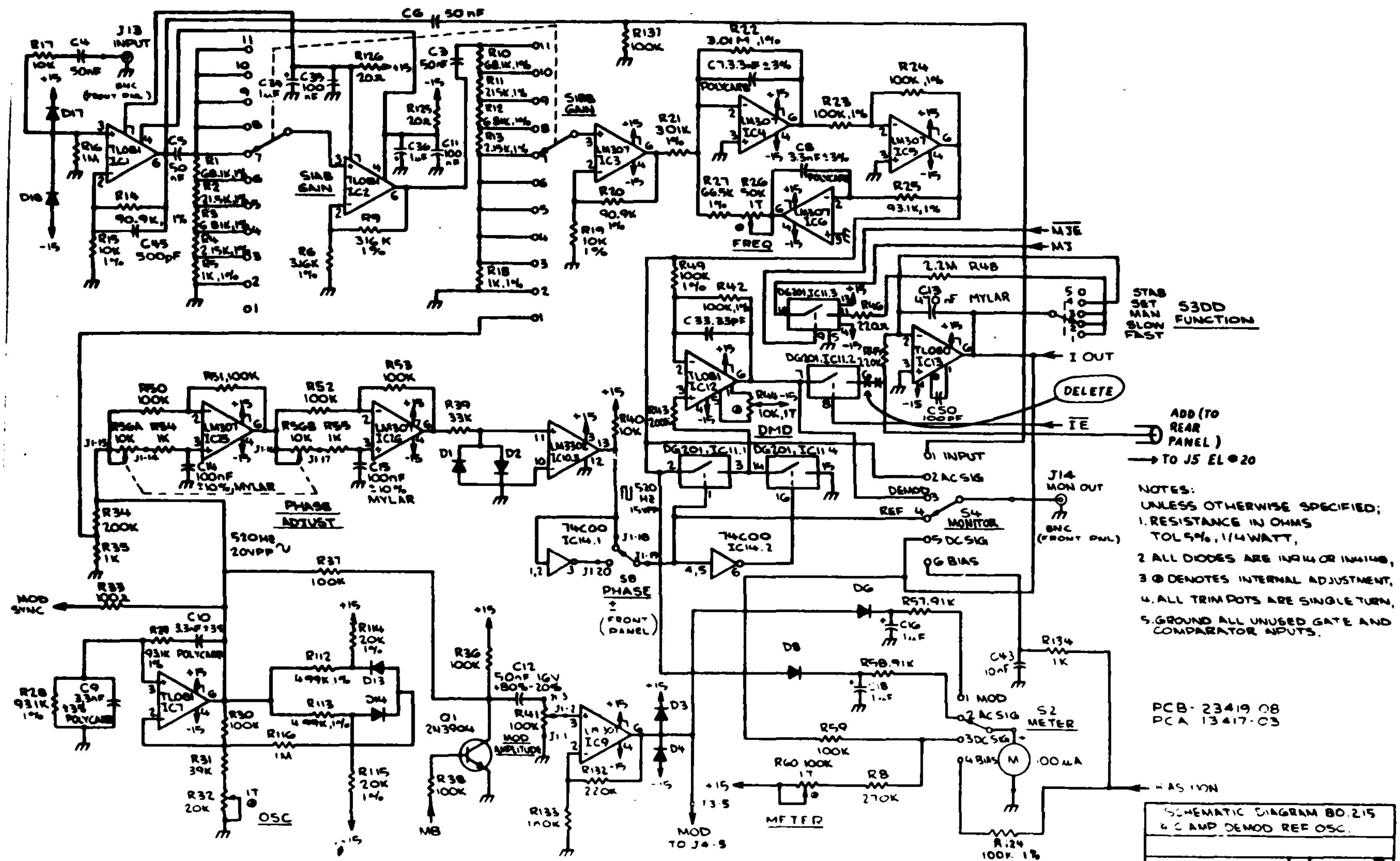


Figure 38. Modification to Lansing for EL #11, TEA AFC

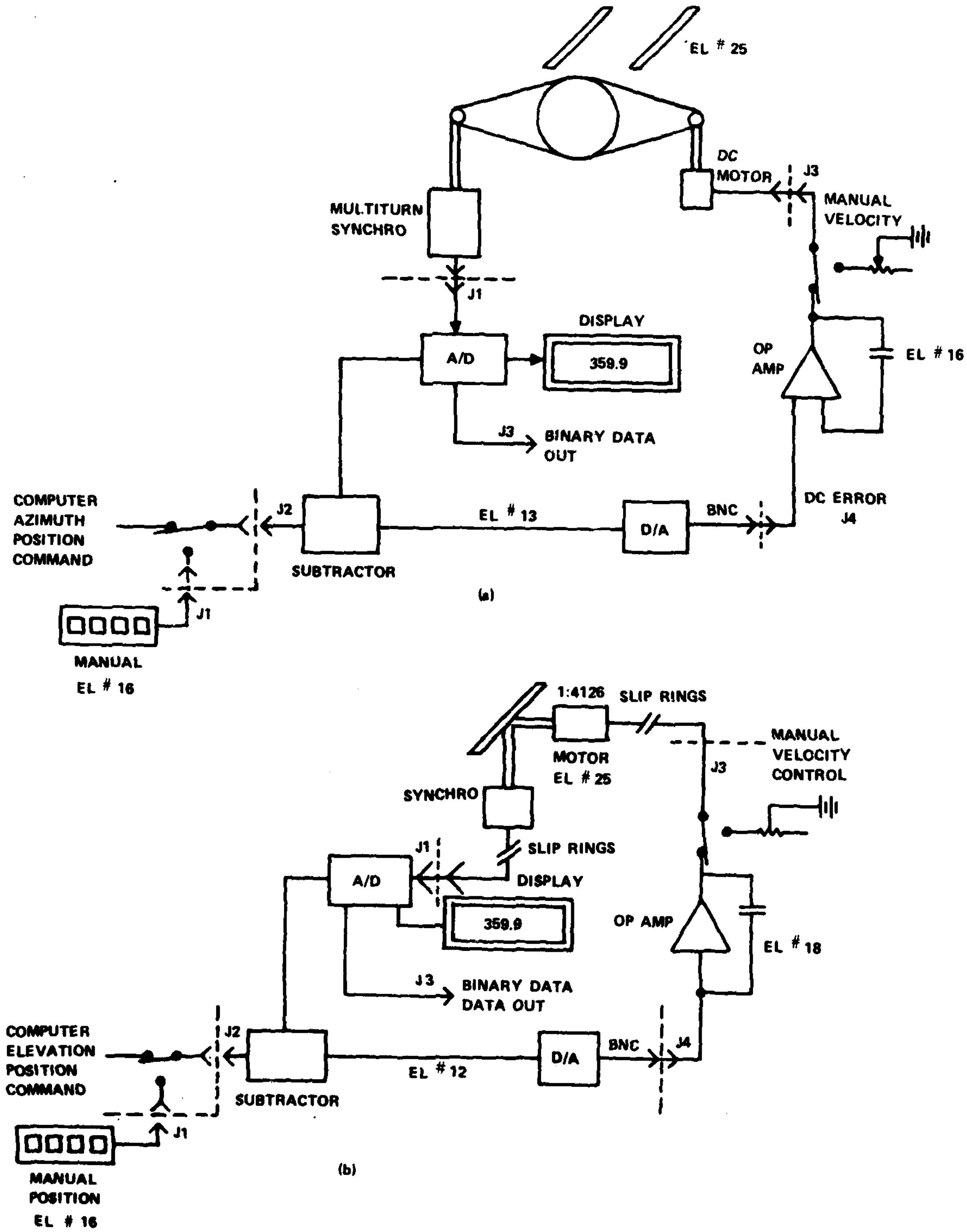


Figure 39. Digital Position Command Servo
a) Azimuth, b) Elevation

Both axes are driven by geared-down DC motors, and both motors are coupled to the driven axis by non-slip belts (polypropylene and steel cable formed into a chain). To isolate the strains (owing to driving torque) from the angle readout, the synchro shaft encoders are coupled to the axes with a separate smaller "chain". In the case of the azimuth encoder, the chain sprocket ratio is 10:1, and a suitable 1:10 gear inside the azimuth synchro provides the net 1:1 readout. This gearing is necessary because of the large (12-1/2 inch) diameter azimuth throat required to accommodate the 12-inch diameter telescope beam. The chain drive and power system has been designed to provide the required .25° precision and .1° stability in the face of a 10 mph wind. Since the maximum rotation rate is only 2 rpm, the drive motors need only be about 1/30 hp.

In the position control system, the command position angle from the computer is compared with the actual azimuth (or elevation) position indicated by the synchro shaft angle encoder and an error signal is generated. The error signal drives the motor in a typical servo loop to put the mirror into the command position. In alternate modes, the motor can be set manually to a desired position or constant azimuth and elevation scan rates. A synchro rather than an optical or mechanical digital angle encoder was selected to avoid a large number of slip rings on the huge 13-inch diameter azimuth bearing.

The technique by which we match the customer's digital position command to an analog servo is shown in Figure 39. The azimuth or elevation position as measured by the synchro is converted to 14-bit parallel binary by the resolver-to-digital converter, A/D. The instantaneous digital position is compared with the digital command (from the computer or manual input) and an error signal generated, by the subtractor. This 14-bit parallel error signal is converted to a ±10 volt analog signal by the D/A. The analog error signal is amplified by a power op amp to the several ampere current level necessary to drive the AZ/EL motors. The loop is closed mechanically and the error driven to zero.

The digital position from the A/D is also presented as two outputs. This 14-bit binary parallel angle position goes back to the customer signal processor and it goes to a display unit which presents the instantaneous angle in degrees decimal to the local operator. This system was prepared from "standard" components by the Computer Conversion Corporation and represents a low cost method of getting high accuracy and assurance that the various digital modules will match the time, voltage and encoding format. The CCC technical manuals and wiring diagrams are enclosed.

The cabling for EL #13 and #14, shown in Figure 39, is as follows:

(1) The 14-bit command for scanner input (angle) coming from the customer computer goes to the 25-pin male connector, J2, on the rear panel of the azimuth and elevation display chassis, EL #13 and EL #12. In the event it is desired to control the scanner position digitally and manually and locally, this connector is replaced by one coming from EL #16 and #18 (see Figures 39 and 42). Scanner

positions can also be controlled by analog signals directly from chassis EL #16 and #18.

(2) The 14-bit binary scanner output (angle) is available to the customer computer at the 25-pin female connector on the rear panel of #13 and #12, J3. A BCD output option is available from CCC.

(3) The DC servo error to the op. amp. driver amplifier (EL #16 and #18) comes from the BNC connector on the rear panel of the two CCC chassis: (Apparently the manufacturer's drawings are not complete.)

(4) The synchro output on each scan axis drives the synchro digital converter via the 10-pin female connector, J1, on the rear panel of the CCC chassis. These cables are already in place. The azimuth cable has a connector ready to be plugged into the azimuth synchro. The elevation cable has free ends for connection to the scanner azimuth axis slip rings.

EL #14

The second oscilloscope, in position EL #14 is identical to EL #4. The three signal inputs are simply channel #1, channel #2 and trigger. Most signals are taken from patch panel, EL #15. For monitoring the AFC systems EL #9, #10, and #11 a separate BNC connector supplying any of several AFC signals (via the monitor switch) and a 520 Hz (dither) sync are taken directly from in front of those three panels.

120V AC is from the distribution panel 19 or 23.

EL #15

The patch panel, EL #15, is used to supply any of a number of signals from throughout the laser radar system for scope displays, 4 and 14. A suggested list of signals and an arbitrary position arrangement is shown in Figure 40. A variety of feedthrough terminations and TROMPETER 50 ohm patch cords and paralleling jacks have been supplied. For low frequency, high level signals the patch socket can be merely connected (in back of panel 15) to the desired signal, in parallel using a BNC TEE. The TEE can be as far away from the patch panel as desired. Where there is an impedance match necessary or an RFI pickup problem the connection and adequate patch is more exacting. Figure 41 shows the twelve test points to be displayed in terms of the radar functional diagram.

The pickoff and termination technique for each point is as follows:

#1 Upper: TEA AFC IF. (EL #20)
Use TEE located at patch panel.
Keep oscilloscope line short.

#2 Upper: Gated TEA discriminator. (EL #20)
Same as #1 Upper.

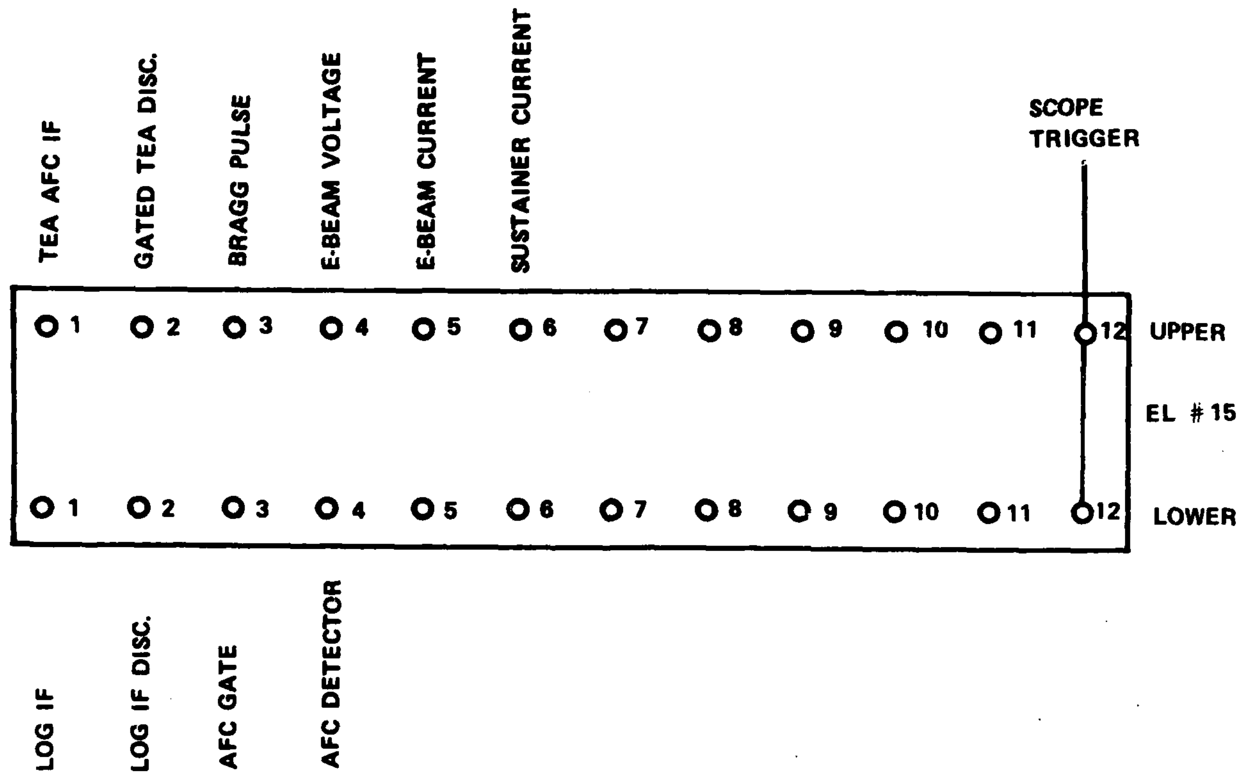


Figure 40. Suggested Patch Panel Connections, Front View, EL #15

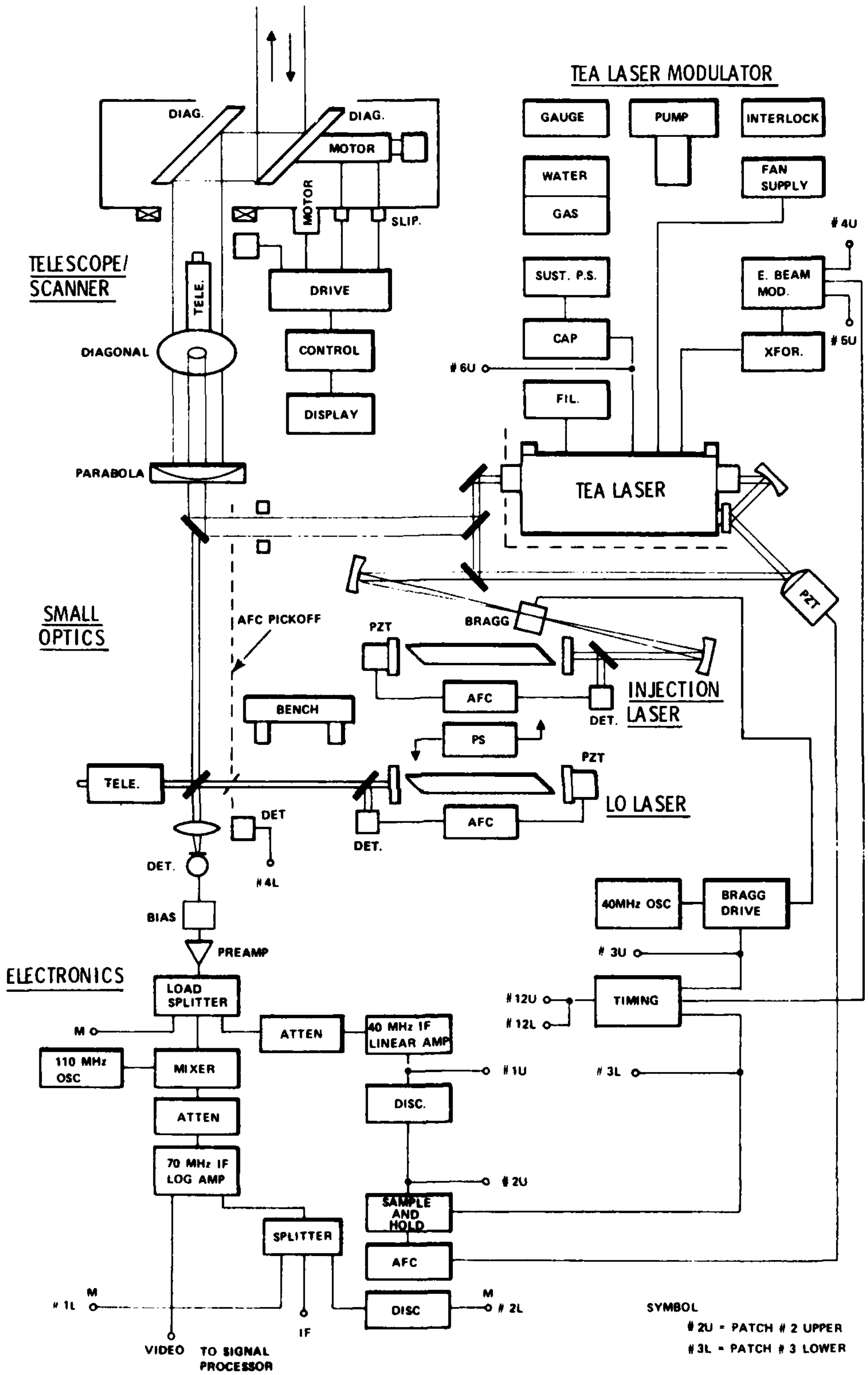


Figure 41. Suggested Patch Panel Pickoff

#3 Upper: Bragg pulse. (EL #17, J5)
Use 50 Ω feedthrough termination at patch panel.

#4 Upper: E-beam voltage. (EL #36)
Use 50 ohm feedthrough termination at patch panel (for calibration)

#5 Upper: E-beam current (EL #3c)
Same as #4 Upper.

#6 Upper: Sustainer current (current transformer EL #1b)
Same as #4 Upper.

#12 Upper: Scope trigger (EL #17, J3)
#12 Lower: Scope trigger common. Use one 50 ohm termination feed-through at patch panel. Keep cables to scopes short.

#1 Lower: Log IF (EL #20)
Use 50 Ω termination at scope when used and at patch panel when not used.

#2 Lower: Log IF disc (EL #20)
Same as #1 Lower

#3 Lower: AFC gate (EL #17 J7)
Terminate at patch panel.

#4 Lower: AFC detector (EL #27)
Use 50 ohm termination at scope when used.

EL #16 and EL #18

Chassis 16 and 18 provide the center for manual position or velocity control of the azimuth and elevation scan angles. For manual positioning in binary steps the switches S1 through S14 are set at the 14-bit parallel binary word desired. (See Figure 42.) This mode requires that the cable plug from J1 (on this chassis) be connected (in rear) to the digital input, J2, of the scanner display chassis (EL #12 and 13) in place of the plug from the computer. The inconvenience of the manual plug change is preferred to cumbersome electronic switching since the manual control will only be used for test and calibration. As shown, the 5 volts necessary to excite the manual control switches comes from the UA78MOS regulator, which in turn uses the same 24 volts as the servo driver electronics.

The other function of this chassis is to provide the power op-amps to drive the scanner motor.

The power op amps, AM8530, are supplied with both +24 and -24 volts. The scanner motors, Globe Type BD, 100A104-100 and Type LL, 3A1003-1 for azimuth and elevation respectively, are high ratio gear motors only an inch or so in diameter and thus require a relatively small amount of power. The input for the op-amp, J4, comes from the error signal (BNC) plug on

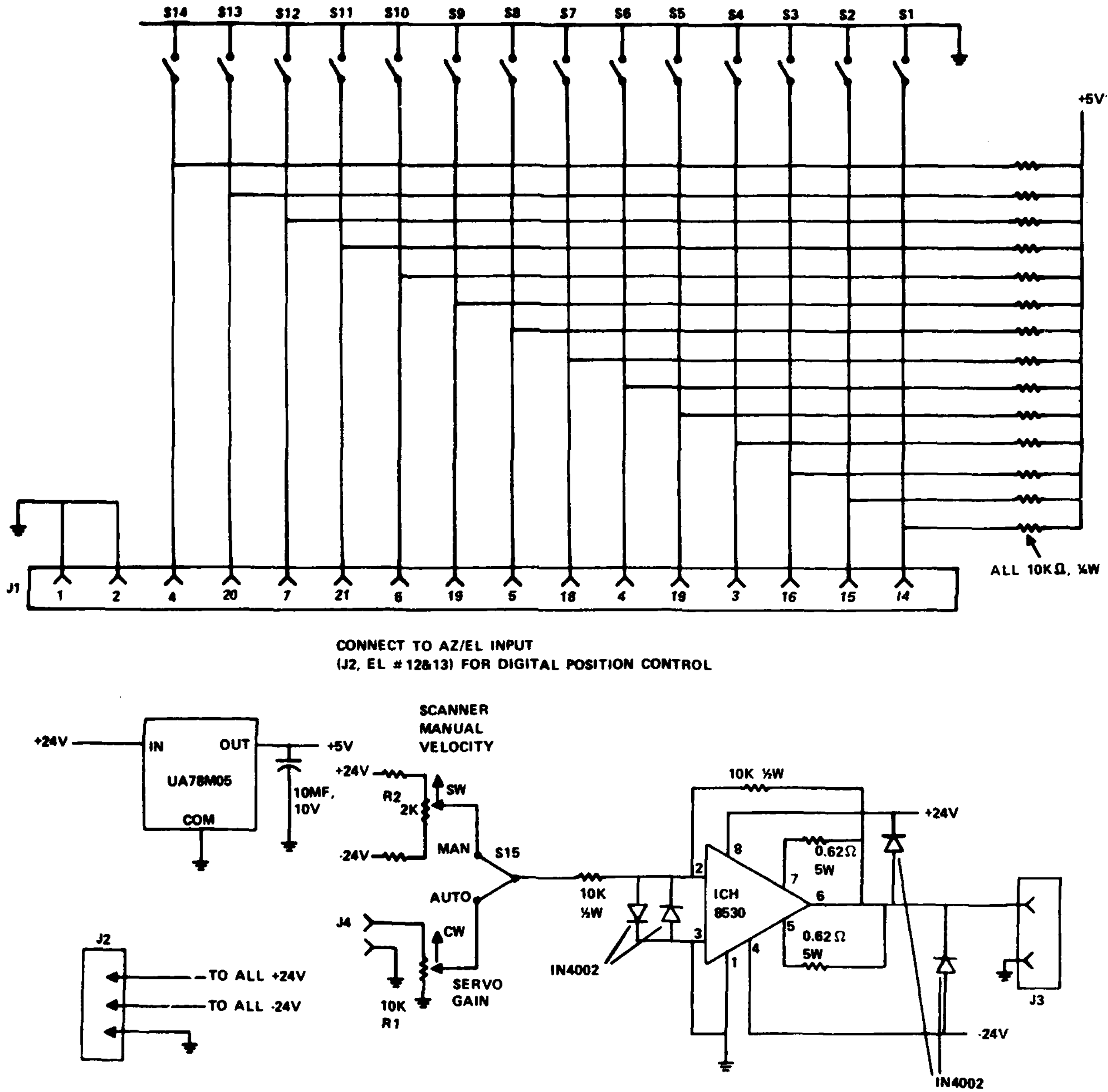


Figure 42. Azimuth and Elevation Control Chassis EL #16 and EL #18

the rear of the scanner display chassis. The op-amp output J3 goes to the Globe motors on the scanner. (See EL #25.)

The suggested front and rear panel plug and control position are shown in Figures 43 and 44. DC power comes from EL #21. This chassis has not been wired but all the components have been supplied, in a box marked Electric Components for EL #16, 18.

EL #17

The function of the pulse trigger generator, EL #17, Figure 45, is to provide the base 50 Hz pulse repetition rate and a series of synchronized pulses with delays suited to several functions. (See Figure 45.) For example, the Bragg modulator should start sufficiently early before the TEA laser excitation, that the injection laser signal dominates the frequency of the TEA laser regeneration. Further the Bragg modulator must be shut off soon enough before the main TEA laser output to prevent optical feedback yet late enough to maintain injection mode control. The delay adjustments are accessible to the operator on the front panel of 17.

The basic circuit of the pulse generator is, (see Figure 46), an NE555 Astable multivibrator adjusted to generate the base prf followed by four one shot multivibrators, 74LS123, adjusted to provide the various delays. The circuit provides separate isolation of the gate outputs from their display monitor signals. Figures 43 and 44 show the suggested layout of signal outputs and controls. The circuits have been wired but not tested. Only one power cable for DC +15 volts is needed, as shown.

EL #19, #23

The local 120 volts distribution panels, EL #19 and #23 provide the AC for all 8 power plugs in rack number 3.

EL #20

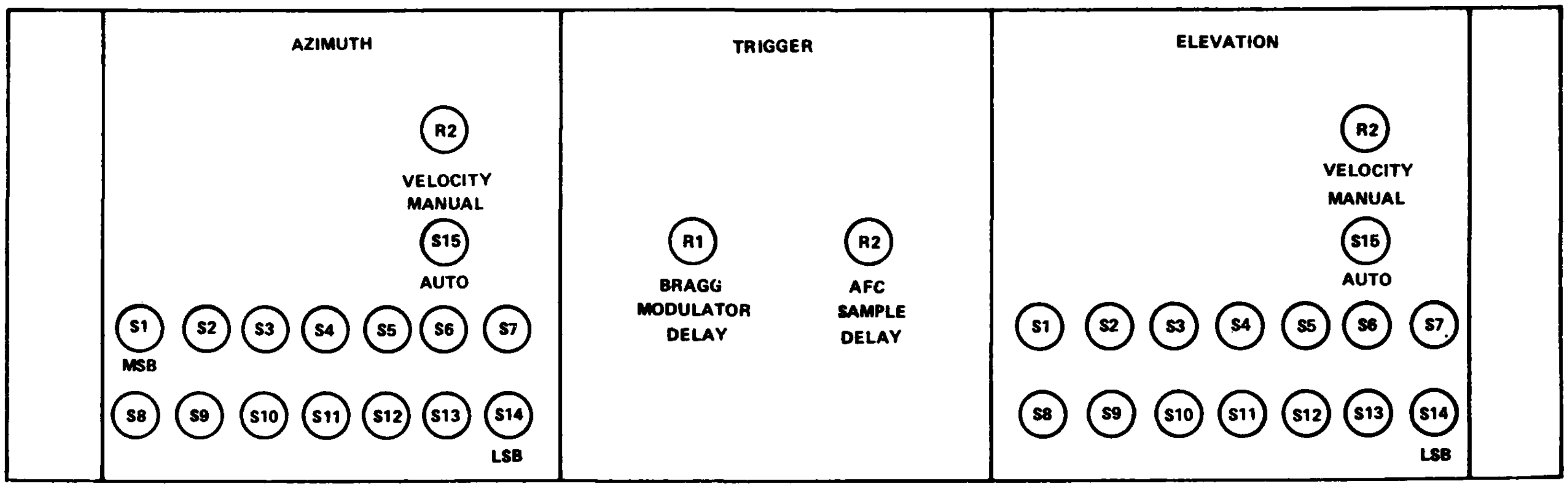
Most of the circuitry of the laser radar heterodyne receiver, EL #20, is in the form of manufactured equipments. (See Figure 47.) There are, for example, two intermediate frequency amplifiers made by RHG. One is a linear IF at 40 MHz used for TEA laser frequency control and the other a LOG IF at 70 MHz to provide wideband doppler data to the customer computer. Manufacturers spec sheets for the receiver are collected together to form a booklet in the box of technical manuals supplied.

The receiver chassis has eight BNC connectors on the rear panel to be connected as follows:

J1, 40 MHz output from HgCdTe detector EL #27

J2, AFC IF to patch panel EL #15

J3, Gated AFC Discriminator to patch, EL #15



S1-S14 SPST
S15 SPDT
R2 2KΩ POT W/KNOB

EL # 16

R1 — 50KΩ POT W/KNOB
R2 — 25KΩ POT W/KNOB

EL # 17

S1→S14 SPST
S15 SPDT
R2 2KΩ POT W/KNOB

EL # 18

Figure 43. Azimuth and Elevation Control, Front Panel (EL #16, 18)

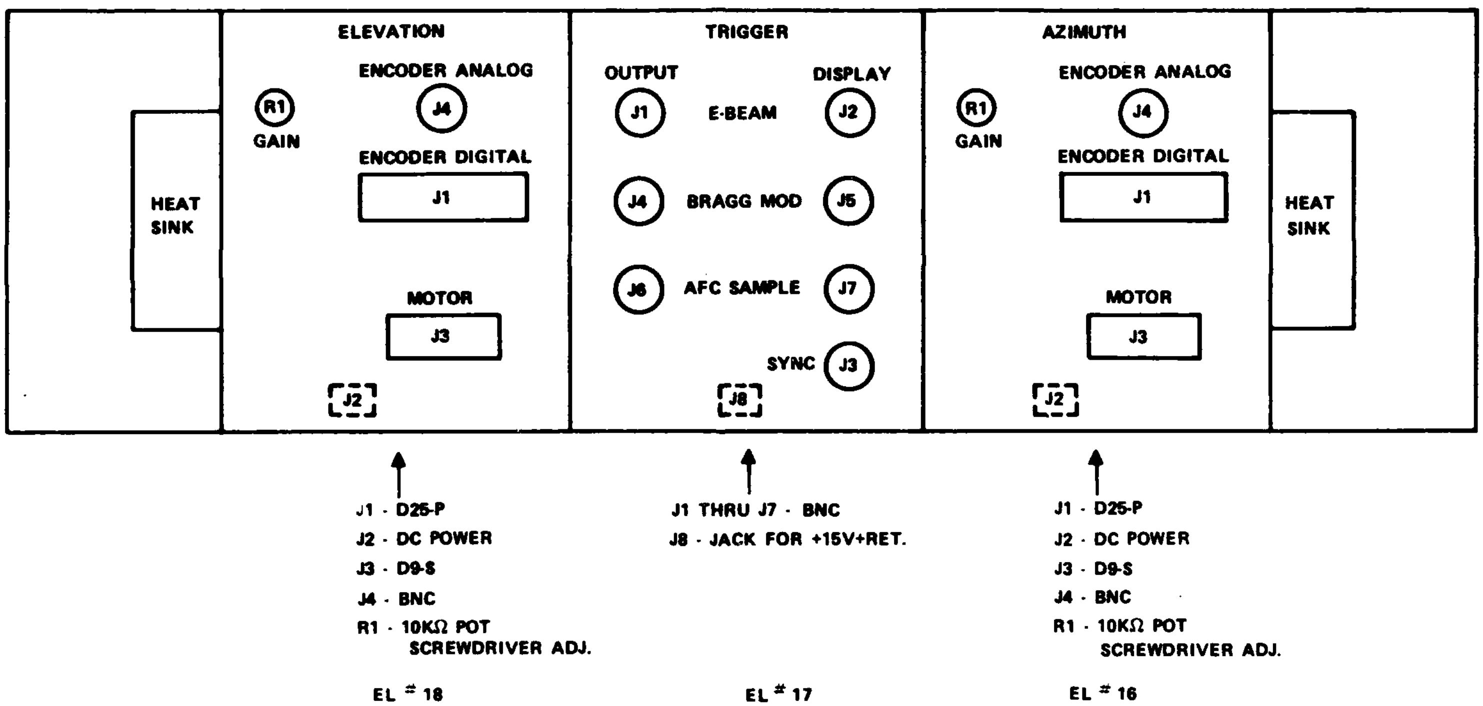


Figure 44. Azimuth and Elevation Control, Rear Panel, EL #18, 16

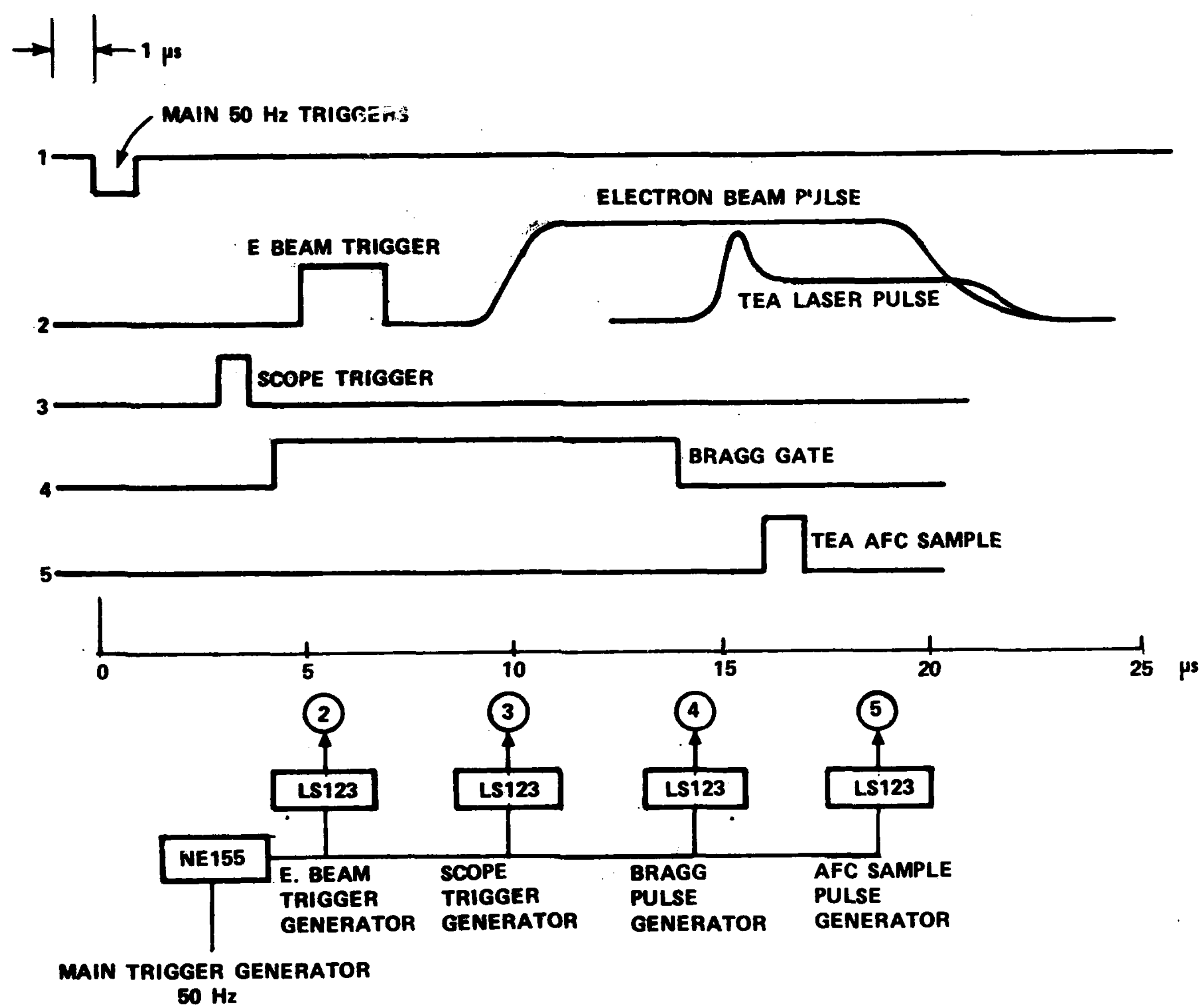


Figure 45. Pulse Trigger Timing

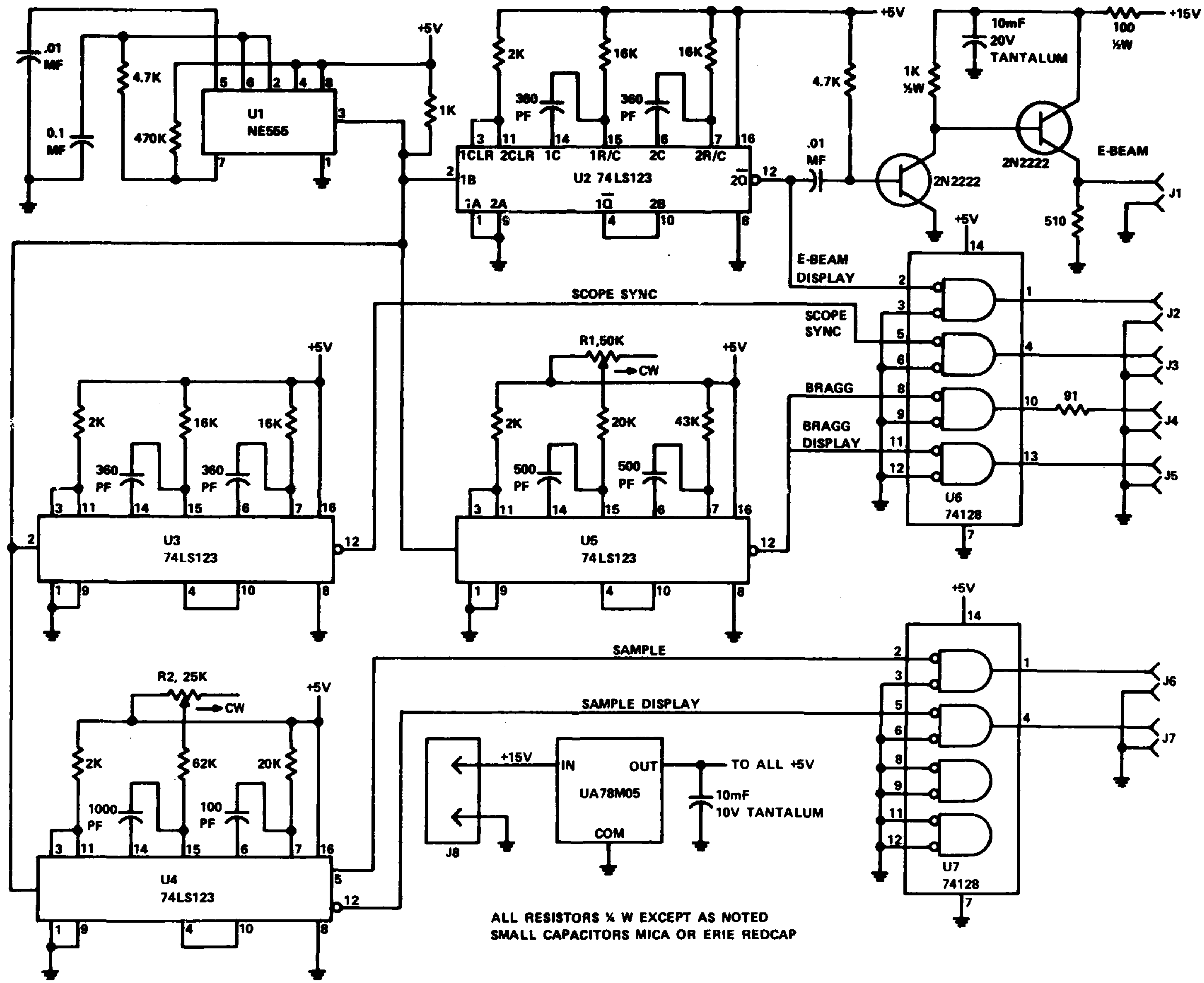


Figure 46. Trigger Generator, EL #17

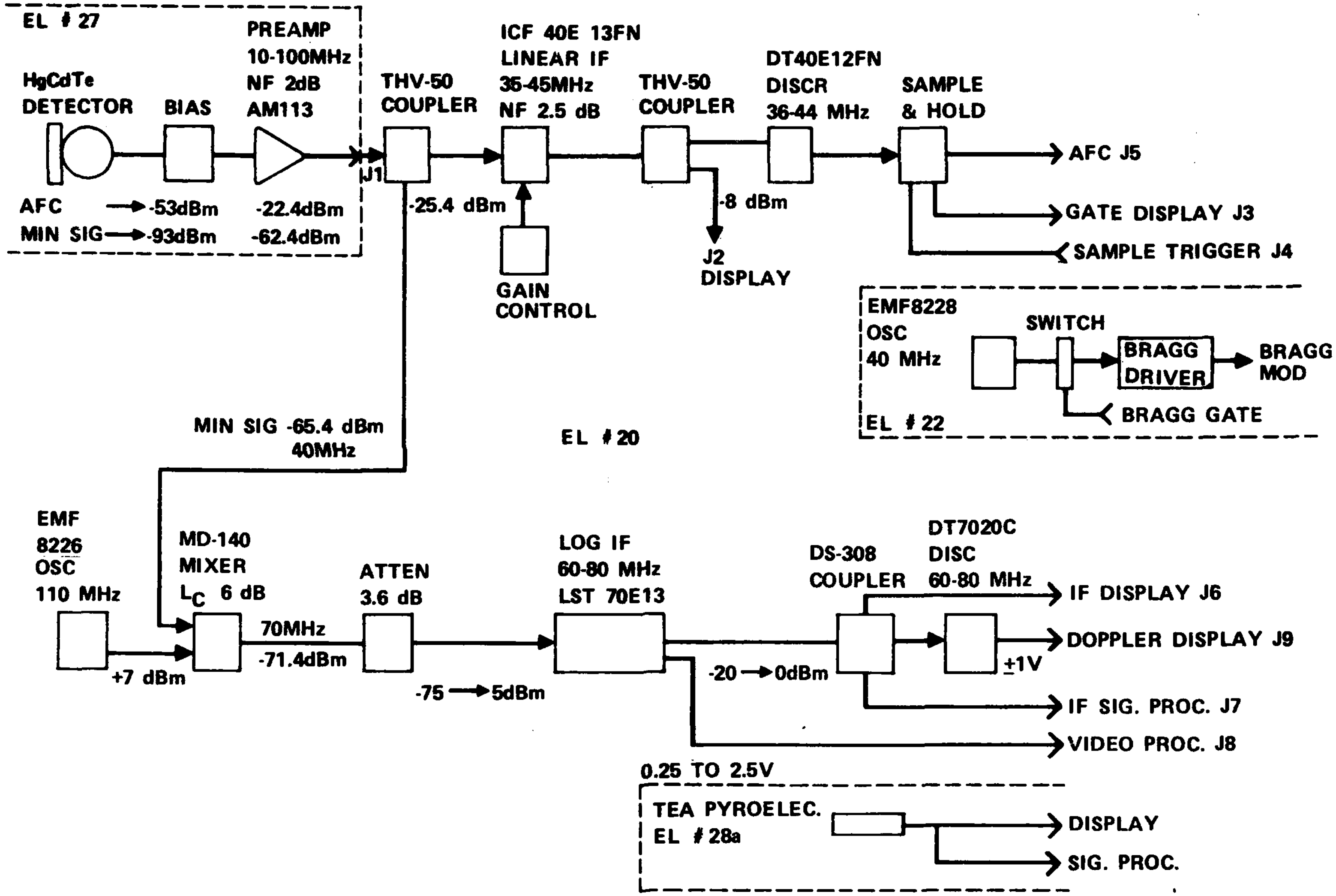


Figure 47. Receiver Electronics, EL #20

J4, Sample and hold trigger from EL #17

J5, Gated AFC discriminator to TEA AFC, EL #11

J6, Log IF to patch panel, EL #15

J7, Log IF to customer computer

J8, Log IF video to customer computer

J9, Log IF discriminator to patch panel EL #15

The chassis requires ±15 volts from power supply EL #21.

The sample and hold circuit used to convert the AFC discriminator bipolar pulses to a bipolar DC AFC error signal uses a Datel/Intersil SHM-6. The spec sheet for this is in the booklet "Components of Receiver Chassis EL #20" to be found in the manufacturer's manual box. The recommended circuit is in Figure 49. Operating levels and gain adjustments for this chassis are discussed in Volume II.

EL #21

The DC power supply chassis, EL #21, provides four voltages, plus and minus 15 volts and plus and minus 24 volts with more than enough current capacity to provide for all the systems electronics. We suggest, however, DC for the four detectors on the optical bench be supplied by batteries internal to each chassis to reduce RFI pickup. Figure 50, the Power Tec DC power supply, shows the four OEM modules and their terminals as connected on this chassis. Minus 24 volts is TB-3 terminal 1. Plus 24 volts is TB-1 terminal 5. Plus 15 volts is TB-1 terminal 1 and minus 15 volts is TB-1 terminal 14. Common grounds are TRB-3 #6, TB-1 #4, 10 and 11.

EL #22

The Bragg driver supplies 12 watts of 40 MHz power to the Bragg modulator in 10 microsecond bursts providing injection laser wavelength to the TEA laser cavity synchronized to TEA laser oscillator buildup. The three components involved, an EMF 40 MHz oscillator, a quad diode (Anzac MD-140) switch and a 20-watt (ENI) amplifier are already mounted on chassis EL #22. The circuit, shown in Figure 51, uses the Bragg gate from terminal J4 of chassis EL #17 into J2. This gates the 40 MHz excitation from the EMF oscillator into the ENI amplifier. The ENI output (adjusted by the 50 ohm pot to be no more than the 12 watts dissipation capability of the Bragg modulator) goes to the Bragg modulator EL #36 on the optical bench via terminal EL #J3. The use of a solid state relay to protect the Bragg modulator in the event of loss of water is optional. A suitable solid state relay is mounted in Chassis 22.

The EMF 8228 spec sheet is stapled to the ENI booklet in the manuals box.

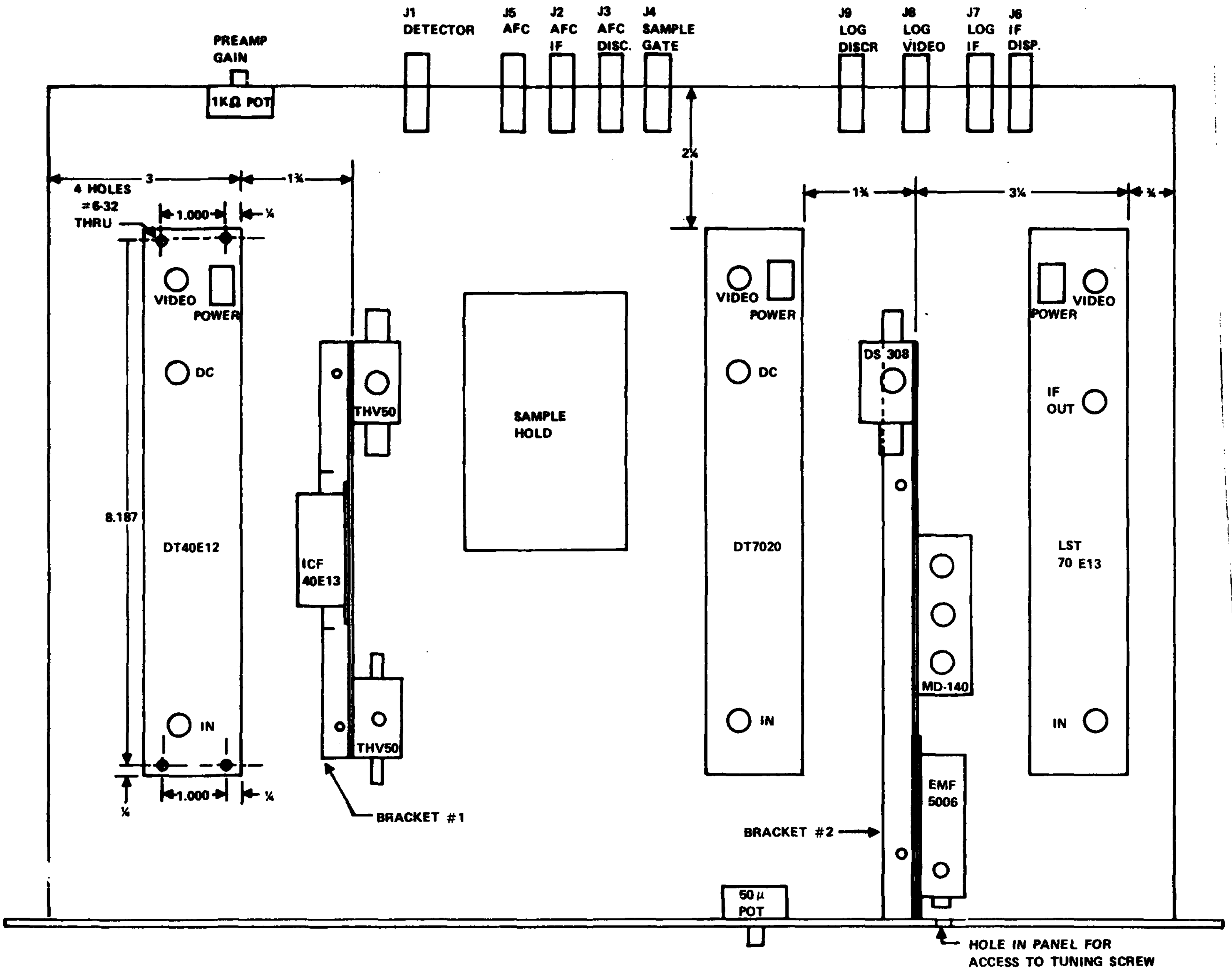


Figure 48. Receiver (EL #20) Layout

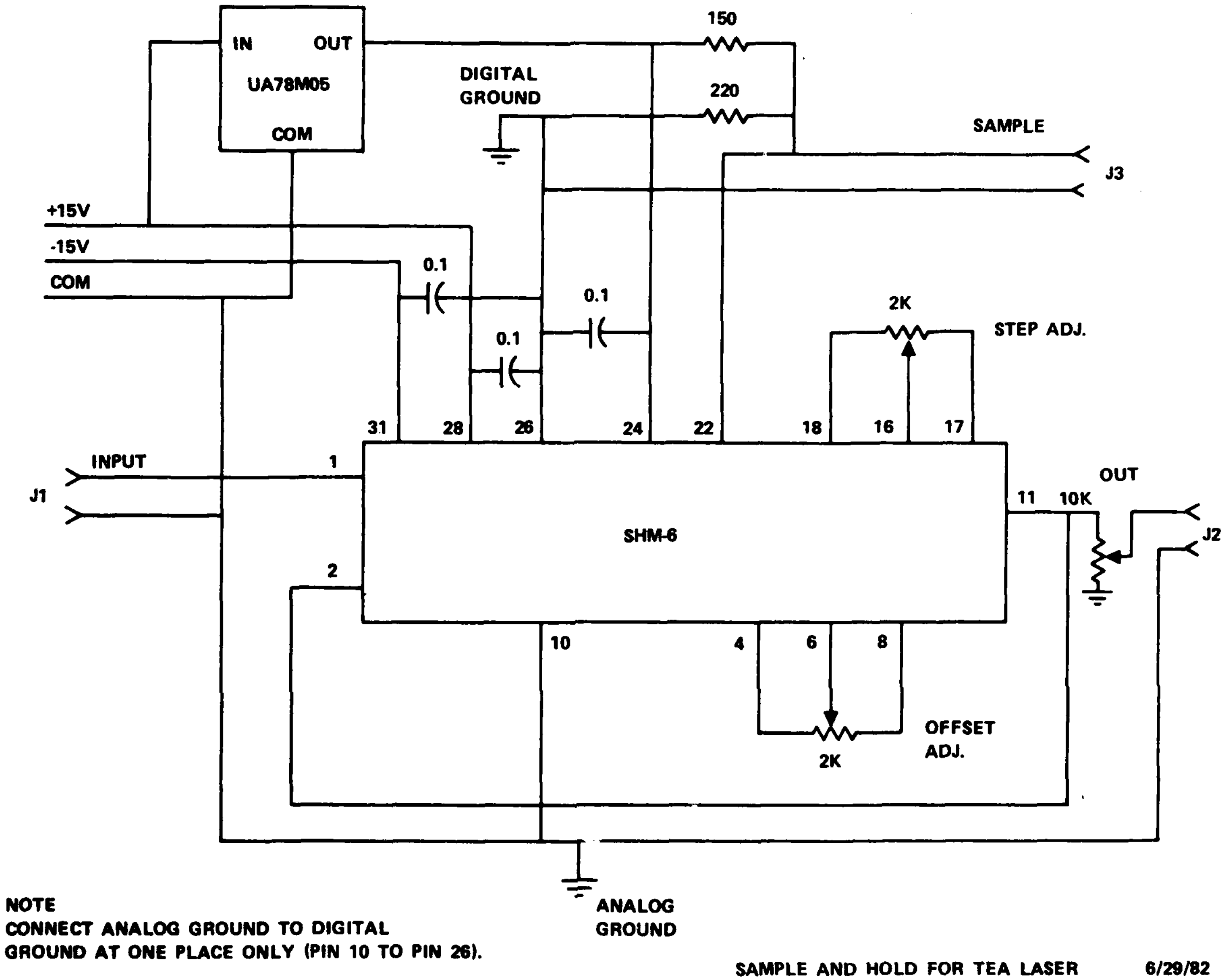


Figure 49. Recommended Circuit

AD-A135 059 PULSED HETERODYNE CO2 LASER/SCANNER SYSTEM VOLUME 1 2/2
ASSEMBLY REPORT(U) GENERAL ELECTRIC CO SYRACUSE NY
ELECTRONICS LAB G B JACOBS JUN 83
UNCLASSIFIED AFGL-TR-83-0191-VOL-1 F19628-80-C-0184 F/G 17/9 NL

END
FILMED
1-84
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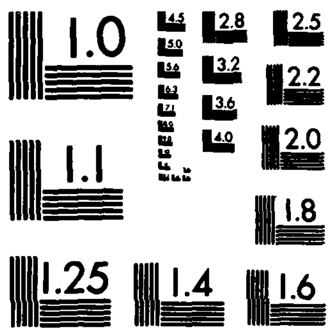


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

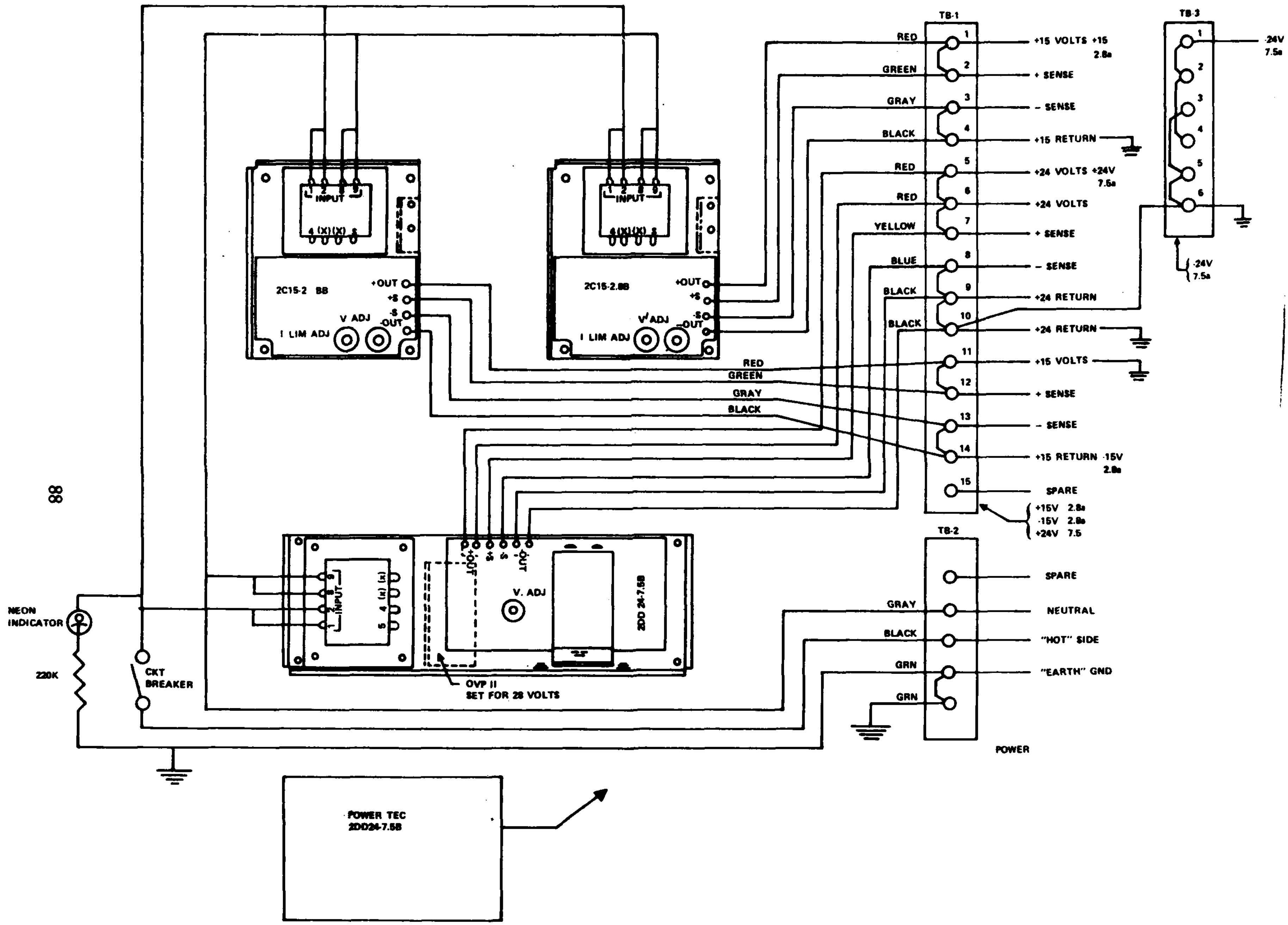


Figure 50. D.C. Power Supply

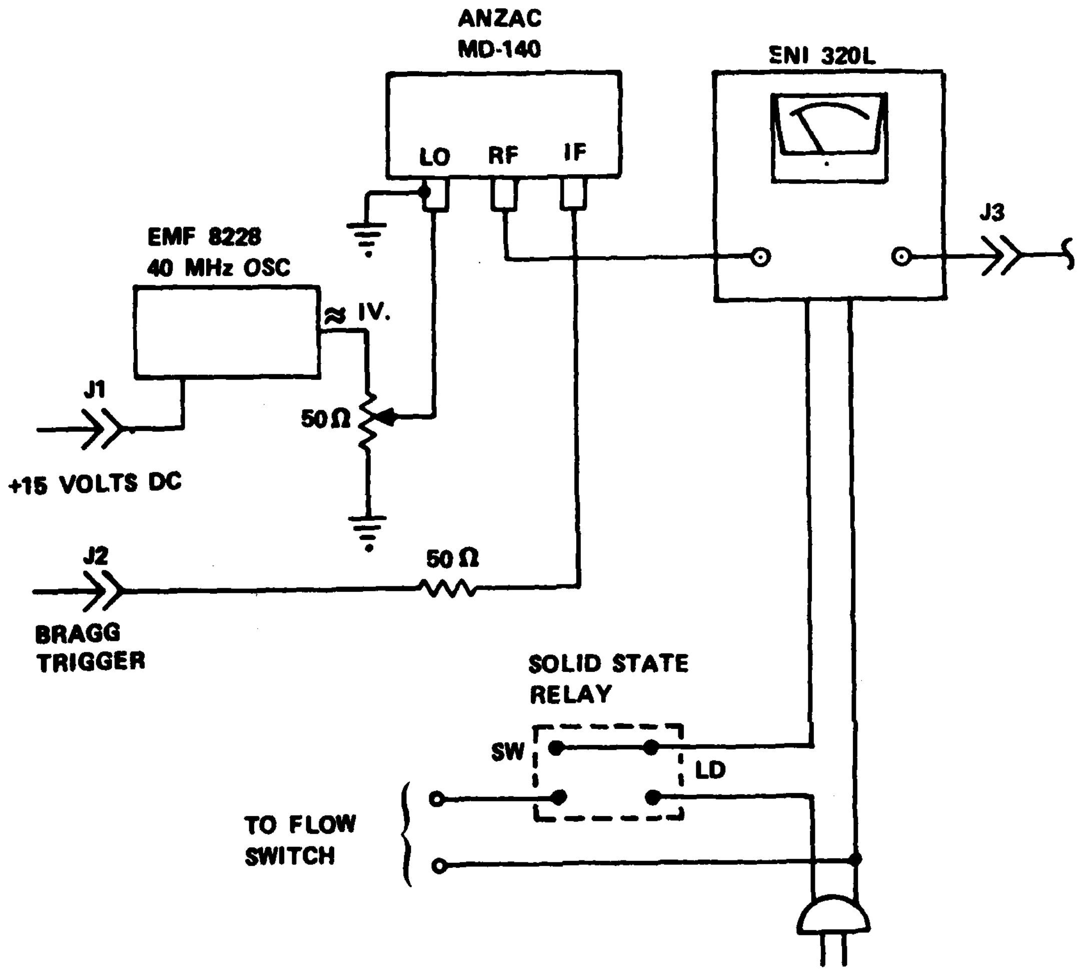


Figure 51. Bragg Driver, EL #22

EL #23 and EL #24

Discussed earlier.

EL #25

The scanner, EL #25, provides the electrical loads for the scanner motor drivers EL #16 and 18 and the scanner difference encoders EL #12 and 13. The scanner and its interconnection were described under these titles and shown in Figures 39, 42 and 44.

In summary the scanner cabling is as follows:

(1) Azimuth synchro on EL #25 to J1 on EL #13. Cable supplied.

(2) Azimuth motor on EL #25 to J3 on EL #16.

(3) Elevation synchro to five rings of azimuth bearing slip ring. Cable supplied.

(4) Elevation synchro brushes (five) on azimuth bearing slip ring assembly (see Figure 23) to EL #12 terminal J1. Cable supplied.

(5) Elevation motor to two rings of azimuth bearing slip ring.

(6) Elevation motor brushes (two), on azimuth bearing slipring assembly to J3 of EL #18.

When the TEA laser radar is in operation TEA laser transmitter power may be reflected back into the receiver detector when the elevation and azimuth axes are in certain directions -- (such as pointing directly at a highly reflecting building nearby). Further, in the continuously scanning mode set by the elevation manual velocity control it would be desirable that the system not waste time directed toward the ground. To avoid these problems a set of limit switches, operated by detents on the elevation and azimuth axis, can be set up to stop or to reverse the scan direction in certain intervals. Limit switches and detents have not been provided. Of course, for computer control of scan angles these problems can be corrected in the computer program.

EL #26

EL 26a is the TEA laser that sits above the TEA laser electron gun EL #26b. TEA laser and gun construction and assembly is discussed under the optical assembly section, chassis SO #38. The primary electrical load of the TEA laser are the sustainer electrodes. The connection to these, from the sustainer capacitor, are described under EL #1b. The NaCL window heaters on the TEA laser have been given the number EL #4 and those connections are described under that title. The connection to the TEA laser CO_2 gas circulating fans are discussed under EL #2, the E-beam control panel, which supplies power to these fans. Figure 29 shows the cable from TB 3-1 of EL #2 to the fan plug on the TEA laser. The cable is supplied.

The connections to the nine split phase 60 Hz Rotron fans inside the TEA laser are shown in Figure 52. The manufacturer spec sheet is attached to the "MISC" group in the tech manual box.

The electrical load of the electron gun, EL 26b, is the filament, 98 volts, 9 amperes DC (see Figure 19) and the cathode pulse of 120 kV 15 amperes, discussed under the E-beam modulator, EL #3, and the E-beam control EL #2. The connections from the modulator to the electron gun high voltage bushing, is shown in Figure 32. The physical length is about 2 inches. The primary cabling problem here is the mechanical one of corona shielding, providing sufficient spacing to prevent arc-over and providing mechanical means to prevent damage to either of the ceramic feed-through insulators. The vacuum gun bushing is difficult to replace so a usable spare (salvaged from the discontinued GE heterodyne laser radar facility) has been provided in box marked EL #26b.

EL #27

The HgCdTe detector made by New England Research is shown in Figure 9 and discussed under optical assembly of SO #16. Also shown in Figure 9 is the circuit box, used to hold the detector bias and preamp close to the detector. The circuit is shown in Figure 53. The connection to the detector (from J1) should be as short as possible.

The laser heterodyne detector EL #27 generates 40 MHz doppler signals as weak as -93 dBm. (See Figure 47.) In the high current short pulse environment of the TEA laser RFI is a major problem for detector shielding. The cable from J2 to the receiver chassis, (EL #2 terminal J1) should be located physically such as to help reduce RFI and insulated from the case. Figure 53 shows the power to the Anzac AM113 as coming from the 15-volt DC power of EL #21 (via J3). The AM 113 requires 70 ma. However if RFI becomes intolerable it may be necessary to use an internal battery.

Although the major portion of the RFI (from the thyratron and TEA laser sustainer discharges) is over before the target signal returns, the detector circuit recovery time may still cause target readout problems. Further, the TEA laser heterodyne AFC signals (which are at time zero) may be noisy even if the AFC pickoff power approaches detector damage levels.

The AM113 has been packed with the detector in box labeled SO #16.

The NER detector tech manual is located with the others.

EL #28

The electrical chassis' EL28a and EL #28b use three pyroelectric detectors between them. These detectors (plus a spare are packed in the optical components box SO #18 (which corresponds to EL #28b). The electrical boxes are also packed and labeled under the appropriate "SO" number.) Figure 54 shows the circuits used for chassis 28a and 28b.

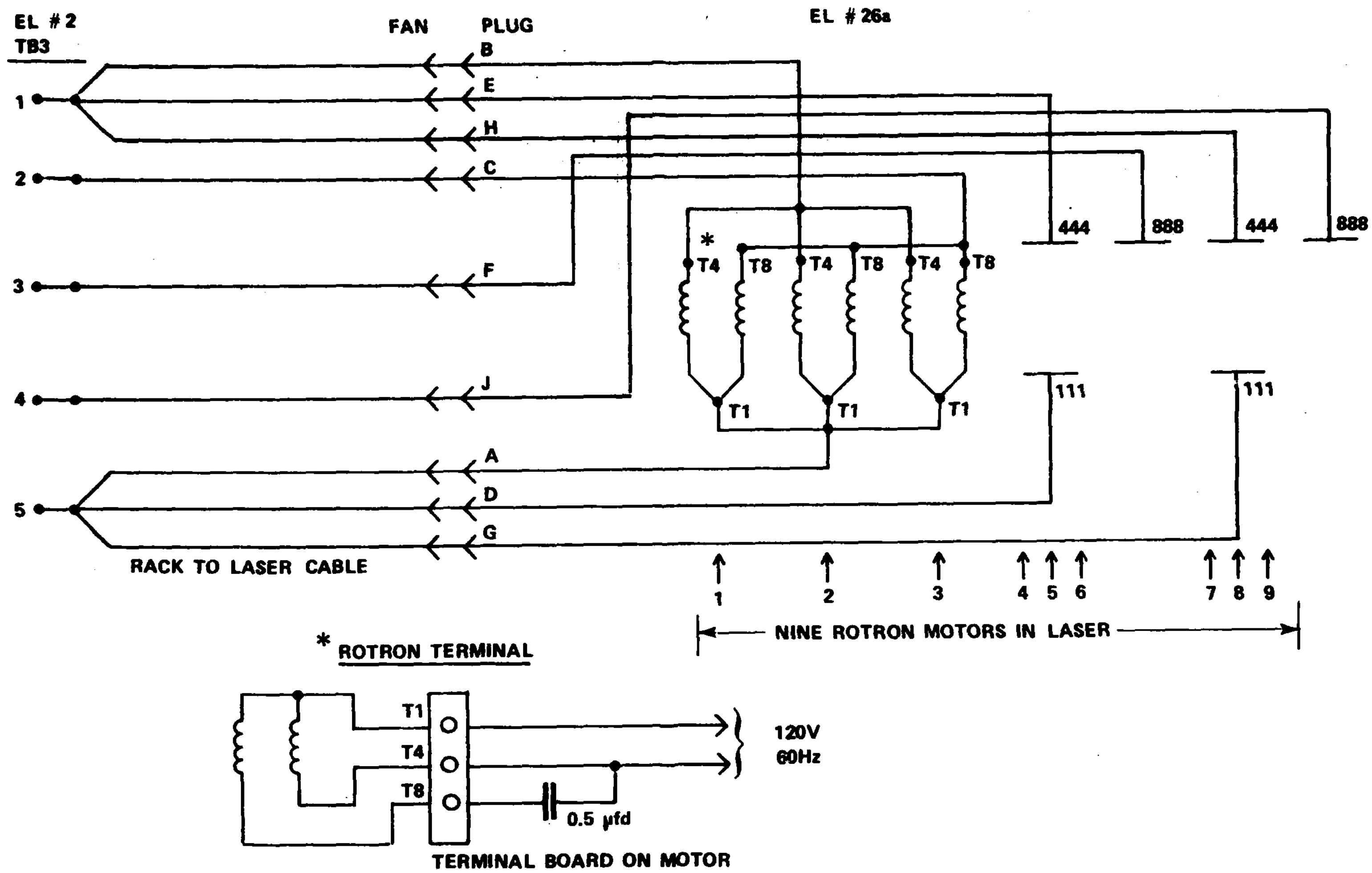


Figure 52. Cabling to TEA Laser Fans, EL #26a

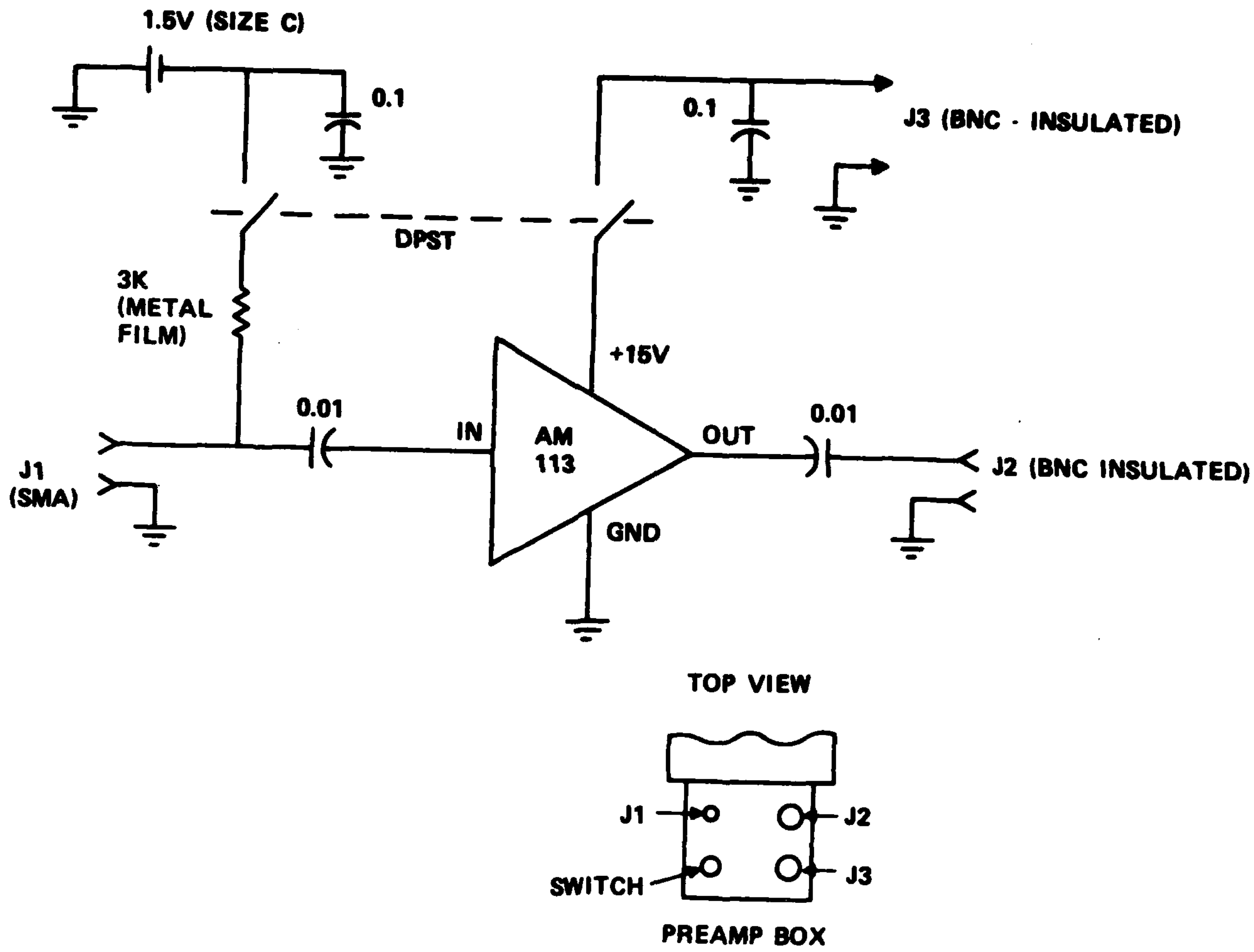


Figure 53. Heterodyne Detector Preamp; EL #27

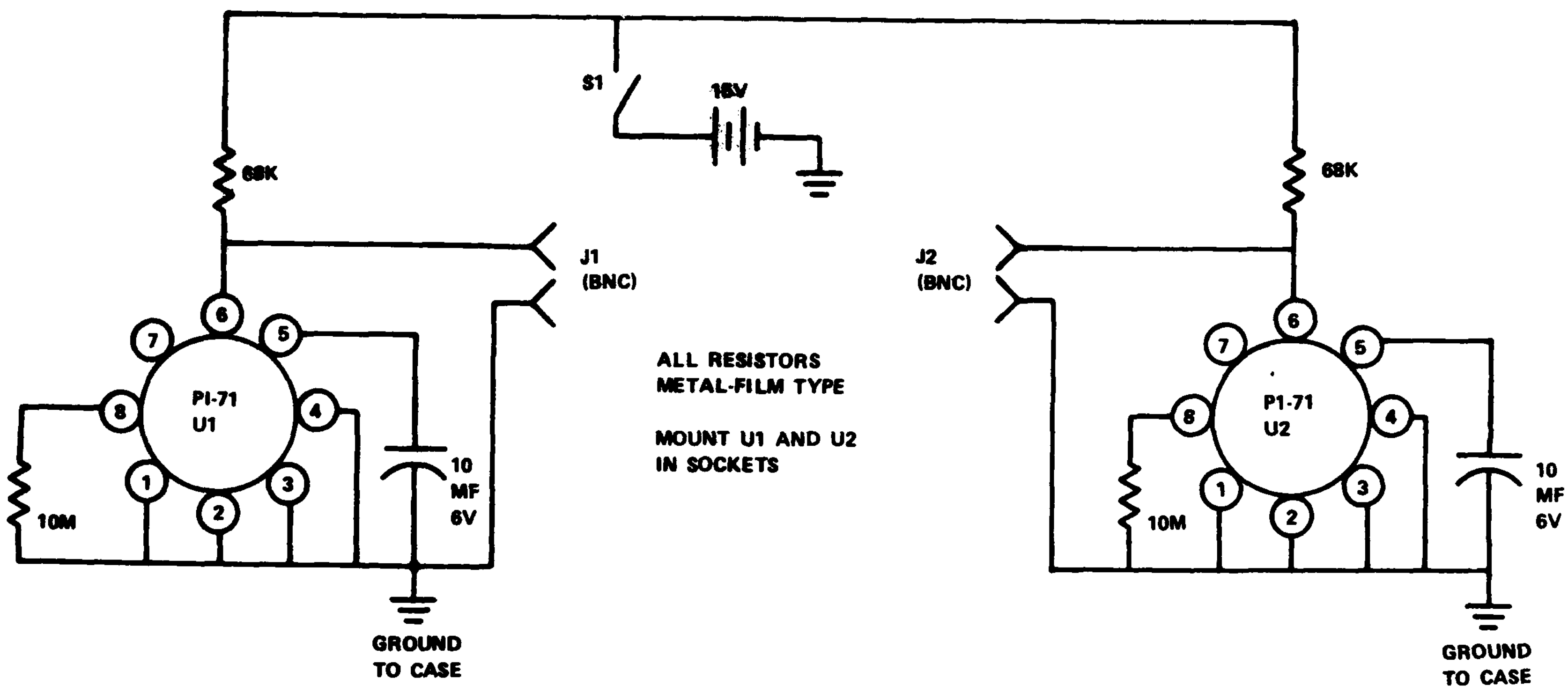


Figure 54. Pyroelectric Detector for EL28a and 28b

In Figure 54 we show two pyroelectric detectors. This circuit would be used as it is shown for dither detector pair EL 28b. J1 and J2 will go to J-10 pin C of EL #9 and EL #10 (depending of course which detector goes with which AFC stabilizer). (See Figure 36.) For the case of the TEA power monitor detector, EL #28a, only a single section of Figure 54 would be used and the 10 megohm resistor would be reduced to provide the desired bandwidth. Its output J1 (or J2) goes to the jack #4 lower of the patch panel, EL #15, as shown in Figure 40. The dither detector connections are also described under the titles of the EL #9 and #10, LO and Inj AFC stabilizers. In both cases we suggest use of internal batteries since the current drain is so low and the RFI so high. Technical manuals for the Molectron pyroelectric detectors are enclosed.

EL #29

Two tanks (Matheson) of premixed He/N_2/He are needed. Each uses 2000 psi regulators, needle valves, flow gauges and hoses, as shown in Figure 14 and discussed under the laser optical components SO #22 and SO #35. The mixtures are (75% He, 15% N_2, 5% CO_2) for the low pressure lasers and 48%, 40%, 12%, for the TEA laser. Purity is not critical.

EL #30

The cooling water manifold connections and corresponding flow switch (interlock) settings for the low pressure laser/Bragg modulator (0.1 gpm), diffusion pump (.25 gpm), E-beam gun (1.5 gpm), and TEA laser 2 gpm are shown in Figure 13. The only electrical connections are the flow switches, discussed under EL #2, EL #3a and EL #8. We have supplied only the three lowest level flow switches.

EL #31

Power for the diffusion pump on the TEA laser E-beam gun comes from E-beam control panel EL #2. The power cable, vacuum interlock and water flow interlock for this unit are described under EL #2, E-beam control panel.

EL #32

Power for the electron gun roughing pump and its vacuum interlock are described under EL #2.

EL #33

Connections to and controls for the two low pressure lasers EL #33 are described under SO #22 (CO_2 lasers) and EL #8 (LO/Inj. power). High voltage partition feedthrough connectors have been supplied.

EL #34 and EL #35

The electrical heaters to prevent absorption of atmospheric moisture by the two NACL windows, EL #34, on the TEA laser (EL #26b), must be left on continuously when the windows are installed. These two heaters draw about 200 watts supplied by two "dimmer switches" installed in panel EL #35 of rack #2. The two "pilot lights" on EL #35 are intended to assure the operator that power is on. The temperature control is not critical. The temperature of the NACL window housing on the TEA laser should feel hot but not uncomfortable to the inside of the wrist. Figure 55 shows the cabling, supplied, and circuit. Handling of the windows was discussed under SO #37 and SO #39.

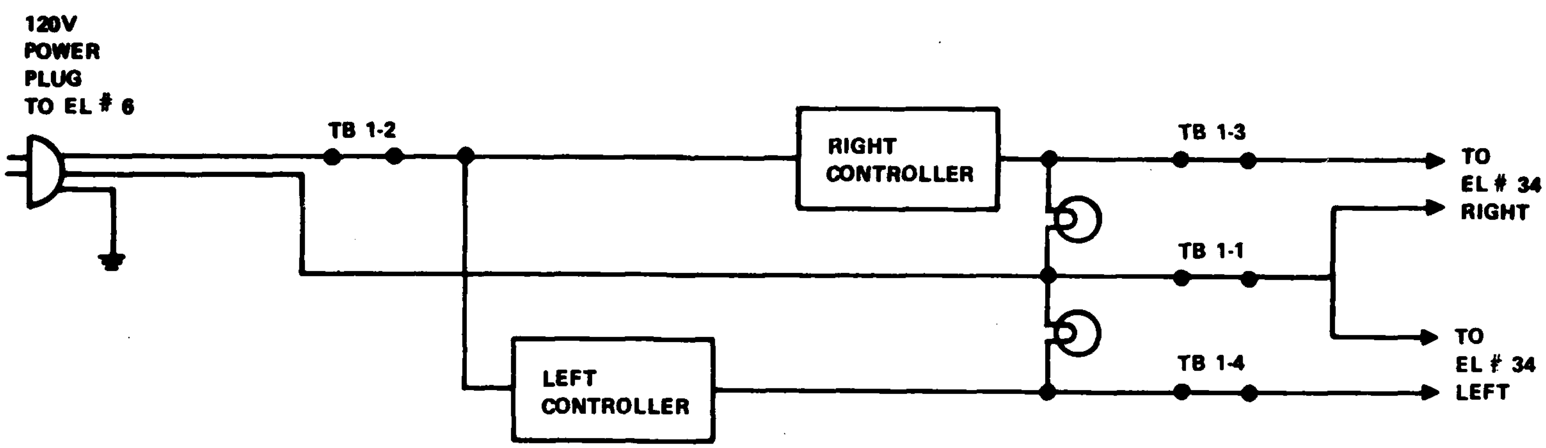


Figure 55. TEA Laser Window Heater Control, EL #35

5 SAFETY PRECAUTIONS FOR THE PULSED HETERODYNE CO_2 LASER/SCANNER SYSTEM

The following precautions pertain to the high power CO_2 laser radar system (Contract F19628-80-C-0184) which is the subject of this document. This unit is sent by General Electric disassembled to the Air Force at Hanscom AFB, MA., where it will be reassembled in a trailer by the customer. If assembled and/or operated improperly, operating personnel or bystanders can be injured or killed. The purpose of this section is to list some of these hazards and indicate how they may be minimized.

Laser radar is an advanced technology and utilizes techniques requiring knowledgeable and thoroughly trained scientists for its assembly and operation. It is essential that proper procedures and effective and conspicuous warning signs be used to discourage operation by unqualified personnel.

Although there are many potential sources of injury in any high power electro-optical equipment, the chief sources of hazard of this apparatus are:

(1) Ozone

(2) High Voltage

(3) Laser Radiation

(4) X-Radiation

This section presents details of these hazards and how they should be handled. While the procedures are generally known to technicians qualified to assemble and operate this equipment, this section is included for emphasis and as a reminder. To apprise operating personnel of these hazards, we have prepared warning signs and urge the Air Force to attach these in conspicuous places on the final installation.

The major safety assurance is training. We request the Air Force to conduct periodic training programs for all personnel having access to this equipment. The General Electric Company stands ready to prepare and conduct such programs on request from the Air Force.

The four dominant safety hazards for this equipment are:

(1) Gas poisoning of personnel in the operating building due to ozone generated by high voltage discharge.

(2) Electrical shock due to high continuous and pulse voltages generated and delivered among the several units of the equipment.

(3) Eye and skin damage due to the high power radiation from the several lasers used in the system.

(4) Ionizing radiation in the form of x-rays from the high voltage electron gun used in the transmitter laser.

Other hazards exist such as eventual damage to hearing (due to acoustic pulses generated by the transmitter laser) or fire hazards (due to oil filled electrical equipments). This section, however, addresses only the four main hazards.

Ozone

The atmospheric pressure (TEA) CO_2 laser and the two low pressure CO_2 lasers in this system use less than 10 CFH STP gas mixture of about 10% CO_2. Although exact fractions are unknown, if 1% of this were continuously converted to ozone the laser would generate ozone at a rate of 0.1 cubic feet per hour. In an unventilated trailer laboratory of 3000 cubic feet this would cause a dangerous level (0.1 ppm) in about two minutes. When installed in a large well-ventilated laboratory, we have found the ozone buildup to be negligible but clearly in the special case of this installation special precautions are necessary. Fortunately, the precautionary technique is simple. The exhaust of the three lasers is merely directed out the ceiling of the trailer. The TEA laser exhaust is a small 1/8" pipe fitting on the top of the laser. The low pressure laser exhaust is the high pressure side of the roughing pump.

Proper ventilation of the exhaust of the CO_2 lasers is essential to the safe operation of this system.

High Voltage

The system consists of 40 separate electrical chassis or boxes, described elsewhere in the assembly and operating instructions. Nearly every unit contains a variety of voltages including the usual 120V, 60 Hz domestic power. In addition, several commercial units are used that contain high voltages such as two oscilloscopes and a vacuum gauge which, like a home television set, are clearly marked, carefully housed and technically described in their own manuals. We discuss here the three special high voltage subsystems whose conditions of operation require special attention. These are:

(1) Low pressure CO_2 Laser, EL#33

(2) Electron Beam Modulator, EL#3

(3) TEA Laser EL#1, EL#26

As in any high power electrical system, the first general precautions are (a) all conducting components a person might touch should be solidly and permanently grounded, (b) a convenient grounding stick should be provided to remove the temptation of touching apparatus after only the power itself is turned off, and (c) equipment should not be repaired or adjusted by a lone operator.

(1) Low Pressure CO_2 Laser

This system uses a 20 kv power supply, EL #8, delivered through ballast (current limiting) resistors located in Rack #2 and transmitted by a cable to the 4 electrodes of the two low pressure lasers. The danger points are the electrodes and windows of the laser and the ballast resistors. The hazard can be reduced by mechanical shields over all three and by interlocking the power supply to the door of Rack #2.

(2) Electron Beam Modulator

This unit consists of four chassis containing high voltages, EL #3a, 3b, 3c, and 3d. EL #3b is the 25 kv power supply whose voltage is controlled by EL #3a. EL #3c is a 3 kv pulse generator that drives the high voltage (120 kv) electron beam modulator, 3d. All units contain or are cabled to high voltages that are shielded according to customary engineering practice. Because of technical requirements, the high voltage output of EL #3d is partially exposed. It is connected to the electron gun of the TEA laser under the optical bench and partially shielded by the table and the skirts of the electron gun. Nevertheless it should be shielded by other barriers and marked clearly with signs to prevent someone from coming within one foot of the high voltage bushing.

(3) TEA Laser

The TEA laser uses 20 kv power from the sustainer capacitor box EL #1b. This capacitor is charged from the commercial power supply EL #1a. The door to the power supply is interlocked, the 20 kv DC to the sustainer capacitor box is carried by shielded cable and passed into the box by shielded connectors. The capacitor's energy is passed out of the box by shielded leads and connectors and attached to a bushing on the laser whose connection is covered with rubber potting compound. The exposed metal fasteners of the box are connected together for grounding. Holes in this box are provided for cooling air. Energy stored in this capacitor is extremely large. All exposed metal should be solidly grounded, with heavy copper braid. The time constant of the capacitor and the bleeder, in EL #1a, is about 30 minutes. If an individual removes the input connectors before this time after shut-off or reached into the connector's sheaths, he could receive a lethal shock. To avoid these hazards, the grounding stick should be permanently applied to all metallic components whenever the equipment is disconnected or opened for adjustment.

Laser Radiation

To set up this system a commercial Helium-Neon (Red) laser is used to align the mirrors and other optical components. The danger is damage of the retina due to the red beam. The usual precaution with these low power lasers should be followed: avoid looking directly into the beam of the laser and use protective goggles when possible.

The laser radar operates at far-IR wavelength, 10μ, at which wavelength the eye is opaque. The danger is thus due to burning of the skin or eye not damage to the retina. The New York State CO_2 Laser Safety Standard is 10^{-2} joules per cm^2 for pulsed lasers and 10^{-2} w/cm^2 for CW lasers. The TEA laser beam has an intensity of up to 1.0 joules/cm^2 (5 joules/pulse) and the low pressure CO_2 lasers put out up to 10 watt/cm^2 and higher at points in the system where the beam is focused. Although these beams are confined to the optical system and normally exist only from component to component on the optical bench, one could get his eye into these beams by bending over or inadvertent movement of a beam. To avoid this, a shield or cage should be lowered over the table once the alignment and operating conditions have been set.

The normal power out of the TEA laser is no more than 1 joule per pulse and when expanded to the 20 cm output beam diameter has an intensity of less than about .004 joules/cm^2. Thus even for a bystander directly outside the trailer house the power on the eye would normally be less than prevailing standards. However, to avoid any possible danger under any circumstances of power or optical focusing, we recommend that the scanner not be allowed to point at anyone, however far away.

X-Radiation

The attached figures show the TEA laser, some preliminary x-ray levels and the location of some temporary, lead shielding installed to supplement the 1/2" lead shielding. The latter is permanently attached to the laser and electron gun and hidden from view by the aluminum housing. The temporary shielding plus the permanent shielding is adequate if the operator is exposed below the levels described in the following paragraphs. If exposure beyond these levels is contemplated, several areas should be shielded more heavily depending upon the number of hours an operator will be exposed. These areas are (1) the foil plate that lies between the gun and the laser, (2) the two laser windows from which the laser beam emerges, (3) the underside of the electron-gun, (4) the high voltage bushing blister which has only 1/16" shielding on the operator side and none on the table side, and (5) the rim of the laser end plate.

We have made measurements of the TEA laser x-ray levels in millirems per hour which unit expresses the fact that a given radiation level is dangerous depending upon the time of cumulative exposure. Federal standards call for no greater than 2 1/2 millirems per hour if the operator will be exposed 40 hours per week, 50 weeks per year. Thus a year's cumulative exposure should be less than 5 rems. It calls for no greater than 100 mr/h for any given week of 40 hours. These levels are for the more vulnerable parts of the body rather than say the fingers or feet.

In respect to higher exposure levels for short exposure periods and lower exposure levels for pregnant women the US Nuclear Regulatory Commission (NRC) regulations and applicable State Regulations should be consulted. The US NRC and some state regulations recommend that during the entire 39 consecutive week gestation period the maximum permissible dose equivalent to the fetus from occupational exposure of the expectant mother should not exceed 0.5 Rem.

Figures 56 and 57 show that at electron beam current levels somewhat less than maximum power (95 kv, 11a, 10 μs, 50 pulses per second). The x-ray levels impinging above knee level are in the range of 2 to 50 millirems per hour on the operator side and 12" away from the laser. At five feet away these levels would be 0.1 to 2 millirems/hour (if the source is small compared to its distance). At ankle height, 12" away, the radiation is coming from nearly overhead and thus it too would be the 2 millirem range at 5 feet.

Thus it is clear that while, in the lightly augmented shielded system, there is an x-ray hazard, it becomes negligible for an operator who stays five feet away from the system or approaches closely for only brief periods.

Further shielding is easily added. Figure 58 shows the shielding delivered with the system and designed in particular to cover major leaks in the initial shielding system of Figures 56 and 57.

General Electric Company urges the Air Force to train its operating personnel to limit their distance and exposure time according to the Federal and/or State standards and to use all the temporary shielding GE has supplied whenever the system is used.

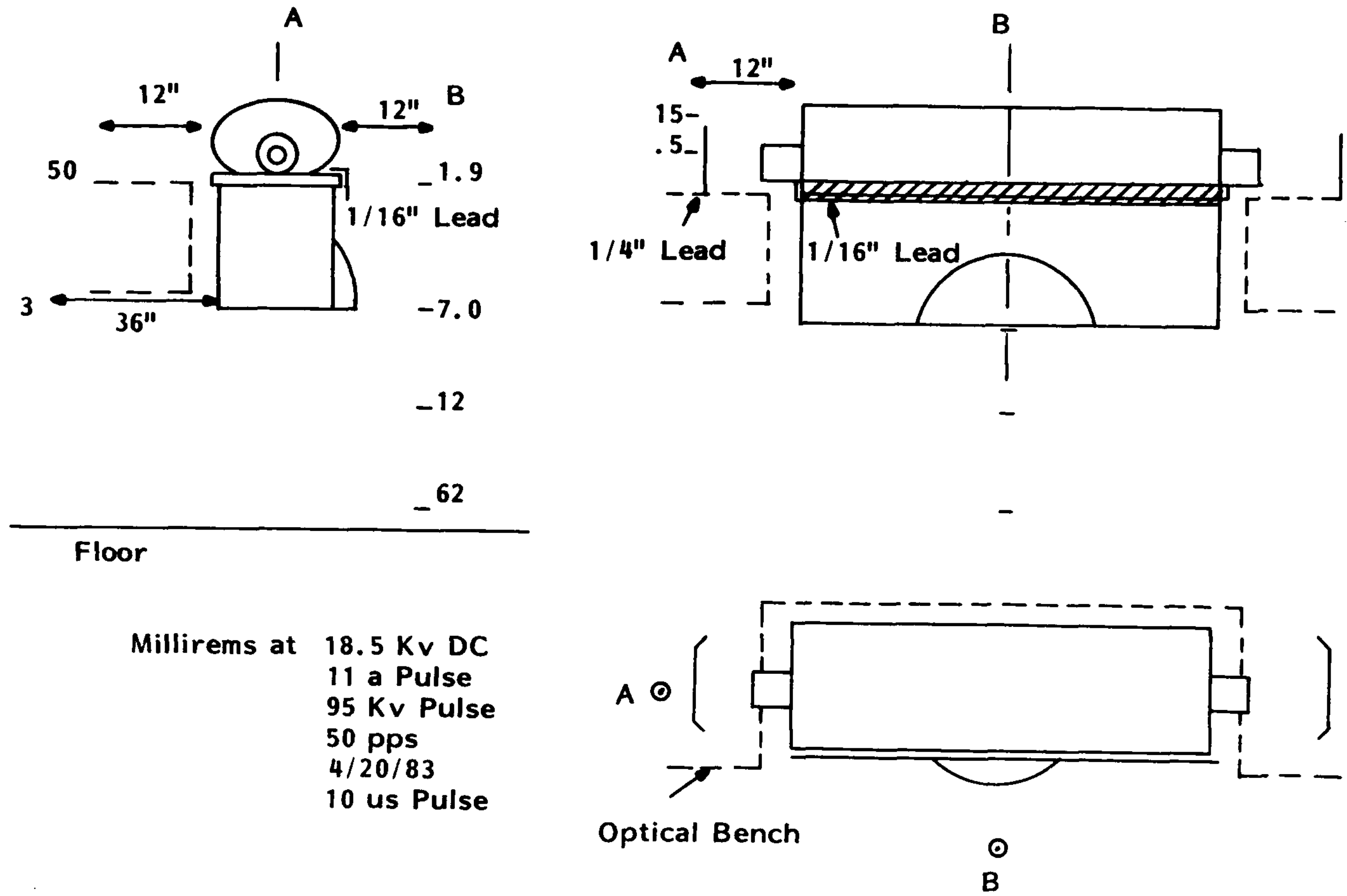
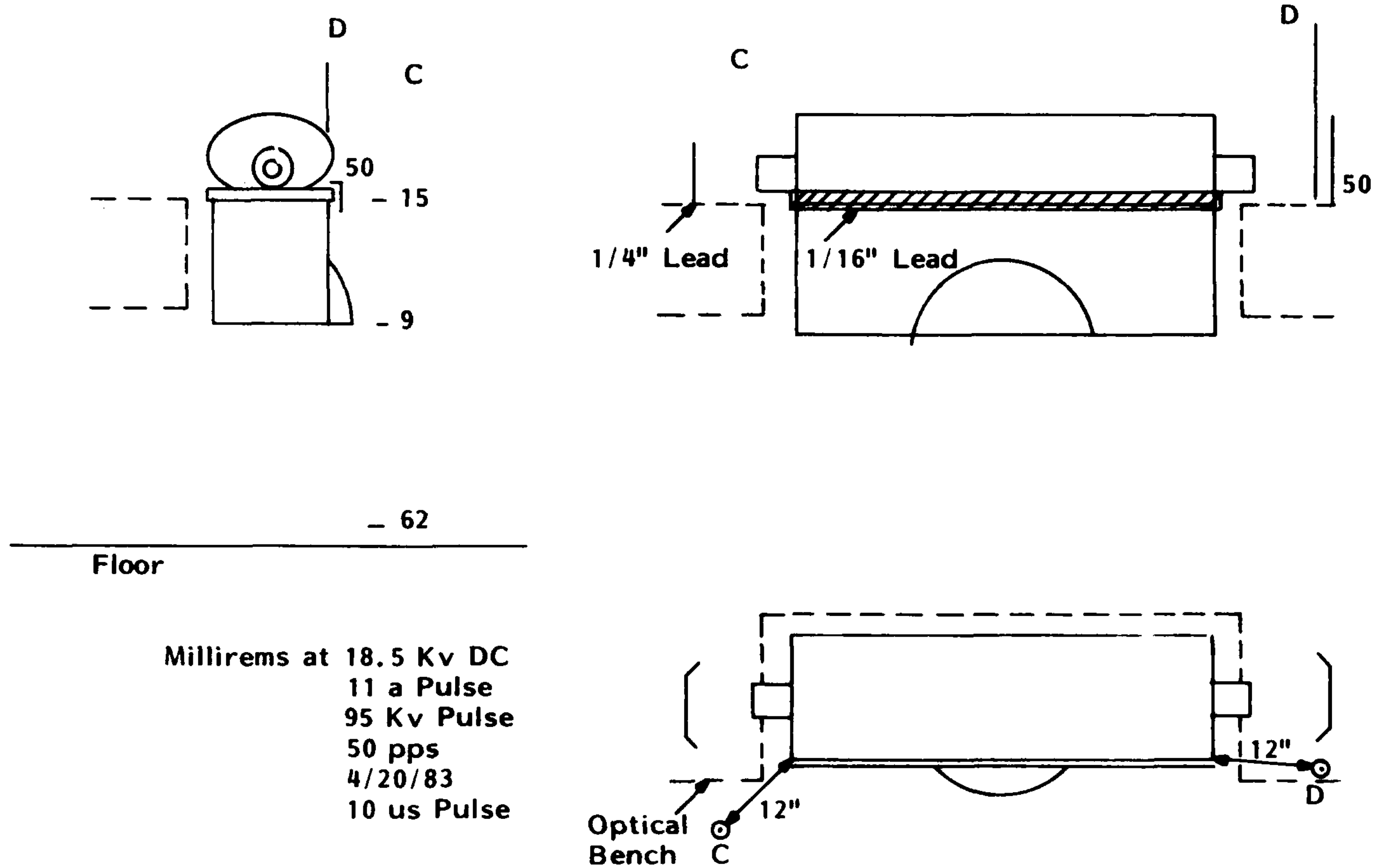


Figure 56. TEA Laser X-Ray Levels, Axes A & B



Millirems at 18.5 Kv DC
11 a Pulse
95 Kv Pulse
50 pps
4/20/83
10 us Pulse

Figure 57. TEA Laser X-Ray Levels, Axes C and D

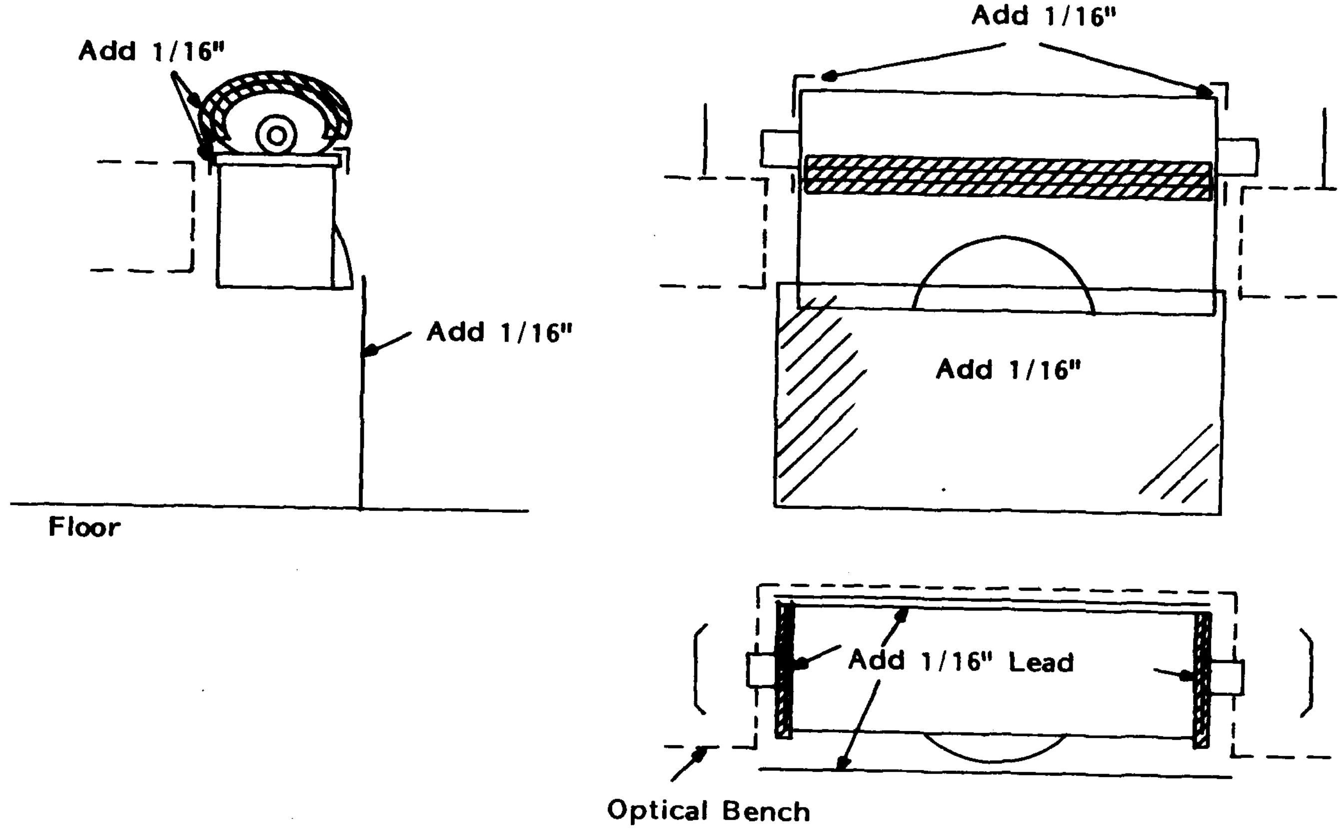


Figure 58. TEA Laser Additional X-Ray Shielding

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