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PRODUCTION AND ENGINEERING METHODS FOR CARB–TEK® BATTERIES IN FORK LIFT TRUCKS

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JAMES C. SCHAEFER
ESB INCORPORATED
TECHNOLOGY CENTER
19 W. COLLEGE AVENUE
P. O. BOX 336
YARDLEY, PA. 19067

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U. S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND
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Molten Salt
Tellurium Tetra Chloride
High Temperature Batteries
Battery Pilot Line

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the technological development of the Carb-Tek® Molten Salt Li/Cl system toward prototype production for eventual assembly into fork lift truck batteries. Engineering developments, cost reductions, and pilot line operations are described and discussed. Significant failure mode is attributed to certain cell components. Seals are a problem.

Abstract

408 647 (trade name)

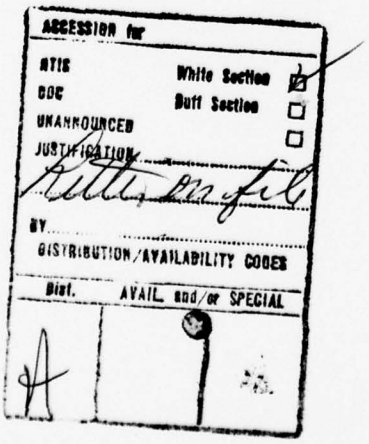
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STANDARD OPERATING PROCEDURES

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STANDARD OPERATING PROCEDURES
FOR 25 KWH
Li-Al/LiCl-KCl/C-$TeCl_4$ Molten Salt
Fork Lift Truck Battery Size Cells

INTRODUCTION

The procedures presented in this manual are designed to facilitate the manufacture of cells and batteries on a pilot plant or on a full-scale basis. In order to fill both requirements the following philosophy and format have been adopted.

1. Basic concept of an operation is presented.
2. The necessary sequential steps to accomplish an operation are presented.
3. Necessary parameters are given along with acceptance, rejection or rework situations.
4. No specific equipment items or designs are included unless they are unique or unexpected.
5. The information presented in the above four requirements are such that full latitude can be exercised in design, capacities, rates to fit the needs and desires of the organization utilizing this manual.

Several general considerations apply to the operations conducted in the inert atmosphere.

1. The inert atmosphere must be maintained at 1 ppm oxygen or less. Nitrogen is assumed to be present in the same proportion as in air.
2. The water content must be kept to a minimum at a dew point of -70° C or lower.
3. Porous and fibrous materials such as ceramics, asbestos gloves, cloths, etc. must be thoroughly degassed and dried before being introduced to the inert gas system.
4. All motors must be either brushless or be fitted with high altitude type brushes.
5. All welds pertaining to cell integrity must be performed in the argon atmosphere and must pass a helium leak check.
6. All bearings and lubrications must be suitable for high altitude or outer space use.

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Figure No.	Subject	Subject No.
1	MM-1 Cell Can Body	I-A-1-a-0
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3	MM-1 Cell Top	I-A-1-b-0
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Metal Parts - Cell Body I-A-0

Cans - Specs I-A-1-0

Concept: The cell can is made in two parts. The various components can be laid in the larger, box-like portion, covered with the lid-like portion, and welded. This method is preferred to the method of forcing-in from one end. Forcing-in can cause tearing and misalignment of certain components.

Cell Can I-A-1-a-0

Dimensions of the can are 1.866" x 10.721" x 13.572." It is of two-piece construction. Two blanks of 18 ga. cold rolled low carbon (1008) steel measuring 14.309" x 13.572" and 11.400" x 13.571" are folded as per Figure 1 and Figure 2 to form the cell can body and cell can side respectively.

Cell Top I-A-1-b-0

1/4" x 1 3/4" x 10 5/8 cold-rolled low carbon steel as per Figure 3.

Cell Bottom I-A-1; I-A-1-c-0

1/8" x 1 3/4" x 10 5/8β cold-rolled low carbon steel as per Figure 4.

Anode Bar I-A-2-0

1/4" x 1 5/8" x length to fit battery hook-up configuration.

Salt Reservoir Assembly I-A-3-0

Concept: A reservoir capable of holding a full charge of salt will be necessary if cells are to be filled outside the protective dry box atmosphere. See Figure 5.

Reservoir Body I-A-3-a-0

4.5" O.D. x 12" long x 16 ga. low carbon steel tubing.

Reservoir Top I-A-3-b-0

4.5: dia. x 16 ga. low carbon steel disc with 0.5" dia. hole bored dead center.

Reservoir Bottom I-A-3-c-0

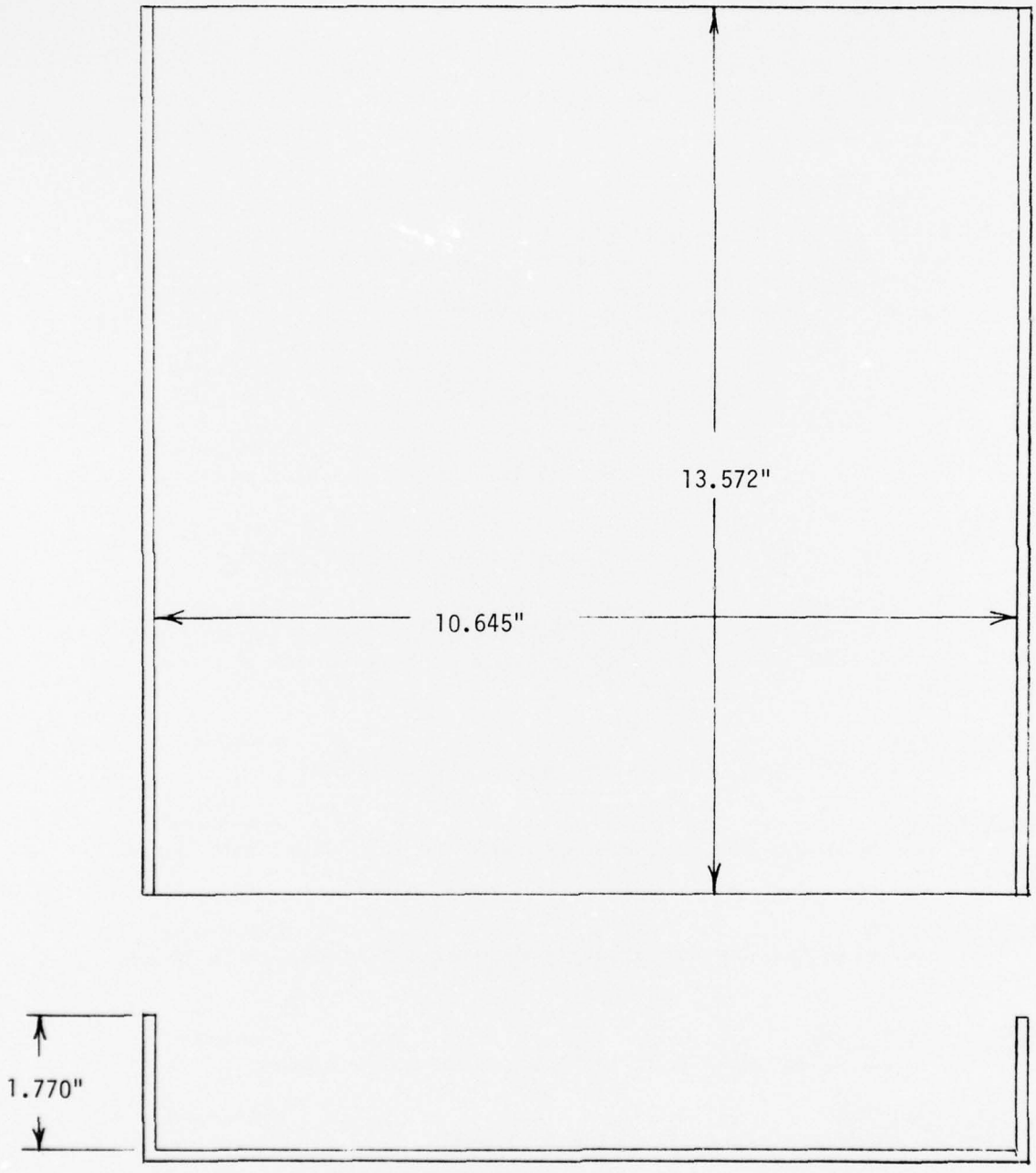
4.5" dia. x 16 ga. low carbon steel disc with 0.5" dia. hole bored dead center.

Reservoir Argon Tube I-A-3-d-0

0.5" O.D. x 0.065" wall x 5" log low carbon steel tubing.

Reservoir Fill Tube I-A-3-e-0

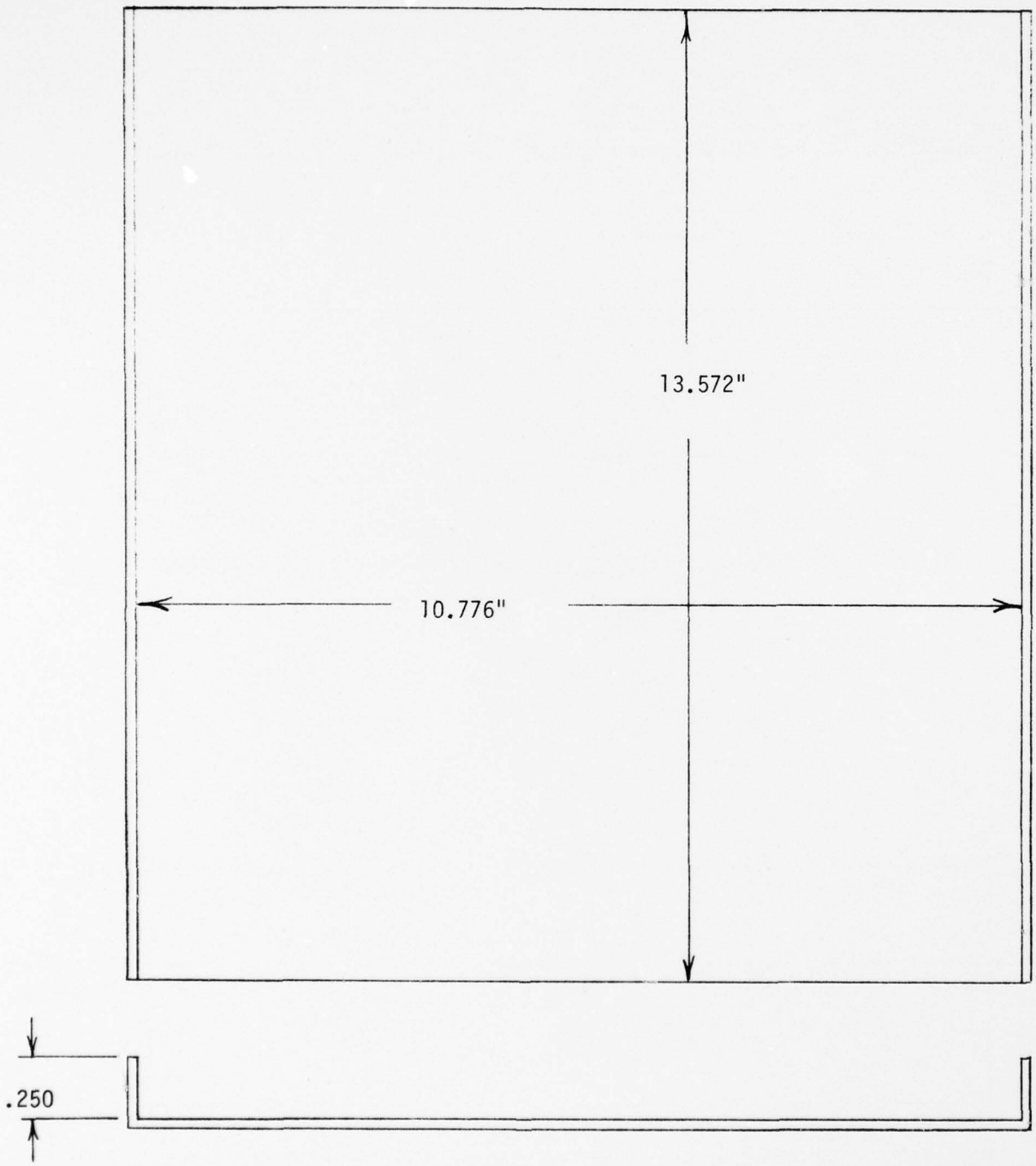
Same as Reservoir Argon Tube with 2" length.



Note: 1. All Dimensions inside, ± 1/64 tolerance
2. Material: 18 GA. Cold Rolled Low Carbon Steel (#1008)

MM-1 CELL CAN BODY

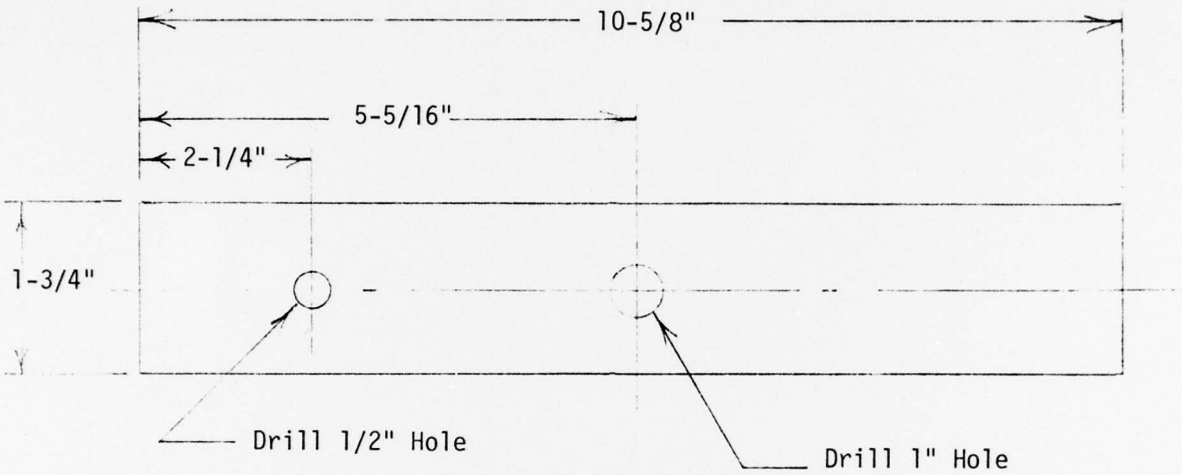
Figure 1



Note: 1. All Dimensions inside, ± 1/64" tolerance
2. Material: 18 GA. Cold Rolled Low Carbon Steel (#1008)

MM-1 CELL CAN SIDE

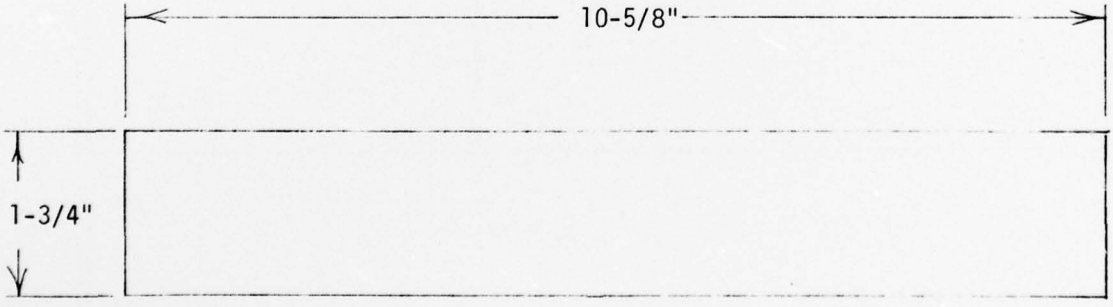
Figure 2



Material: 1/4" thick cold rolled low carbon steel flat stock (#1008)

MM-1 CELL TOP

Figure 3

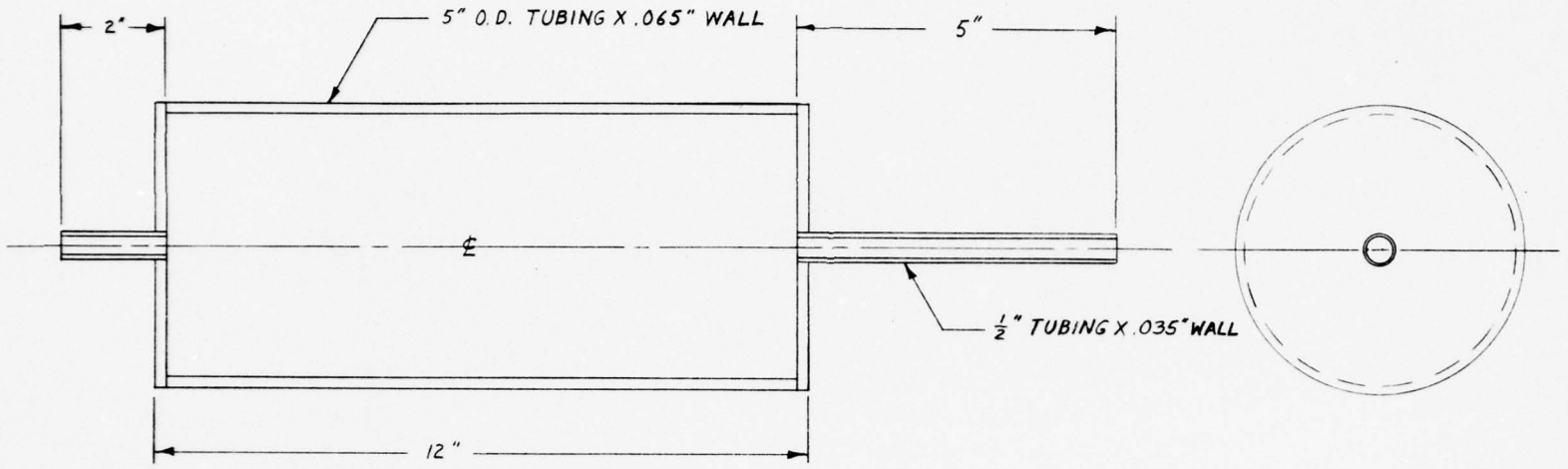


Material: 1/8" thick cold rolled low carbon steel flat stock (#1008)

MM-1 CELL BOTTOM I-A-1-c-0

Figure 4

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
3/20/78		REDRAWN		L.P.	



HALF SECTION

DESIGN/RELEASE APPROVALS	
APPROVED BY	DATE

DRAWN BY R.E.B | DATE 10-3-77
CHECKED | SCALE NONE
MATERIAL: CARBON STEEL 16 GA.
DO NOT SCALE DRAWING
TOLERANCE

FRACTION	DECIMAL	ANGLES
±1/64	.XX ±.010 .XXX ±.005	±1/4°

ESB INCORPORATED
TECHNOLOGY CENTER
YARDLEY, PENNSYLVANIA

SALT RESERVOIR

DRAWING NO. ESB-C109 B

Figure 5

Cathode External Lead - Cold Seal Type I-A-4-0

Concept: For test purposes, or lack of a hot seal type external lead, it may be necessary to attach a long tungsten lead and a surrounding tube to the top of the cell so that molten salt can be forced into the annular space to such a height that the salt freezes and forms an effective seal against air penetration (See Figure 6a).

Cathode External Lead Tube I-A-4-a-0

1" O.D. x 0.065" wall x 16" low carbon steel tubing.

Cathode External Lead Vent I-A-4-b-0

1/4" O.D. x 0.065" wall x 8" low carbon steel tubing.

Cathode External Lead Conax Fitting I-A-4-c-0

Conax catalogue item #EG-375-A-V.

Cathode External Lead - Hot Seal Type I-A-5-0

As per Vendor - Figure 6b

Quality Control I-A-6-0

All parts must be cleaned as per IV-B-0 section and introduced into the dry box system as quickly as possible to prevent recontamination.

Metal Parts - Cell Interior I-B-0

Screen -Anode I-B-1-0

Concept: An anode screen is used to assist in retaining the anode alloy in place against the call can wall and to provide current collection where the screen contacts the face of the anode.

Tools:

1. Scissors
2. Tape measure
3. Wire brush
4. Unitek spot welder 1-132-01

Material:

1. Wire screen 304 s/s/ 18x18 mesh .009 wire diameter
2. One top cell plate, one bottom cell plate and short cell side, one long cell side

Spec:

1. Two strips of wire screen cut to 13" x 36" I-B-1-a-0

Forming: I-B-1-b-0

1. All steps to be performed in dry box
2. All metal parts cleaned with wire brush

Assembly: I-B-1-c-0

1. Using spot welder, weld screen to the walls of the short and long side of cell
2. Cut edges of screen so a 3/16" open area is left on both ends of cell, so top and bottom plate will fit in place

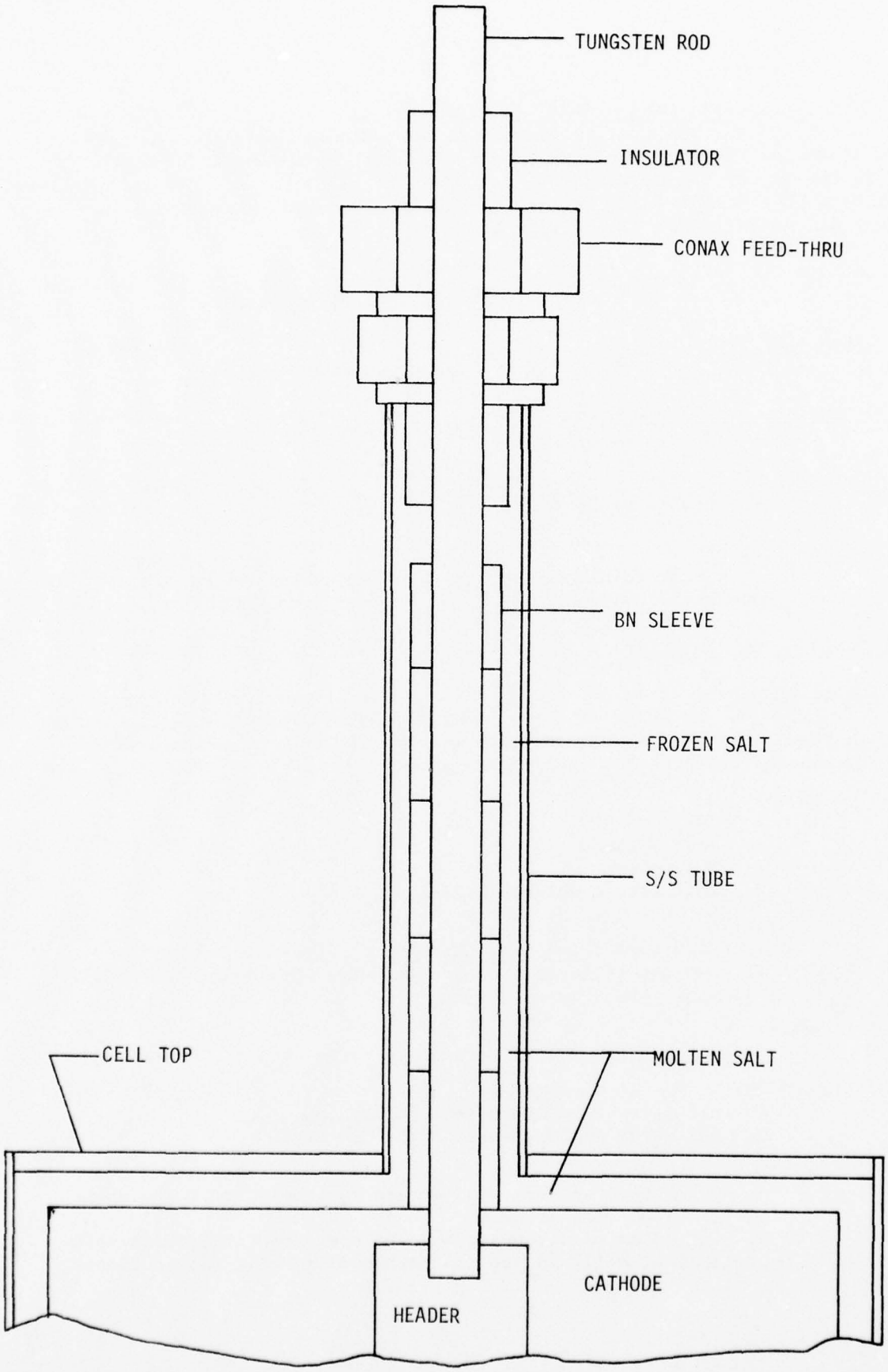


Figure 6a CATHODE EXTERNAL LEAD COLD SEAL TYPE

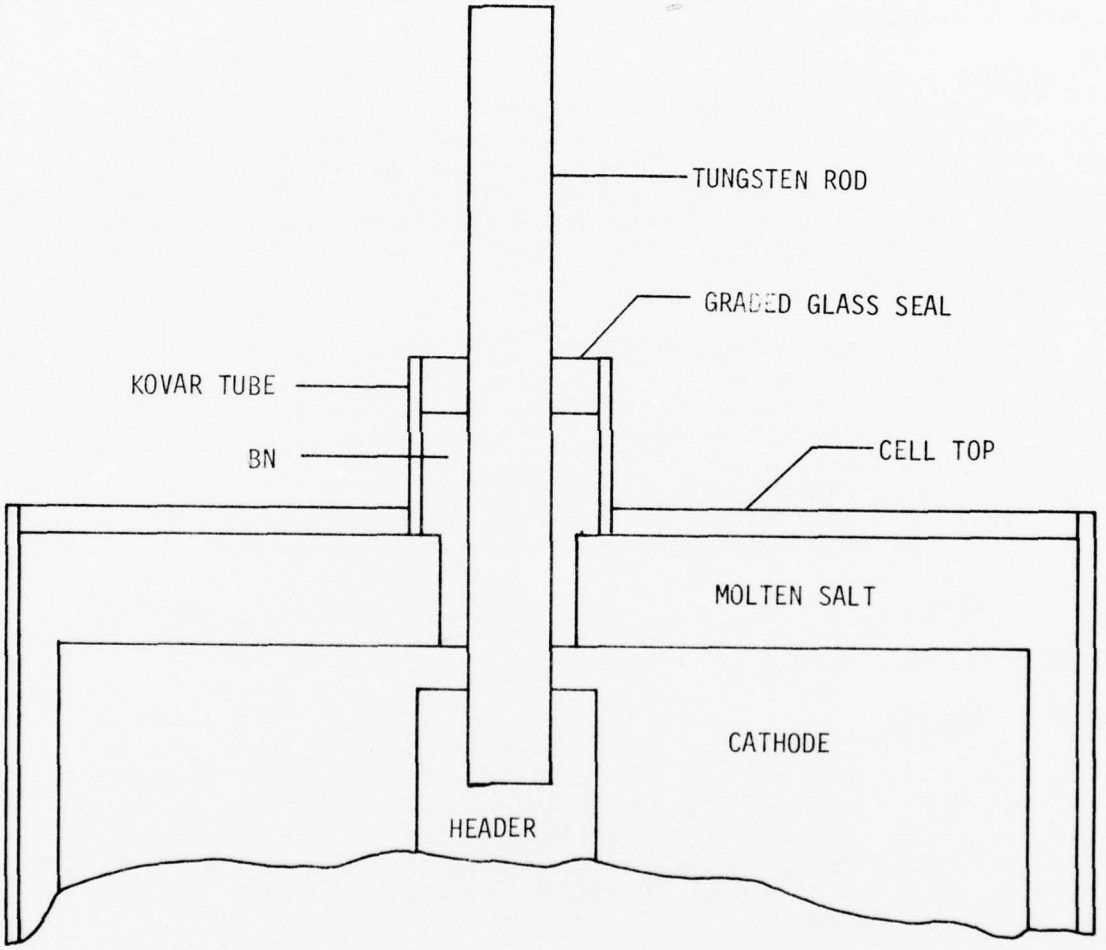


Figure 6b CATHODE EXTERNAL LEAD HOT SEAL TYPE

3. Overlap screen on area just spot-welded and cut off excess
4. Use excess screen to spot-weld on top and bottom plates of cell can. Trim edges with scissors
5. Cell anode screen now ready to be completed using Cell Assembly (II-C-0)

Quality Control I-B-1-d-0

Anode screens and top and bottom cell pans must be cleaned as of Section IV-B-0 before induction into the dry box.

Screens - Cathode I-B-2-0

Concept: The BN separator is crusty and firm during cell assembly due to a sprayed coating of salt. At cell operating temperatures the salt crust will melt leaving the BN fibers with little physical support. In time the fibers can settle or travel. A screen is formed around the BN-cathode assembly to assist in holding the BN mat fibers against the cathode. The screen must be formed and attached such that no part of the screen will contact the cathode or the external lead.

Tools:

1. Spot welder #226
2. Scissors
3. 3/4" bar, #801
4. Metal frame #804
5. C-clamp
6. Tape measure
7. Bar, #802
8. Aluminum strips 1" x 13", total of 4

Spec. I-B-2-a-0

Wire screen SS-304, 18 x 18 mesh x .009 wire diameter, must form box 14.5" x 10 1/3" wide x 1 3/8" thick.

Forming I-B-2-b-0

1. Cut one piece of screen with scissors to 31 1/2" x 12.0."
2. Take bar #801 and form 3/4" edges on screen by bending. Place the bar on one edge of the screen along the 31 1/2" length turn the bar over one time away from operator.
3. Bend the outer screen flush to the edge of the bar to form a 90° angle. Repeat steps 1, 2, 3 for other side as seen in Figure 7.

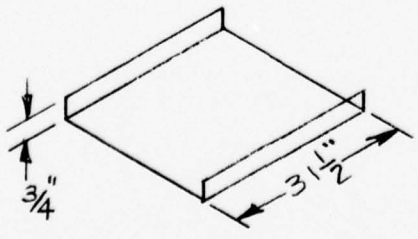


FIGURE 7 - FORMING CATHODE SCREEN

4. Measure to center of screen and mark.
5. Measure and makr a line 3/4" on each side of the center line.
6. The 3/4" edges on each side of the screen are to be cut along the mark lines and bent flat.
7. Make a 45° angle cut on each tab that was bent flat.

Assembly I-B-2-c-0

1. Secure spot welder cable to metal frame with C-clamp.
2. Place Al strips on each edge of frame. Place a bar on one edge of frame side to give proper width to screen form.
3. Screen should be fitted over a welding frame. Overlap sides; spot-weld entire length of screen; repeat procedure on other side.
4. Pull 3/4" bottom tabs down on screen and spot-weld to sides of the screen.
5. Turn off welding machine; remove power cable and C-clamp from frame and slide screen off of frame.
6. Measure 14 1/2" from the bottom of the screen and cut excess screen away.
7. Measure 13" from the bottom of the screen edge on each narrow side and mark and cut out with scissors as in Figure 8.

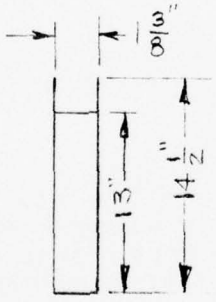


FIGURE 8 - CATHODE SCREEN ASSEMBLY

8. Cut a 1 3/8" x 1 1/2" square out of the screen from the center of the bottom edge as seen in Figure 9.

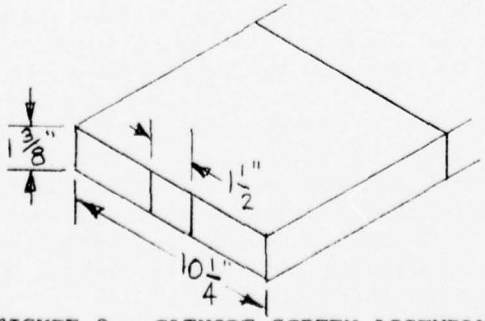


FIGURE 9 - CATHODE SCREEN ASSEMBLY

Quality Control I-B-2-d-0

1. Each finished screen assembly must be cleaned as of Section IV-B-0 before induction of part in Dry Box

Cathodes I-C-0

Component Specs I-C-1-a

Carbon I-C-1-a-0

Carbon used in the fabrication of the cathodes is PCB, 30 x 140 activated carbon purchased from Calgon Corp.

Carbon Cement I-C-1-b-0

The above carbon granules are bonded with resin #SD5143 purchased from theBorden Chemical Company

Current Collection Components I-C-1-c-0

Graphite Cloth I-C-1-c-1-0

Graphite cloth is used as a current collector located in the central plane of the carbon cathode. The cloth is called Grafoil^{R} Grade GTA purchased from the Union Carbide Corporation. The size is 12 3/8" x 10 13/16" x 0.030".

Graphite Header I-C-1-c-2-0

The header is machined from blocks of graphite grade 2000 purchased from the Stackpole Carbon Company. The header serves to connect the tungsten external lead to the Grafoil^{R}. See Figure 10 (ESB #C095)

Tungsten Lead I-C-1-c-3

The tungsten external lead is high purity, free of thorium oxide and specified as "clean." The rod is purchased from Hogan Industries (See I-A-4-0 and I-A-5-0.)

Tellurium Tetrachloride ($TeCl_4$) I-C-1-d

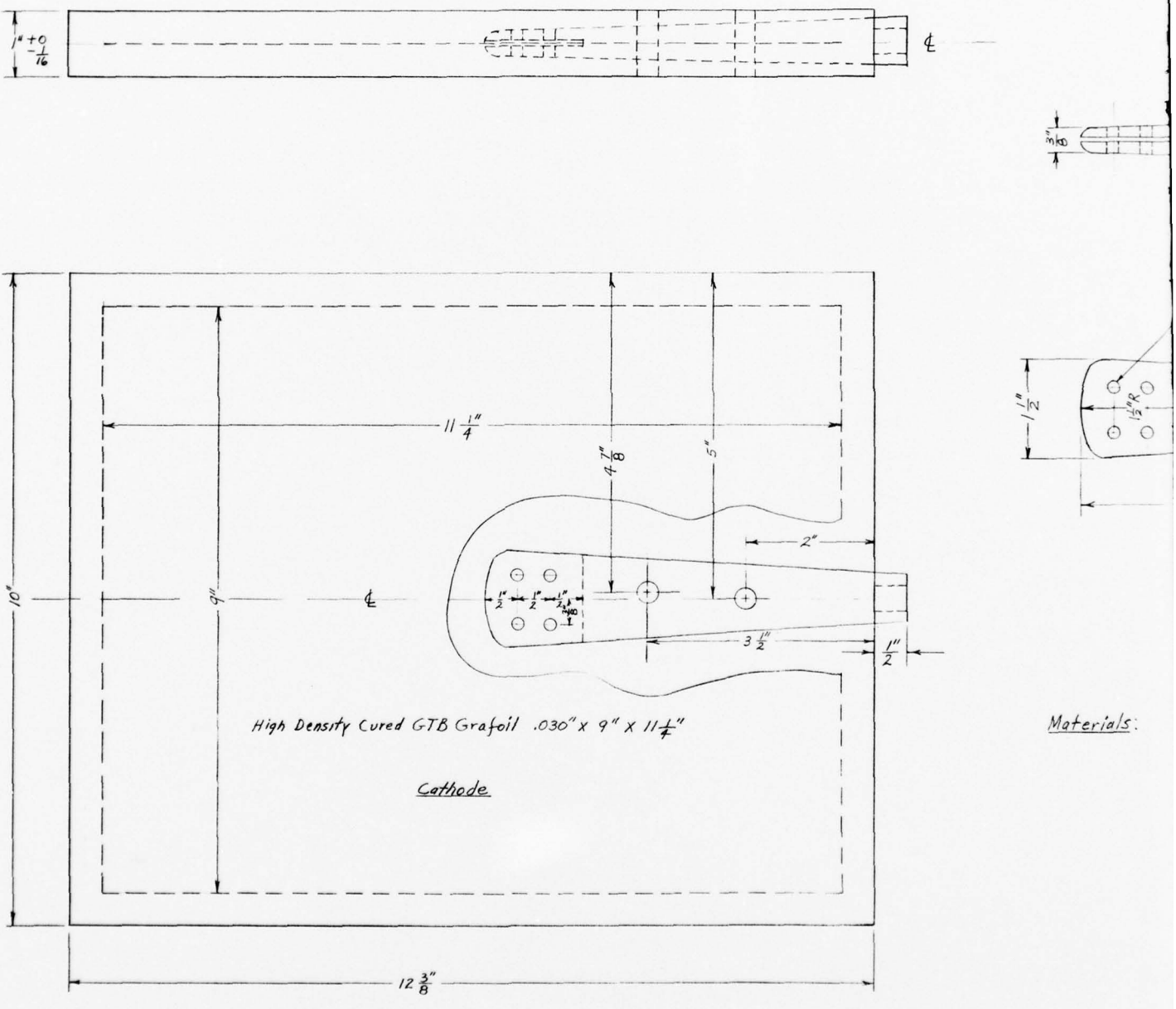
$TeCl_4$ additive of 99.70 to 99.999% purity is available from Great Western Inorganics. Minimum purity acceptable is the 99.70% material and should be packed under argon. Storage in an inert atmosphere is preferable. Glass containers are preferred. Shipments made in plastic bottles have often failed due to moisture and oxygen penetration.

Component Fabrication and Assembly I-C-2-0

Cathode Fabrication I-C-2-a-0

Concept: Since carbon is a poor electrical conductor it is difficult to collect electrons from every portion of the electrode. To assist in collection and to reduce the IR drop, a sheet of graphite cloth is placed in the central plane of the cathode and extending toward the edges of the cathode but not far enough to be exposed. The cloth is connected to the graphite header that extends from the top-center of the cathode to about the three dimensional center of the unit. The header changes in shape from a thick section capable of accepting the tungsten external lead to a thin-wide section at the lower end. The cross-sectional area of the header is essentially constant from the top to the bottom. (See Figure 10) Fabrication by Gaines Industries. The cathode is actually two electrodes in parallel since it is divided by a graphite cloth and is positioned between the two anode electrodes.

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High Density Cured GTB Grafoil .030" x 9" x 11 1/4"

Cathode

Materials:

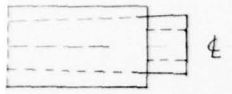
NOTE: CENTER GRAFOIL AND GRAPHITE HEADER IN CARBON BODY 1" X 10 X 12 3/8"

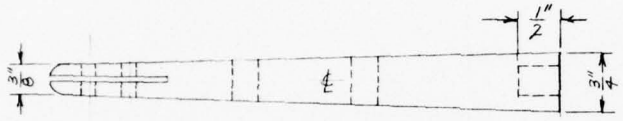
Figure 10

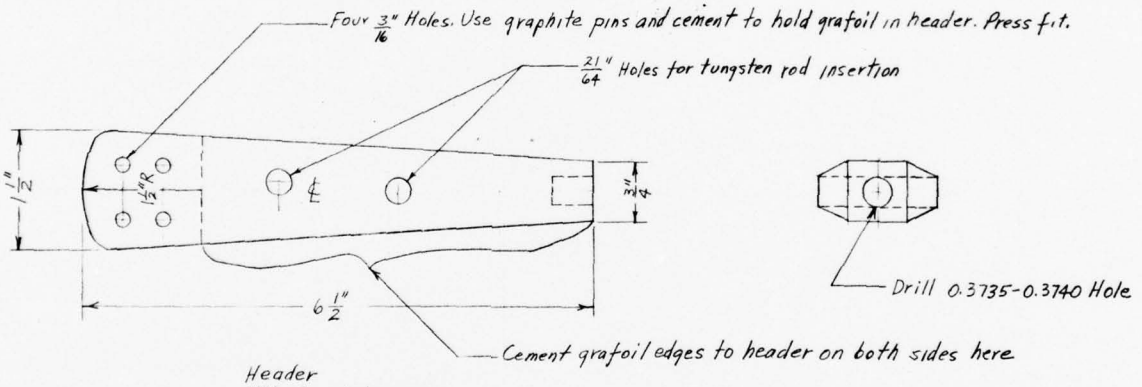
BARCLAY BROTHERS, INC.

DATE	BY/M	REVISION RECORD	AUTH.	DR.	CK.

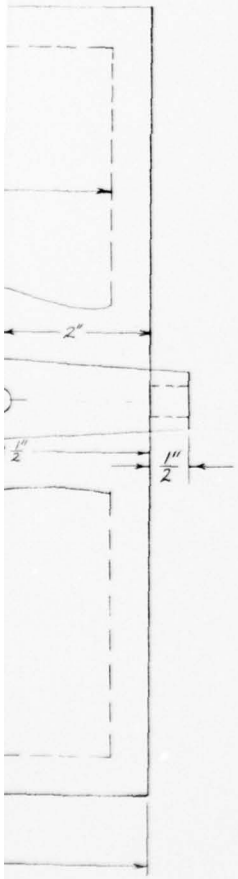
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Header
Mtl.- Graphite 2000
Note: Round Off All corners and edges.



Materials:

1. Union Carbide H.D. Cured GTB Grafoil or approved equal.
2. Stackpole Carbon Co. Graphite 2000 or approved equal.
3. Atlas Chemical Co. Cement Furan 100.
4. Borden Chemical Co. Durite SD-5143 Thermo-setting resin.
5. Calgon Corp. Pittsburg Type PCB 30x140 Activated Carbon or approved equal.

2

1" X 10 X 12 3"/8

DESIGN/RELEASE APPROVALS		DRAWN BY R.E.B.	DATE 7-6-77	ESB INCORPORATED TECHNOLOGY CENTER YARDLEY, PENNSYLVANIA
APPROVED BY	DATE	CHECKED	SCALE FULL	
		MATERIAL As Noted		MM-1 CATHODE
		DO NOT SCALE DRAWING		
		TOLERANCE FRACTION ±1/64 DECIMAL .XX ±.010 .XXX ±.005 ANGLES ±1/4°		DRAWING NO. ESB-C095 D

Figure 10

Carbon and Cement I-C-2-a-1-0

(See I-C-1-a-0 and I-C-1-b-0)

Cloth and Header I-C-2-a-2-0

(See I-C-1-C-1-0 and I-C-1-C-2-0)

The cloth and Header are "buttered" with Furan-100 cement, manufactured by Atlas Minerals and Chemicals Company, at all junctures prior to pressing and shaping cathode. This step is performed by Gaines Industries.

Activation Bake-Out I-C-3-0

Before procedding, conduct Quality Control procedures under I-C-6-0.

Concept: To activate the carbon by degassing and baking under vacuum conditions. Heat treat vessel must be capable of withstanding 900° C under vacuum. Carbon cathodes must not be exposed to air at any time after activation.

Safety: Follow all safety precautions in handling heavy equipment.

Equipment and Tools: (See Figure 11 - Heat Treat System)

Heat Treat Vessel (Figure 12)
Furnace
Controllers
Open-end wrenches: 2 - 3/4; 1 - 7/16
Cathode rack for Heat Treat (Figure 13)
Teflon tape
Small pipe wrench
Gas trap vessel
30" and 24" thermocouple (or vessel lid)
Vacuum pump
6 - 1/3 x 1 3/4 bolts and nuts
Bakeout dolly

Steps:

1. Insert into cathode rack holder, 5, pre-bakeout, inspected cathodes.
2. Carefully lower the holder into bakeout vessel (BOV).
3. Clean Viton o-ring and flange groove with a dry rag. (This will insure a vacuum tigh seal.)
4. Place BOV lid on top of the vessel.
5. Inser the 6 - 1/2 x 1 3/4 bolts and nuts.
6. Cross torque the bolts until maximum torque is applied.
7. ATTACH hoist chain to two bolts.
8. ATTACH hoist to the chain; lift and insert vessel into furnace.
9. Remove hoist chain for the vessel.
10. Remove electrical junction box cover and test for lack of continuity to the vessel.
11. The test: Using Simpson meter, 10,000 ohm scale; DC switch on positive; clamp the red lead to one terminal strip. The black lead is clamped to the vessel.

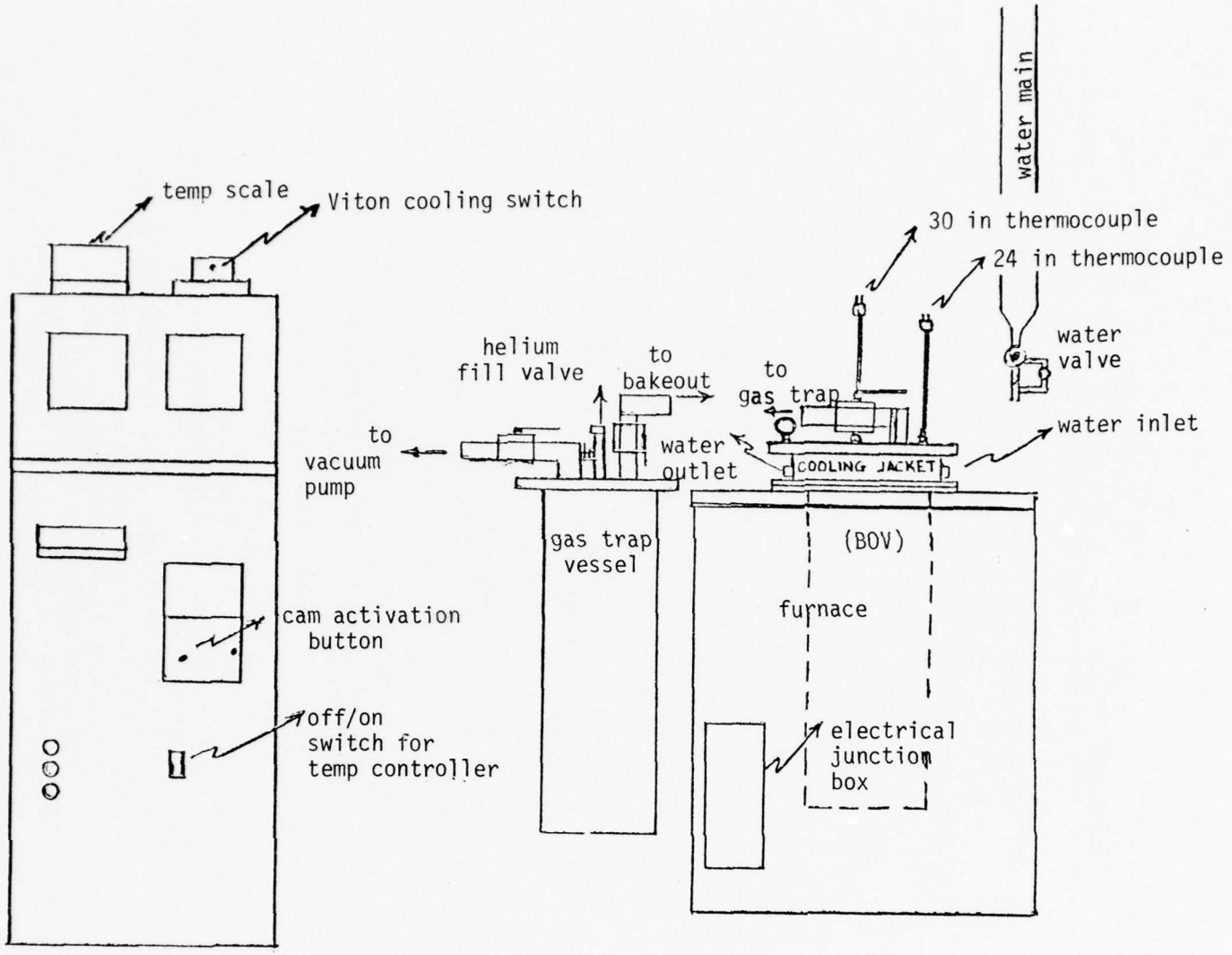


Figure 11 HEAT TREAT SYSTEM

4/25/77

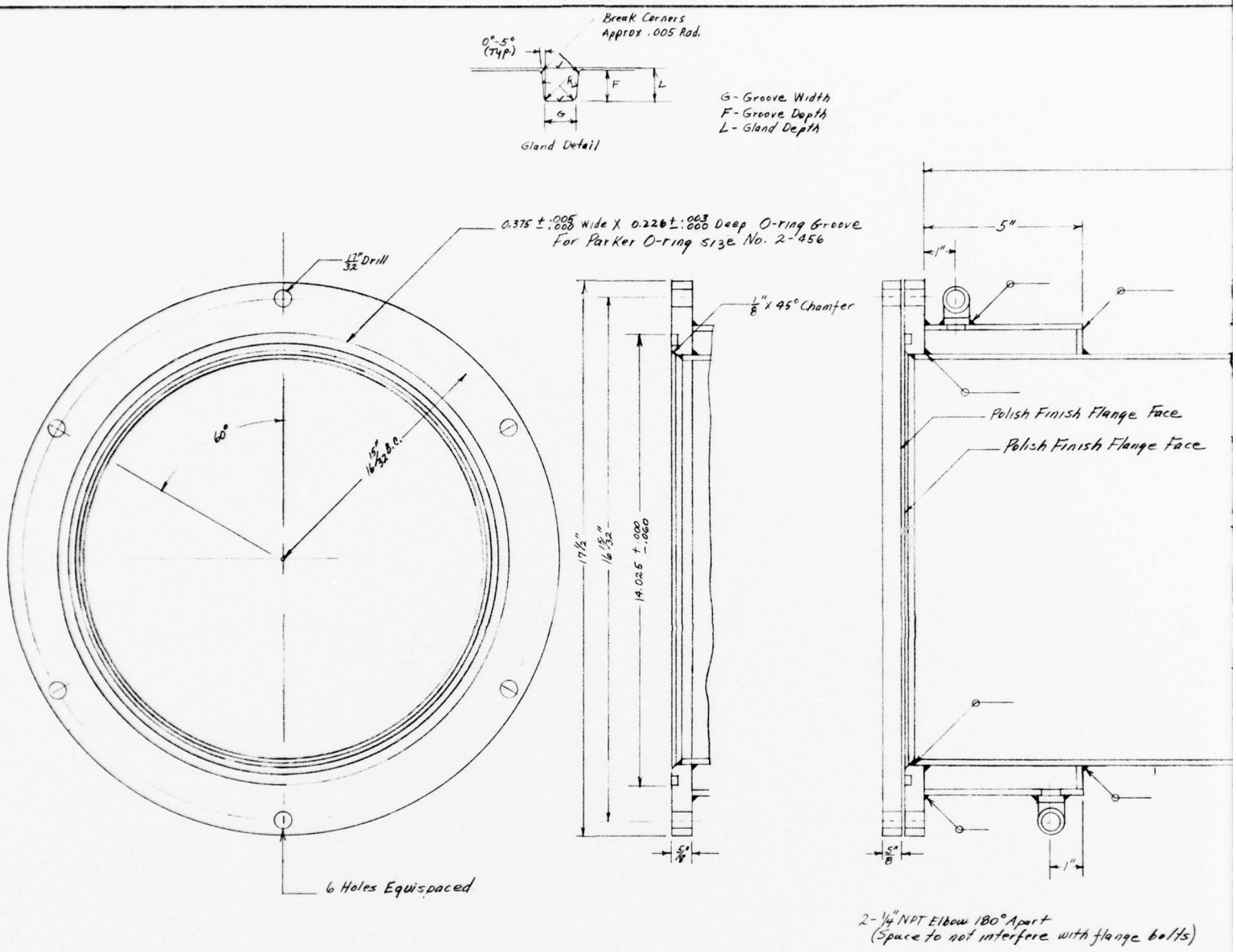
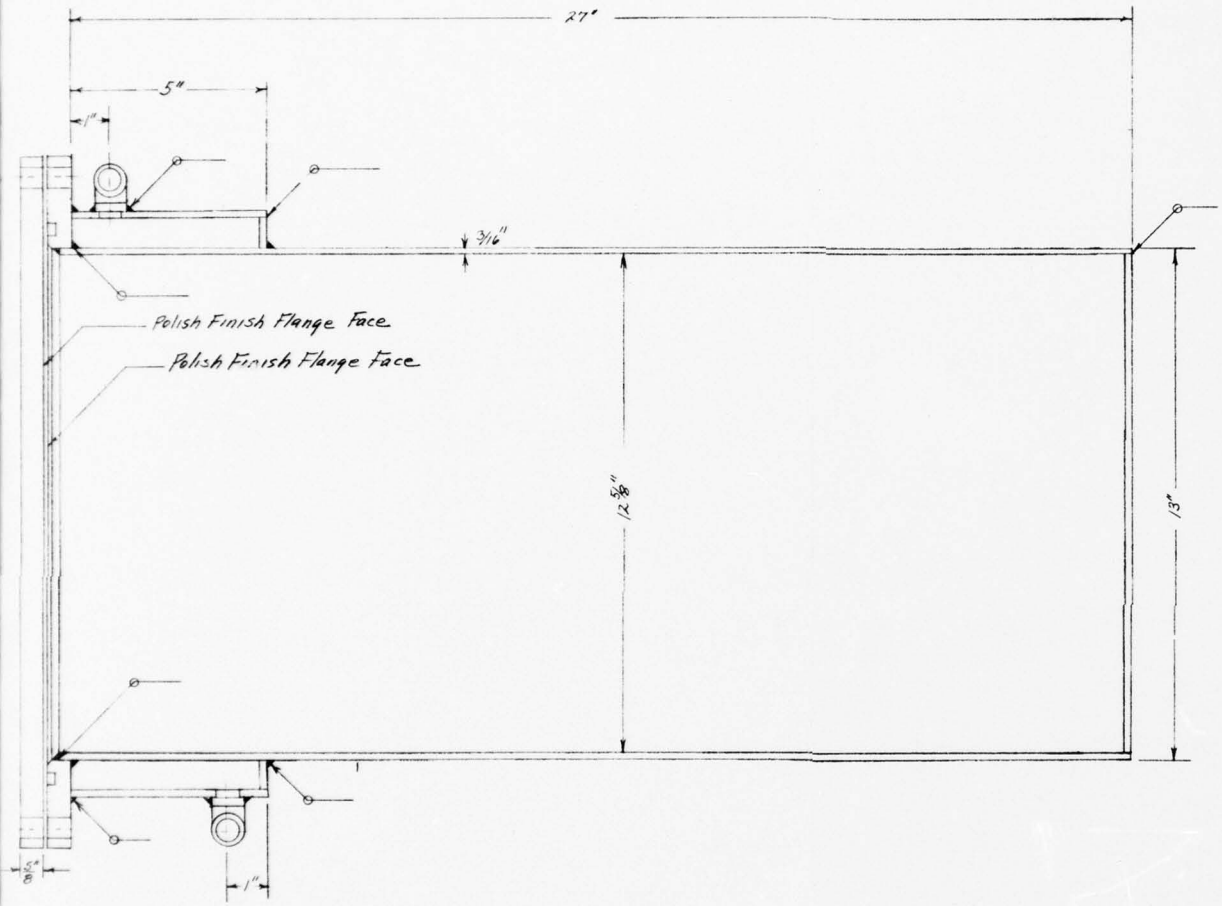

Break Corners
Approx. .005 Rad.
0°-5°
(Typ.)
R
F
L
G
Gland Detail
G - Groove Width
F - Groove Depth
L - Gland Depth
0.375 ± .005 .003 Wide X 0.226 ± .003 .000 Deep O-ring Groove
For Parker O-ring size No. 2-456
17/32" Drill
60°
16 15/32" B.C.
6 Holes Equispaced
1/8" x 45° Chamfer
17 1/2"
16 15/32"
14.025 ± .000 .060
5/8"
5"
1"
Polish Finish Flange Face
Polish Finish Flange Face
5/8"
1"
2-1/4" NPT Elbow 180° Apart
(Space to not interfere with flange bolts)

Figure 12

DATE	BY	REVISION RECORD	AUTH	DR.	CK.



-1/4" NPT Elbow 180° Apart
(Space to not interfere with flange bolts)

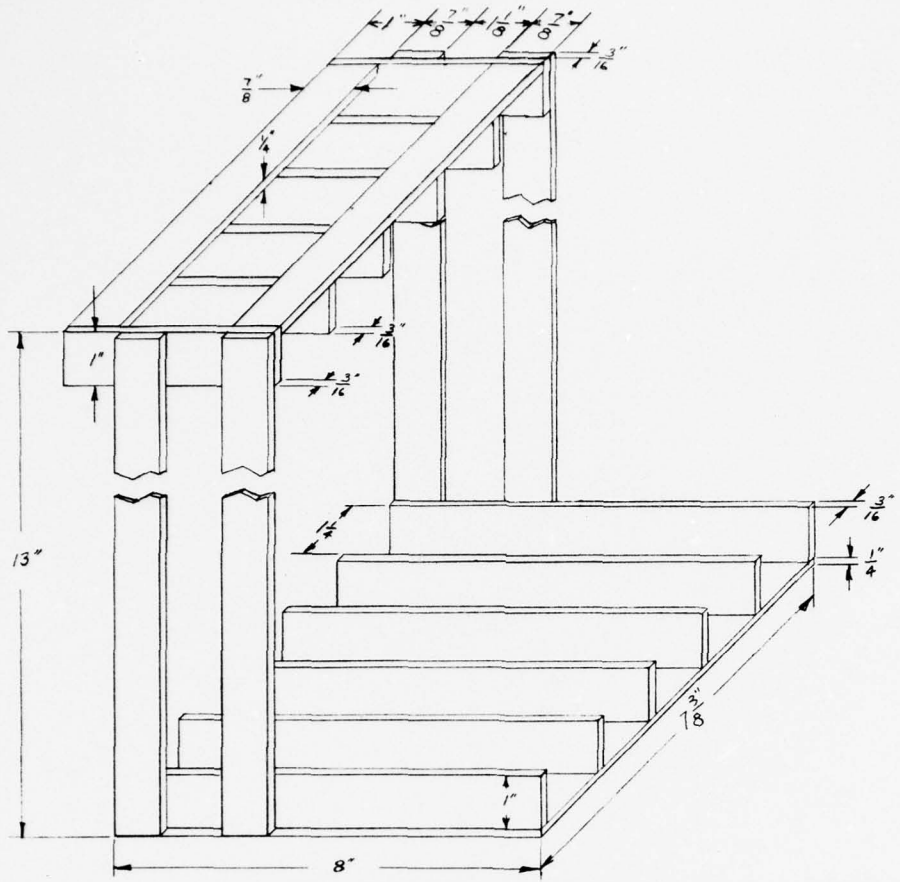
DESIGN/RELEASE APPROVALS	
APPROVED BY	DATE

DRAWN BY R.E.B.	DATE 3/18/75	ESB INCORPORATED TECHNOLOGY CENTER YARDLEY, PENNSYLVANIA	
CHECKED	SCALE 1/2		
MATERIAL 304 S/S		M.M-1 Cathode Heat Treatment Tank	
DO NOT SCALE DRAWING			
TOLERANCE			
FRACTION ±1/64	DECIMAL .XX ±.010 .XXX ±.005	ANGLES ±1/4°	DRAWING NO. ESB-0017 D

2

Figure 12

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
3/78		REDRAWN		LR	



DESIGN/RELEASE APPROVALS	
APPROVED BY	DATE

DRAWN BY P.S — DATE 11 - 4 - 77
CHECKED — SCALE NONE
MATERIAL: 304 SS
DO NOT SCALE DRAWING
TOLERANCE: FRACTION ± 1/64 | DECIMAL .XX ±.010 .XXX ±.005 | ANGLES ±1/4°

ESB INCORPORATED
TECHNOLOGY CENTER
YARDLEY, PENNSYLVANIA

CATHODE HOLDER

DRAWING NO. ESB - C 108 — B

Figure 13 CATHODE RACK FOR HEAT TREAT

12. If continuity reading is infinite (d) proceed to Step 14. If continuity reading is less than (d) proceed to the next step.
13. Slide vessel in proper direction to eliminate continuity reading; in other words, recenter the vessel in the furnace. Interval clearance is needed between vessel and heating elements to prevent shorting.
14. Test each of the four terminal strips; repeat steps 11, 12, 13.
15. Replace electrical junction box cover.
16. Connect to the BOV cooling jacket, water inlet and outlet pipes. (Use teflon tape on pipe threads for water-tight connections.)
17. Insert 30 in. thermocouple into swagelok tube fitting, position #77, located on the lid.
18. Tighten swagelok fitting (hand tight plus 1 1/4 turns with open end wrench).
19. Insert 24 in. thermocouple into swagelok tube fitting, position #88.
20. Repeat Step 18.
21. Connect vacuum hose from gas-trap vessel to bakeout vessel.
22. Open vacuum pump valve, gas-trap valve and bakeout valve.
23. Evacuate bakeout vessel until 30 inch of vacuum registers on the vacuum gauge.
24. Close vacuum pump valve.
25. Open the filling valve and fill the vessels to 4 PSig pressure.
26. Close helium fill valve and bakeout vacuum value.
27. Check all seals and joints for possible leaks using the leak detector-gas leak detector Model 21-200.
28. Tighten nuts or seseat seals until leaks are not registered on gas leak detector.
29. Open vacuum pump valve.
30. Open gas trap valve.
31. Open bakeout vessel valve.
32. Insert thermocouple into tube on bakeout lid.
33. Open cooling jacket water valve.
34. Check for water leaks, tighten if necessary.
35. Throw switch on for Viton cooling system.
36. Throw switch on for furnace temperature controllers.
37. Press button on cam controller, to insure cam activation.
38. After a 24-hour bakeout, the vessel should be cooled.
39. Attach hoist chain as in Step #7.
40. Lift vessel 4 inches - this will allow the heat to escape faster.
41. After the vessel is completely cooled, lower the vessel back into the furnace.
42. Close bakeout vacuum valve and gas trap valve. Disconnect vacuum hose from bakeout vessel.

43. Close water cooling jacket valve.
44. Remove water inlet and outlet pipes.
45. Drain water from cooling jacket.
46. Plug the water inlet and outlet with male plub. (Use teflon tape of threads.)
47. Lift vessel from furnace.
48. Remove hoist chain, immediately introduce vessel into E.B. chamber.
49. Set bakeout vessel on bakeout vessel dolly.
50. Place 2 - 3/4 open end wrenches in the chamber.
51. Close door and glove port doors.
52. Close glove air fill valve.
53. Open slightly vacuum valve on the glove ports (a fast vacuum will loosen the o-ring clamps on the gloves).
54. Open completely main vacuum valve on chamber followed by complete opening of vacuum valve on the glove ports.
55. When chamber is pumped down to 150 microns close main valve.
56. Throw switch on for diffusion pump.
57. After 20 minutes, check vacuum reading.
58. If reading is less than 50 microns, close diffusion pump switch.
59. Close vacuum valve on glove ports.
60. Open Argon filling valve and fill chamber to 0 psig.
61. At the same time as chamber is being filled with Argon, fill glove ports with air by opening air valve slowly. (Some air valve regulating is necessary because the filling rate for glove ports and chamber vary.)
62. Open glove port doors and insert hands into gloves.
63. Open vacuum valve and fill vessel with Argon. (Additional Argon is needed in the chamber to fill the vessel up to 0 psig.)
64. Remove the 30 inch thermocouple for swagelok fitting tube.
65. Remove lid from vessel.
66. Remove cathode holder rack.
67. Remove cathode from the rack.
68. Place cathode in a safe corner in the chamber.
69. Replace rack back into the vessel and attach lid to the vessel, securing it with one bolt and nut.
70. Move vessel from Dry Box #4 entrance port.
71. Transfer cathodes to entrance port.
72. Open door and introduce cathodes to Box #4.
73. Close door to entrance port and remove vessel from EB chamber.
74. Make QC check (See I-C-6-0).
75. Proceed to $TeCl_4$ Impregnation Section I-C-4-0.

$TeCl_4$ Impregnation I-C-4-0

Before proceeding, conduct Quality Control procedures under I-C-6-0.

Concept: Cause the sublimation of $TeCl_4$ and subsequent penetration of the porous carbon cathode followed by cooling and condensation of the $TeCl_4$ within the cathode body. Sublimation to be conducted in an inert atmosphere of argon or in vacuum. Vessel must be capable of withstanding the temperature of the operation and the pressure exerted by the vaporized $TeCl_4$. The amount of $TeCl_4$ retained by the porous carbon is related to the power obtained as a cell.

Equipment and Tools:

Torque wrench - 100 ft-lbs with 1/2" drive
Open end wrench - 1 - 1/8"
Socket for 1/2" driver 1 - 1 1/8"
24 - Grade 8, 3/4" diameter x 3 1/2" long bolt and nuts
Flexitallic Blue Spiral Gasket α4-15304 SS Asbeston Filler
Tellurium treatment vessels and furnace. (Figure 14, (a) C053 (b) C054 (c) C055 (d) C056

Chemicals:

Tellurium tetra chloride, $TeCl_4$, 99.7% purity, purchased from Great Western Inorganics.

Safety:

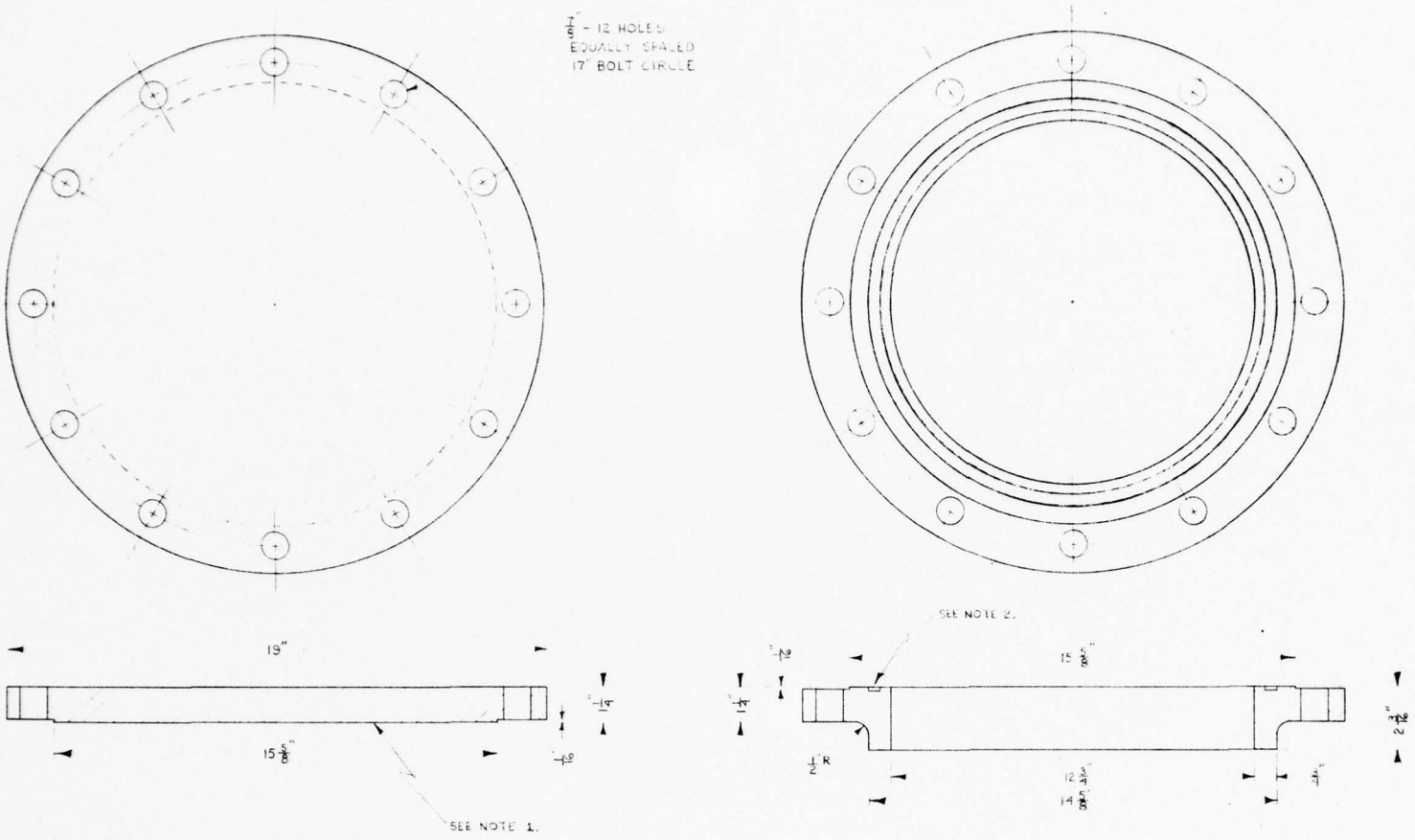
All safety precautions associated with working in the dry box and with handling chemicals should be followed.

Procedure:

1. Weigh out 605g of $TeCl_4$, 99.7% purity, in a weighing dish.
2. Transfer the weighed $TeCl_4$ to the impregnation vessel.
3. Weigh one of the baked-out cathodes to the nearest tenth of a gram. Record the weight.
4. Place the cathode into the vessel with the $TeCl_4$. (Cathode may lean against the interior wall.)
5. Clean gasket groove by removing all foreign particles with a clean rag.
6. Place a new Flexitallic Blue Spiral Gasket into the groove. (These gaskets are only used once. Not reusable.)
7. Lift vessel lid with hoist and lower onto the vessel. (Caution during lifting of lid; safety should be stressed. The lid weighs 100 pounds.)
8. Align bolt holes on the lid with the bolt holes on the vessel flange.
9. Insert the 12 Grade 8 bolts and nuts.
10. Cross torque the nuts with 25 ft-lbs.
11. Repeat steps 1 through 10 for the second cathode to be tellutium impregnated in adjacent furnace.
12. Lift insulation covers with the hoist and place over each vessel.
13. Connect the color-coded dual female banana jacket plugs to appropriate male jacket plugs.
14. Throw main furnace power switch on.
15. Press red bottom to engage preset timer.

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NOTES:

1. FLANGE SURFACE FINISH - 125μ"
2. GASKET GROOVE - 14 1/2" OD. x 13 1/4" ID. DEPTH - .100"
   AVOID ANY RADIAL TOOL MARKS ACROSS THE GASKET SEATING SURFACE

DESIGN/RELEASE APPROVALS	
APPROVED BY	DATE

DRAWN BY S.S.T	DATE 3-31-76	ESB INCORPORATED TECHNOLOGY CENTER YARDLEY, PENNSYLVANIA	
CHECKED	SCALE 3/8 = 1"		
MATERIAL 304 STAINLESS STEEL		FLANGE - T_eCL_4 VESSEL	
DO NOT SCALE DRAWING		DRAWING NO. ESB-C053	C
TOLERANCE: FRACTION ±1/64	DECIMAL .XX ±.010 .XXX ±.005	ANGLES ±1/4°	

Figure 14a

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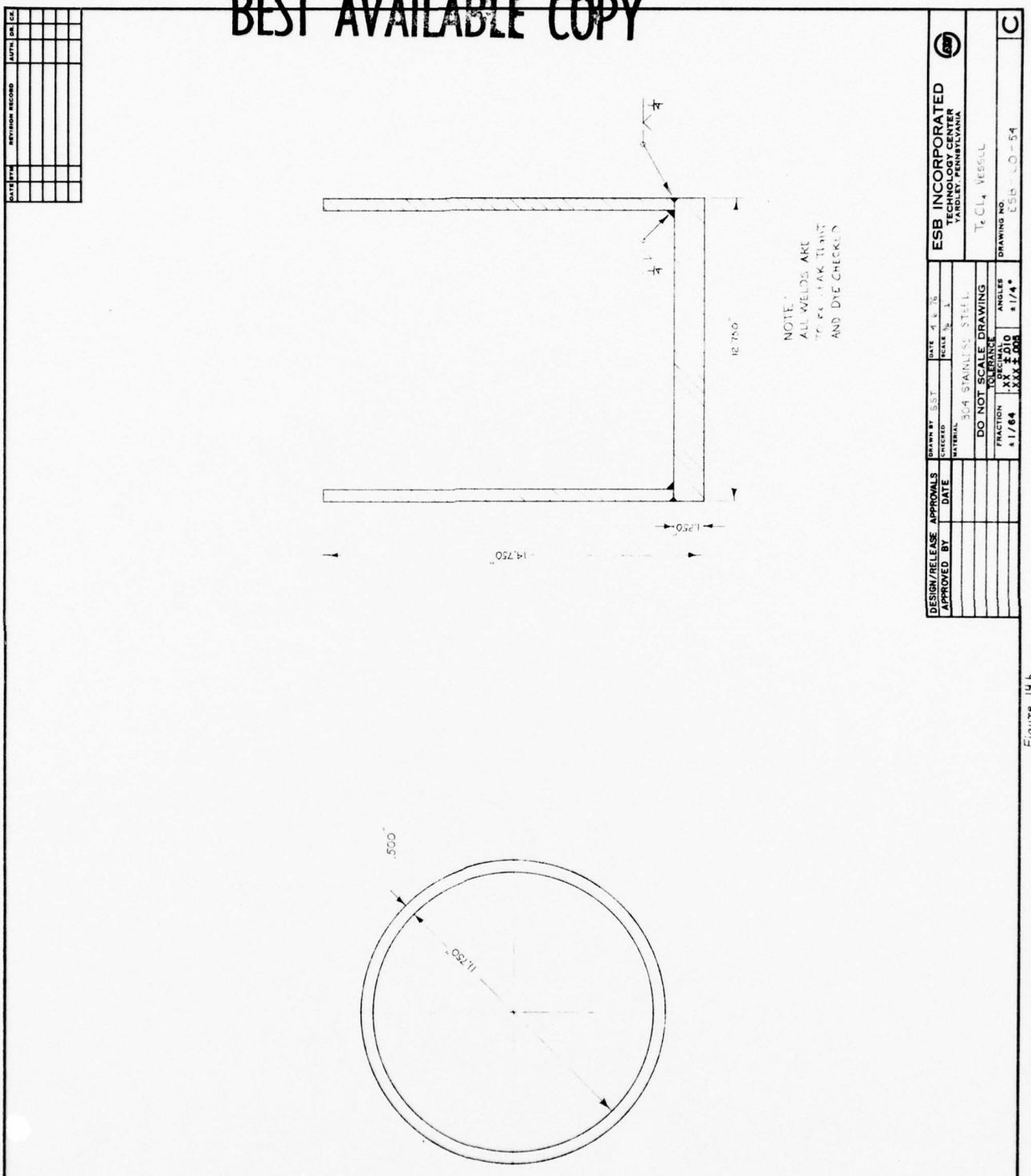


Figure 14b

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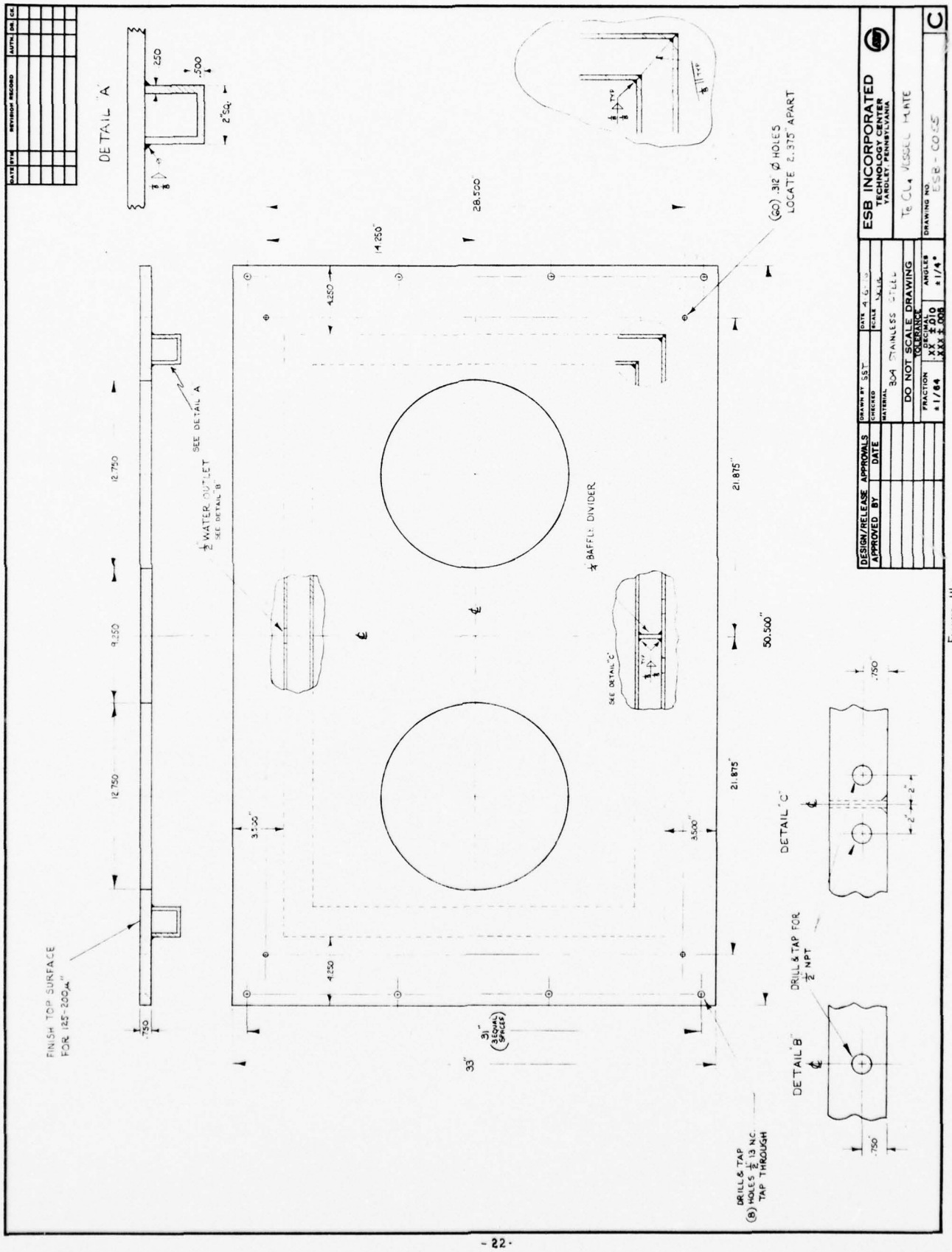


Figure 14c

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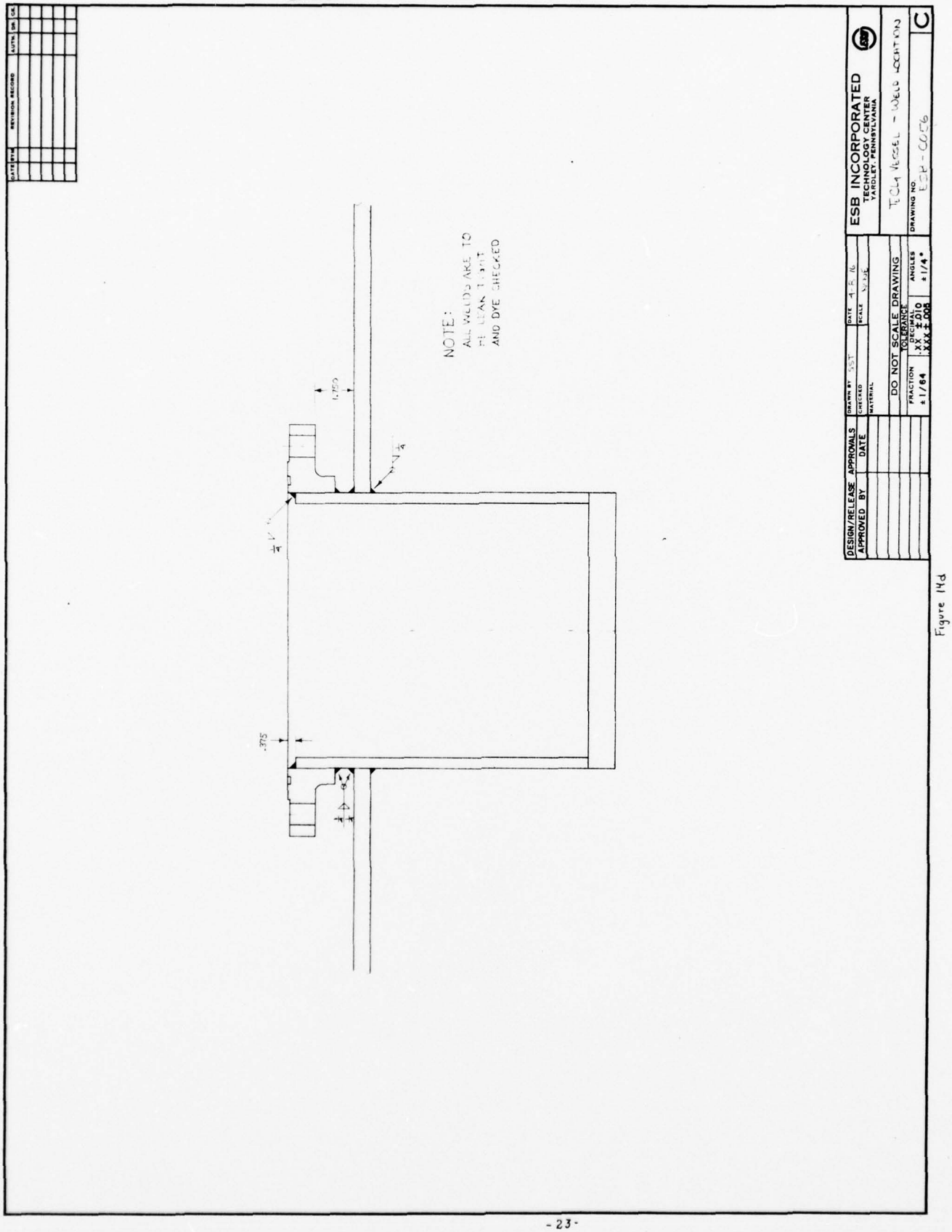


Figure 14d

16. Throw switch on for Love temp controller. (The left controller monitors the left vessel and right monitor the right vessel.)
17. After the completion of Te treat and the cooling of the vessels, disconnect the banana jacket plugs.
18. Remove insulation covers.
19. Remove the bolts and nuts.
20. Attach hoist to eye bolt.
21. Remove lid from the vessel.
22. Remove impregnated cathode.
23. Weigh the cathode, record the weight.
    (Calc. wt. final - wt. initial) x .00265 = % efficiency)
24. Proceed to Section I-C-6-a-0

Formation I-C-5-0

1. Cathodes for formation must be carried through heat treatment and tellurium treatment procedures before the formation process. All Quality Control procedures (I-C-6-0) must be satisfied before going to Step 2.

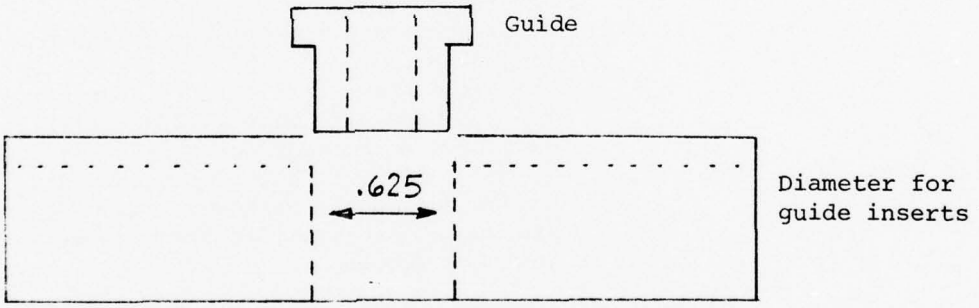


FIGURE 15 CATHODE LEAD GUIDE

2. A. Cold Seal Type Cathode
   (1) Cut off extended header graphite so that W rod can be inserted permanently.
   (2) The pilot hole in the header is .343" in diameter. Using a .3725 reamer, manually start a hole about 1/16" deep. This depression in the wall will act as a seat for the reamer when the fixture is attached.
   (3) Clamp the fixture over the cathode with the reamer placed through the guide, seated in the 1/16" depression. (See Figure 15)
   (4) Visually adjust the fixture so that the reamer is perpendicular with both planes of the cathode. Tighten the fixture so that it will not move during reaming.

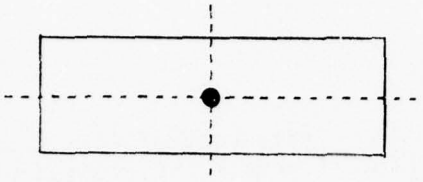


FIGURE 16 CATHODE LEAD LOCATION DIAGRAM

(5) Ream by hand with a clockwise motion. The reamer will follow a straight path due to the guide.
(6) Removing the reamer involves the same clockwise motion.
(7) Check that the reamer has bottomed in the pilot hole by inserting a small probe. The leading edge of the reamed hole can be felt on the graphite wall if the reamer did not bottom.
(8) Remove the fixture.
(9) Insure that all graphite dust is removed from the hole.
(10) W Rod insertion
(a) Use a W rod centerless ground .3735 - .374" O.D.

2. B. Hot Seal Cathodes
(1) Insert a .343 graphite plug into the pilot hole.
(2) Insert .375 - .3755 W Rod in header as per described procedures.
(3) After formation, remove the extended portion of the header.
(4) Using the reaming fixture for control, drill out the graphite plug with a 11/32 drill. A new guide will have to be made for the drill. Present reamer guide will have too much slop.
(5) Do not remove the fixture. Remove the drill guide and replace it with the reamer guide. Ream and insert hot seal.

3. Loading Cathode on Lid
A. Each anode position has a corresponding lid (1 through 6).
B. Loosen conax fitting.
C. Slide tungsten rod through lid into the conax fitting.
D. Adjust distance between bottom of lid and top of cathode to 7 1/2 inches.
E. Tighten conax fitting with channelocks.

4. Positioning Lids
A. Attach winch to lid and raise via footswitch so that cathode clears obstructions.
B. Guide lid over appropriate tank position (1-6).
C. Lower cathode into tank via footswitch with lid numbers toward pilot line wall.
5. Attach voltage sense lead for appropriate position (1-6) and record open circuit voltage on cathode formation data sheet.

6. When no shorting is witnessed by a decrease in open circuit voltage, attach the appropriate power lead (1-6).
7. Formation Cycler Set-up
   A. Turn on appropriate power supply and cycler (1-6). Allow 10 minutes for warm-up. Enable switches off.
   B. Establish cycler operation conditions for constant current charge/discharge.
      (1) API high voltage set point 3.30 volts
      (2) API low voltage set point 1.50 volts
      (3) Timer off
      (4) Current limit off
      (5) API current, set point 100
      (6) Charge hold on
      (7) Discharge hold on
      (8) Place cycler in charge mode
          a. Adjust charge voltage set to 5.0 volts
          b. Press short button and adjust charge current to 36 amps
      (9) Place in discharge mode
          a. Adjust discharge voltage set to 5.0 volts
          b. Press short button and adjust discharge current to 36 amps
      (10) Place in charge mode
      (11) Turn on recorder
      (12) Turn on charge enable, then discharge enable.

      Cathodes are formed for approximately 4 cycles or until maximum capacity is reached. Proceed to C.
   C. Set cyclers for constant voltage charging (enable switches off).
      (1) API high voltage set point 3.0 volts
      (2) Timer on AND for desired charge time
      (3) Place cycler in charge mode
          a. Adjust charge voltage set at 3.31 volts
      (4) Press short button and adjust charge current for 60 amperes
      (5) Turn on enable switches
      (6) Cycle to maximum AH (about 4 cycles)
8. Removal From Formation Tank
   A. Charge cathode to charge cutoff point at constant voltage
   B. Open circuit
   C. Record voltage and remove leads
   D. Raise lid from tank with winch and allow to cool
   E. Open circuit voltage should be greater than 2.80 V.
9. Redip for Salt Coating
   A. Allow cathode to reach room temperature, inspect, weigh and record
   B. When ready for Cathode Unit Assembly (II-B-0), lower cathode into molten salt and remove at such a speed that a thin coating of salt adheres to the surface of the cathode. (This procedure must be performed to ensure the wetting of the BN separator when molten salt is added to completed cell.)

Quality Control — I-C-6-0

General — I-C-6-a-0

Cathodes

As Received

Millivolt drop measurements are to be made on each side of each cathode as received. All readings should be similar. Dissimilar readings indicate areas of poor bonding or discontinuity. (See I-C-6-b-0) Each cathode should be visually examined for breakage and cracks. Breakage is unacceptable Cracks are acceptable if on surface. Deep cracks are acceptable provided the millivolt drop data also indicates acceptability. Grafoil should not be seen at any edge.

Equipment Needed:

Calipers - to measure thickness; header hole depth and diameter.

Tape measure - to measure width and height

Millivolts apparatus - to measure the degree of electro-mechanical contact of carbon to grafoil

Balance - to weigh the cathode (initial weight).

Procedure

1. The cathode is checked for the following specifications:
   a. Height: 12.375± 0.015 inches
   b. Width: 10.000± 0.015 inches
   c. Thickness: 1.000±0.015 inches
   d. Headerhole diameter: 0.375±0.000 inches
   e. Headerhole depth: 1.000± 0.000 inches

   NOTE: See Figure 17, Sec. I-C-1-c-2-0
2. Record all measurements on MM-1 Process Sheet. Initial and date each item.
3. Set up millivolt apparatus as per Standard Operating Procedures for Millivolv Drop Reading; Section I-C-6-b-0.
4. Record millivolt readings on MM-1 Process Sheet-Millivolt section.
5. A visual inspection of cathode is made. All markings on all sides and edges are recorded on MM-1 Process Sheet - Visual inspection section.
6. Cathodes are weighed on balance to the nearest tenth of a gram. Record weight.
7. Cathodes are placed into bakeout vessel as per Section I-C-3-0.

Heat Treat

All units must have been inspected as per above before proceeding with "Heat Treat." Millivolt drop data must be taken as in I-C-6-b-0. The data should show the same or lower average millivolt drop. Large discrepancies indicate damage and unit should be discarded. Examine for cracks and breakage. Breakage requires rejection. Surface cracks are acceptable. Weigh and record each unit.

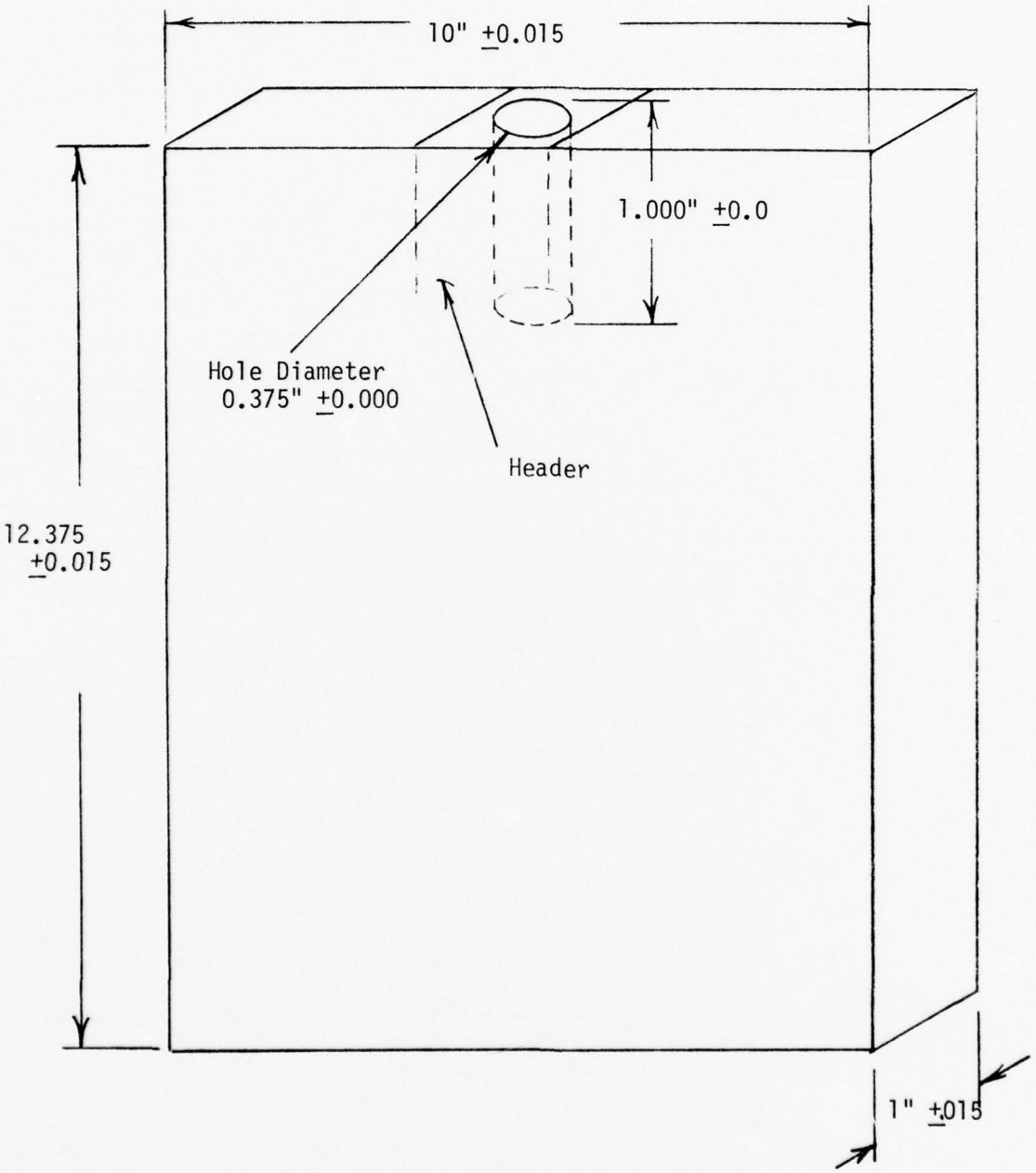


Figure 17 Cathode Lead-Header Diagram

$TeCl_4$ Treat

All units must have been heat treated as per above before proceeding. Same inspections as above (Heat Treat). After weighing, determine the weight pick-up percentage and pick-up efficiency. The pick-up efficiency must be 85% or higher. Units with less pick-up can be retreated to raise the value. A value of less than 85%, however, should be considered suspect with respect to the quality of the sealability of the vessel.

Formation

All units must have passed "$TeCl_4$ Treat" before proceeding. All units must have millivolt drop readings taken after the tungsten rod has been inserted. Cathodes are usually formed within 4 to 5 cycles. Cathodes should generate 140 AH and higher to pass inspection. Units should range from 180 AH and higher for normal requirements based on 4 to 6 hours rates and charging at constant voltage.

Millivolt Drop Measurements I-C-6-b-0

Purpose: To measure the electrical conductivity within the cathode at each stage of preparation up to formation.

Concept: It has been determined that defects can be detected by measuring millivolt drops at numerous points on both faces of the cathodes. Failures have been found by the technique and improved collector designs have been developed as a direct result of this test method. All readings should be relatively close and small. Subsequent readings for a given cathode should remain essentially the same or drop somewhat as each treatment step is completed.

Equipment:

2 alligator clips
1 battery clip
1 millivolt probe
1 millibolt drop indicator or meter
3 wire leads
1 template

Millivolt Readings

1. Apply clamps at proper location on cathode. See Figure 18. The alligator clips, one going to positive current lead and the other to positive millivolt lead, are connected to the header. Be sure that one of the jaws from each clip contacts inside of hole. The battery clamp, which is connected to the negative current lead, is centered and clamped to the bottom of the cathode.
2. Adjust Millivolt Drop Indicator current meter until 5.0 amperes D.C. is registered.
3. Place the template on top of the cathode so that the smaller numbers are near the header and guide edge on template flush against cathode's side.
4. Insert Millivolt probe into the numbered holes on template, following the numbered sequence 1 through 23. See Figure 19.

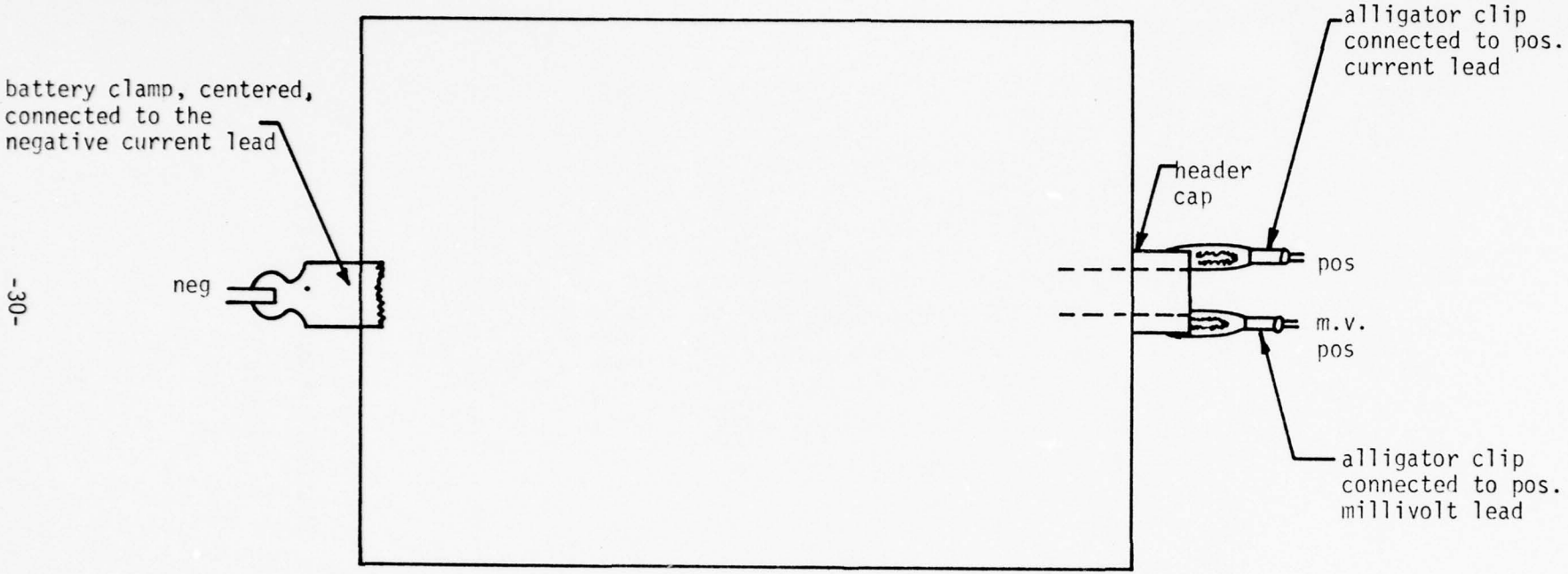
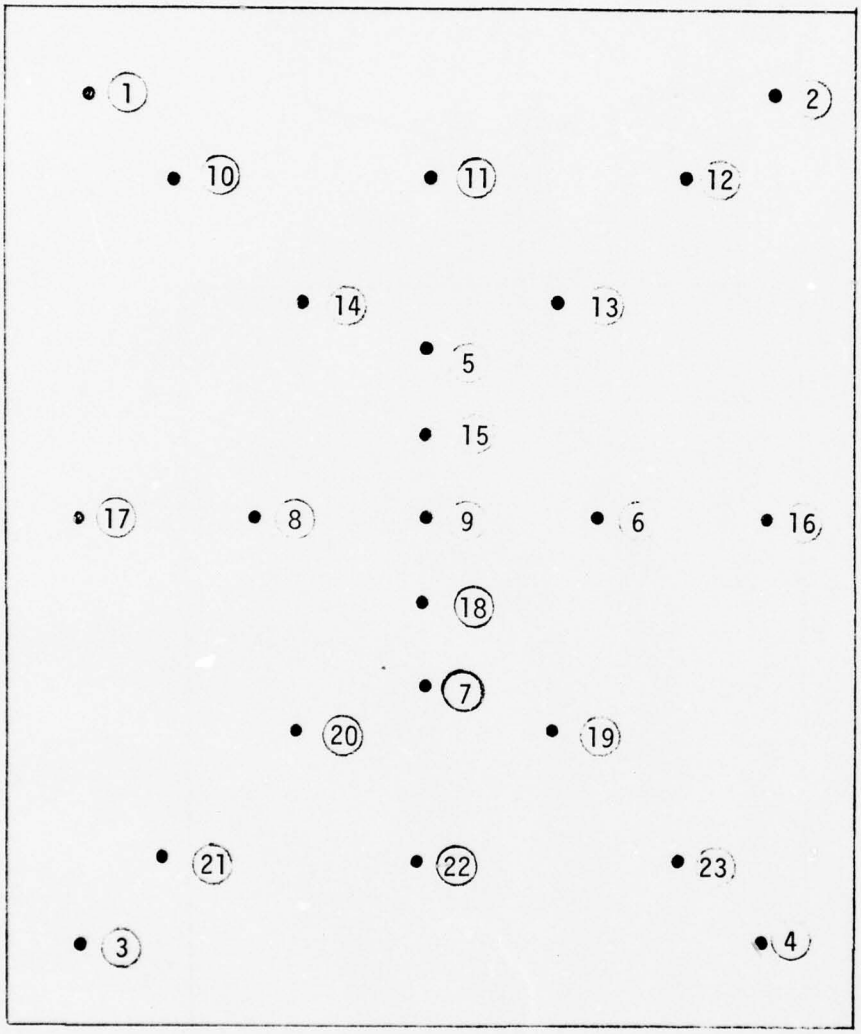


Figure 18 MILLIVOLT READING CONNECTION DIAGRAM



MILLIVOLT READING TEMPLATE

Figure 19

5. Record each reading in millivolts after each insertion.
6. Readings are taken on each side of the cathode, numbered side and non-numbered side, and 1/4" from the header cap.
7. These readings are taken at different stages:
   1st stage - pre-bakeout, both sides
   2nd stage - post bakeout, both sides
   3rd stage - post-impregnation, both sides
   4th stage - post-insertion, both sides
8. Determine low mv and high mv range and calculate average millivolt drop and record.

Anodes - High Density — I-D-0

Component Specs & Forming — I-D-1-0

Lithium — I-D-1-a-0

4" x .040 rolled high purity lithium foil
4" x .020 rolled high purity lithium foil

Specs:
1. 4" x 11 3/4" x .040 one each
2. 4" x 11 3/4" x .020 one each

Aluminum — I-D-1-b-0

ECO or 1100-0 Al .063" x 12" x 48" (ECO Grade is preferred)

Specs:
1. One pc. 1/8" x 4" x 11 3/4" aluminum

Alloy Formation — I-D-2-0

Tools
1. Scissors
2. Screw driver
3. Crescent wrench
4. 12" ruler
5. Steel mold assy.
6. Vac oven
7. 3/4" open end wrench
8. Gloves

Material:
1. 4 pcs 4" x .040 x 11 3/4" Lithium
2. 4 pcs 4" x .020 x 11 3/4" Lithium
3. 4 pcs 1/8" x 4" x 11 3/4" Aluminum
4. 4 pcs .015 x 4 1/4" x 12" Graphite Foil

Forming:
1. All metal and lithium cleaned by wire brush before assembly in steel mold.

Assembly:

1. Place one piece of graphite foil on mold plate.
2. Place .010 and .040 lithium on Al plate and wire brush clean. Weigh and record.
3. Turn over and place lithium side down on graphite foil.
4. Repeat steps 1, 2, 3 until all four mold plates are full.
5. Stack all four mold plates secure with bolts from mold.
6. Preheat vacuum oven to 400° C no vacuum.
7. When temperature is reached, load steel mold assy. into oven. Close door.
8. After oven heats back up to 400° C, run at said temperature for 2 hours.
9. Turn off oven and let mold cool down to room temperature before you remove steel mold.
10. Open mold and carefully remove high density anodes. Clean off with wire brush. Now ready for assembly.

Separators - BN I-E-0

Concept: The electrodes must be physically separated from one another to avoid electrical shorting. The material to be used must be insulating and yet allow the flow of ions. The BN mat, as described below, separates the electrodes and has about 90-95% open pore volume. The mat is prepared around a template and is sprayed with a salt solution that is dried to form a crust. The crust permits handling.

Preliminary Steps I-E-1-0

A. Preparation
   1. Equipment
      a. All equipment should be cleaned prior to making mat.
      b. Careful attention should be paid to cleaning glass which is used for forming mat.
      c. Neva-Clog® filter in slurry apparatus should be cleaned and inspected for signs of corrosion. If corrosion is present, clean filter with mild HCl solution and flush thoroughly with distilled H_2O
   2. Sparging Solution
      a. 7-10 liters of distilled H_2O should be placed in the sparging apparatus.
      b. 95 g/l LiCl and 105 g/l KCl should be added for each liter of sparging solution.
      c. This solution is then stored for later use.
   3. Boron Nitride Roving preparation
      a. 100 g total roving is weighed out into three 1000 ml beakers (roughly 33 g per beaker).
      b. The above amount of BN roving may contain up to 20% recycled roving from previous mats.
      c. Recycled fibers should always be clean.

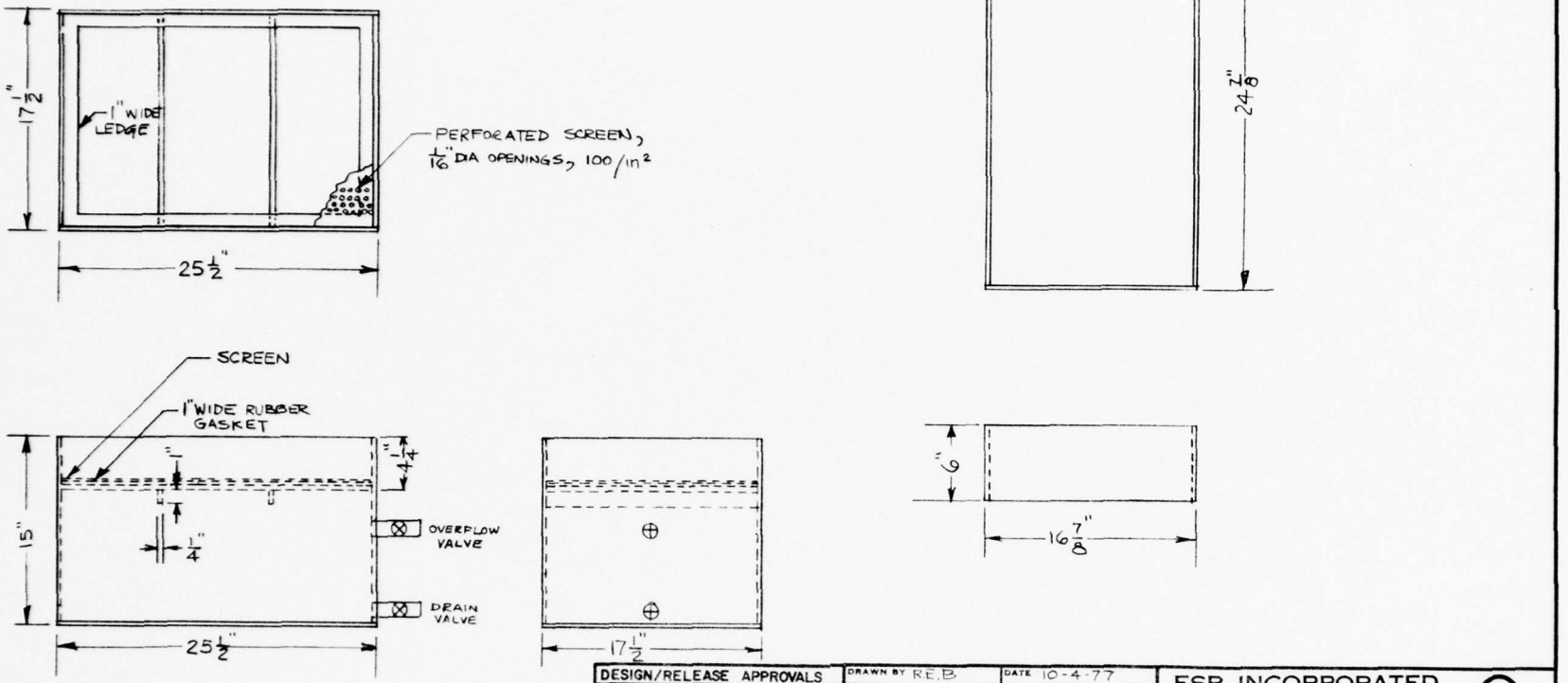
B. Boiling of BN Fibers

1. New strands of BN roving should be divided into three (3) equal portions and placed into three (3) 1000 ml beakers (recycled fibers should be kept out of the boiling process).
2. Approximately 800 m. of distilled H_2O should be added to each of the beakers and heated on a hot plate.
3. Three erlenmeyer flasks filled with 800 ml of distilled H_2O should also be placed on the hot plate to heat.
4. Periodically stir roving/H_2O mixture.
5. When roving has boiled for at least 15 minutes, decant off boiling H_2O and replace with boiling water from erlenmeyer flasks.
6. Replace water in flasks for next boiling.
7. Boil new roving/H_2O mix for at least 15 minutes, stirring periodically.
8. Repeat above procedures until at least 3 but preferably 4 complete boiling cycles have been completed.
9. After final boiling, drain roving completely.
10. Roving may be squeezed dry with the hands, using a pair of clean rubber gloves.
11. Moist roving is then covered with enough reagent grade methanol to soak.
12. Roving should be soaked in methanol for at least 15 minutes. Stir periodically.
13. At end of soak time, decant methanol off and squeeze roving dry again with clean rubber gloves.
14. Rinse with distilled H_2O once. Squeeze dry.

C. Chopping

1. Split sparging solution into three equal portions (approximately 304 liters each).
2. Add one portion of sparging solution to blender.
3. Split new roving strands again into 3 equal portions and add one portion to blender.
4. Seal blender the chop fibers until they are approximately 1-2 inches long (1-5 seconds on low setting).
5. As fibers tend to twist around agitator it may be necessary to loosen them with a spatula. It may be necessary to re-chop the roving that became twisted around the agitator.
6. When all fibers are chopped, pour contents into sparging vessel.
7. Repeat steps 2 to 6 until all roving has been chopped.
8. Sparge fibers until homogenous mix has been achieved. Recycled fibers may be added at this time and sparged with the rest. Thick strands should be removed from the sparging solution.

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
3/20	78	REDRAWN		IPS	



FILTER

DESIGN/RELEASE APPROVALS	
APPROVED BY	DATE

DRAWN BY R.E.B.	DATE 10-4-77
CHECKED	SCALE NONE
MATERIAL ¼" THICK ACRYLIC	
DO NOT SCALE DRAWING	
TOLERANCE	
FRACTION ±1/64	DECIMAL .XX ±.010 .XXX ±.005
ANGLES ±1/4°	

ESB INCORPORATED
TECHNOLOGY CENTER
YARDLEY, PENNSYLVANIA

MAT FILTER & FRAME

DRAWING NO. ESB-C110 B

Figure 20 MAT FORMATION FILTER DIAGRAM

Mat Formation I-E-2-0

1. Be sure that all drains and vacuum connections to the mat forming apparatus are shut off.
2. When all fibers are sparged, pour the contents into the top section of the slurry apparatus. (See Figure 20)
3. Quickly arrange fibers in slurry apparatus with small spatula to get as even a distribution as possible.
4. Pull a vacuum on the apparatus, causing the sparging solution to be pulled from the fibers into the lower section of the slurry apparatus.
5. With vacuum on, press the fiber mat gently with clean rubber gloves to remove residual water.
6. Turn off vacuum.
7. Remove inner section of slurry apparatus.
8. Remove Neva-Clog screen and mat from apparatus.
9. Carefully invert screen and mat onto glass plate.
10. Remove additional H_2O from mat by pressing down on screen with paper towels or suction from a vacuum line with a trap.
11. Life Neva-Clog screen carefully from mat after separating the mat from the edges of the screen by carefully sliding a spatula between the filter and the mat.
12. Flush screen with water and replace in slurry apparatus
13. Center template on mat and cut away edges with razor blade.
14. Remove template; pull straight up. Do not slide off.
15. Spray mat on glass with eutectic binder solution, if necessary. Mat seams should stick together. Do not soak mat; moisten only.

Pocket Formation I-E-3-0

1. Clean teflon block with water to remove dust and foreign material.
2. Place block carefully on mat with top of block centered between slots in mat.
3. Be sure the block is placed such that the tabs of the mat may be folded over onto the block.
4. Using wet spatula, gently pull mat from the glass and fold ends over the block so that they overlap.
5. Smooth the mat into place, wrapping the block as tightly as possible.
6. Fold end tabs in and close off.
7. Gently lift bottom of block and stand on end.
8. Smooth back side of mat with spatula.
9. Smooth mat with spatula.
10. Spray mat with binder solution.

Drying I-E-4-0

1. Transport mat, block and drying stand to oven.
2. Mat should remain in an air oven at 125° C until dry to the touch.

Binder Solution Procedure I-E-5-0

1. In a clean beaker of a suitable size, heat 500 ml of distilled H_2O, preferably on a hot plate with a magnetic stirrer.
2. Add 175 g reagent grade KCl with agitation.
3. Add 158.3 g reagent grade LiCl with agitation.
4. Dilute to 1 liter.
5. Allow to dissolve.
6. Cool and store for use.

NOTE: Binder solution will be applied with a mister; hence it is important that the KCl and LiCl be completely in solution. It may be necessary to add a small amount of distilled H_2O to prevent the mister from clogging.

Electrolyte I-F-0

Specs I-F-1-0

LiCl 48%, KCl 52% pre-electrolyzed in elemental lithium production cells by vendor. Ordered from Lithium Corporation of America as Lithium Chloride/Potassium chloride ingots, 5% Lithium rich. Pack under argon.

Quality Control I-F-2-0

Salt, as received, is sealed against air and moisture attack. Salt can be analyzed for Li and K content but is assumed to be of proper composition since it is drawn from production cells. Salt should be dry and white. Damp or wet salts must be rejected due to introduction of moisture to system and formation of lithium oxides and carbonates. Non-white stock indicates the presence of contaminants and should be rejected.

Cell Assembly II-0

Cathodes (After Formation I-C-5-0) II-A-0

Hot-Seal Type II-A-1-0

The long tungsten rod used as a conductor and holder during the formation step must be removed and a hot-seal type external lead must be inserted.

1. Cut off section of header that extends above the cathode body. Cut must be in line with, or even with, cathode body. This should free the tungsten rod including the small block of graphite holding said tungsten rod. This procedure should expose a pilot hole in the header. (Refer to Figures 6 and 7.)
2. Place cathode in suitable holder to prevent cathode movement. Drill cathode header 1 inch deep with a 23/64" diameter drill. Ream with .3750 reamer.
3. Inspect to ensure hole is clean.
4. Insert hot-seal assembly to 1 inch.
5. Advance to "Cathode Unit Assembly II-B-0."

Cold-Seal Type II-A-2-0

If cathode does not have the header extension and the tungsten rod has been inserted into the cathode body, proceed to "Cathode Unit Assembly II-B-0."

If cathode has a header extension, then proceed to "Hot Seal Type II-A-1-0," steps 1, 2 and 3. Step 4 is the reinsertion of a cold seal type length of tungsten to a depth of 1 inch. Proceed to "Cathode Unit Assembly II-B-0."

Cathode Unit Assembly II-B-0

Concept: The purpose of the cathode unit assembly is to completely surround the cathode with the separator material.

Components (Preparation)

Note: Section I-C-5-0 (9,b) and Cathode Insulation are done simultaneously.

Cathode (See I-C-5-0 (9,b)

Separator, Mat and Cap (I-E-0)

1. Separator (Mat and Cap) are introduced to dry box following a bakeout procedure.
2. The bakeout is 3 hours at 300° C under vacuum. Mats may be stored in the dry box.
3. Cut a hole in center of the bottom of mat. See sketch below:



FIGURE 21 MAT CENTER HOLE DIAGRAM

Screen (Cathode - I-B-2-c-0)

1. The cathode screen is visually inspected, removing any strands which might cause a short.
2. The screen is then dipped into a clean salt bath.
3. Grasping the open end of the screen pocket, with a set of tongs, insert screen into salt bath for 5 seconds.
4. Dip the screen to within 2 inches of the edge at the open end. Remove and allow to cool.

Tools

Spatula
Spot Welder
Scissors
Knife

Cathode Insulation

1. Slide cathode screen over mat. Set to one side.
2. Following Cathode-Dip, allow salt to solidify on cathode surface and then proceed.
3. Grasp cathode at tungsten rod, using asbestos glove, if necessary, and stand upright.
4. Place screen mat assembly over tungsten rod, inserting tungsten rod into hole cut in the mat bottom.
5. Slide screen mat assembly down the rod until contact is made with cathode.
6. Using the spatula, aid screen mat assembly edge as it slides over cathode.
7. Slowly slide screen mat assembly onto cathode until it reaches dry box floor.
8. Lift cathode using tungsten rod with one hand while applying slight downward pressure on mat. Mat will slide into place on cathode.
9. Carefully transfer assembly to spot welding box.
10. Cut away mat flush with cathode bottom.
11. Slide cap over open end of mat and inside screen.
12. Inspect for any holes in mat cap or screen strands and repair.
13. Fold each screen together insuring a tight fit around mat.
14. Pull screen together insuring a tight fit around mat.
15. Spot weld the length of the assembly bottom.
16. Remove excess screen.
17. Slide three 4" BN sleeves over tungsten rod.

Anode Screen (Follow after I-B-0) II-C-0

Tools:

1. Scissors
2. 12" ruler
3. Wire brush
4. Unitek spot welder, 1-132-01
5. Hand shears

Material:

1. Alloy anodes

Spec:

1. 6 pcs. of Anode 1/8" x 4" x 9 3/4"
2. 10 pcs. of Anode 1/8" x 1 1/2" x 4 1/16"

Forming:

1. All anodes will be cleaned by using wire brush before assembly.
2. All anodes cut to proper size.

Assembly:

1. Place 3 pcs. of anode 1/8" x 1 1/2" x 4 1/16" on one side of long cell side.
2. Pull screen over anodes. Spot weld to surface of cell to form three evenly spaced sections. Aluminum side of anode to touch cell surface.
3. Place 3 anodes 1/8" x 4" x 9 3/4" cross-ways in cell can and spot weld in place to form three evenly spaced pockets.
4. Repeat #1 for opposite side.
5. Pull screen over and spot weld to surface of cell into three evenly pockets. Cut off any leftover screen with scissors.
6. Place three anodes 1/8" x 4" x 9 3/4" cross-ways on short cell side can.
7. Pull screen over anodes and spot weld to surface of cell into three even spaces. Cut off any leftover screen with scissors.
8. Place 2 pcs. of anode 1/8" x 1 1/2" x 4 1/6" on bottom plate of cell.
9. Pull screen over anodes and spot weld to surface of cell and cut off any excess screen with scissors.
10. Place two pcs. of anode 1/8" x 1 1/2" x 4 1/16" on top plate of cell. One piece must be cut in half to fit in place.
11. Pull screen over anodes and spot weld in place. Cut screen away from holes at top of plate.
12. Spot weld all edges of screen so there are no loose wires.

Cell Body II-D-0

Can

1. Ensure that the cleaning procedures in Section IV-B-0 were followed for all steel parts before entry into inert box atmosphere.
2. Ensure that anodes have been formed and are in place on the wall sections of the cell.
3. Weld cell can bottom in place in the larger, U-shaped, portion of can. Use welding procedures given in Section II-F-0.
4. Place cathode assembly into cavity.

5. Place remaining wall section on top and clamp in place. Be sure that this wall section is in alignment with other section containing cell components.
6. Weld the two wall sections together and to bottom section.
7. Proceed to next section (II-D-2-0)

Lid with Reservoir 11-D-2-0

1. Construct the lid assembly according to the type of seal to be used, either hot seal or cold seal. See Figure 6b hot seal type and Figure 6a for cold seal type. Be sure to leave top of reservoir open.
2. Insert the required amount of solid electrolyte (See II-E-0) into the reservoir, place cover, including argon tube, and weld closed. Attach vacuum type ball valve to the argon tube, and weld closed. Attach vacuum type ball valve to the argon tube (See II-E-0). Close valve. Cell is ready for leak test (Sec. II-G-0)

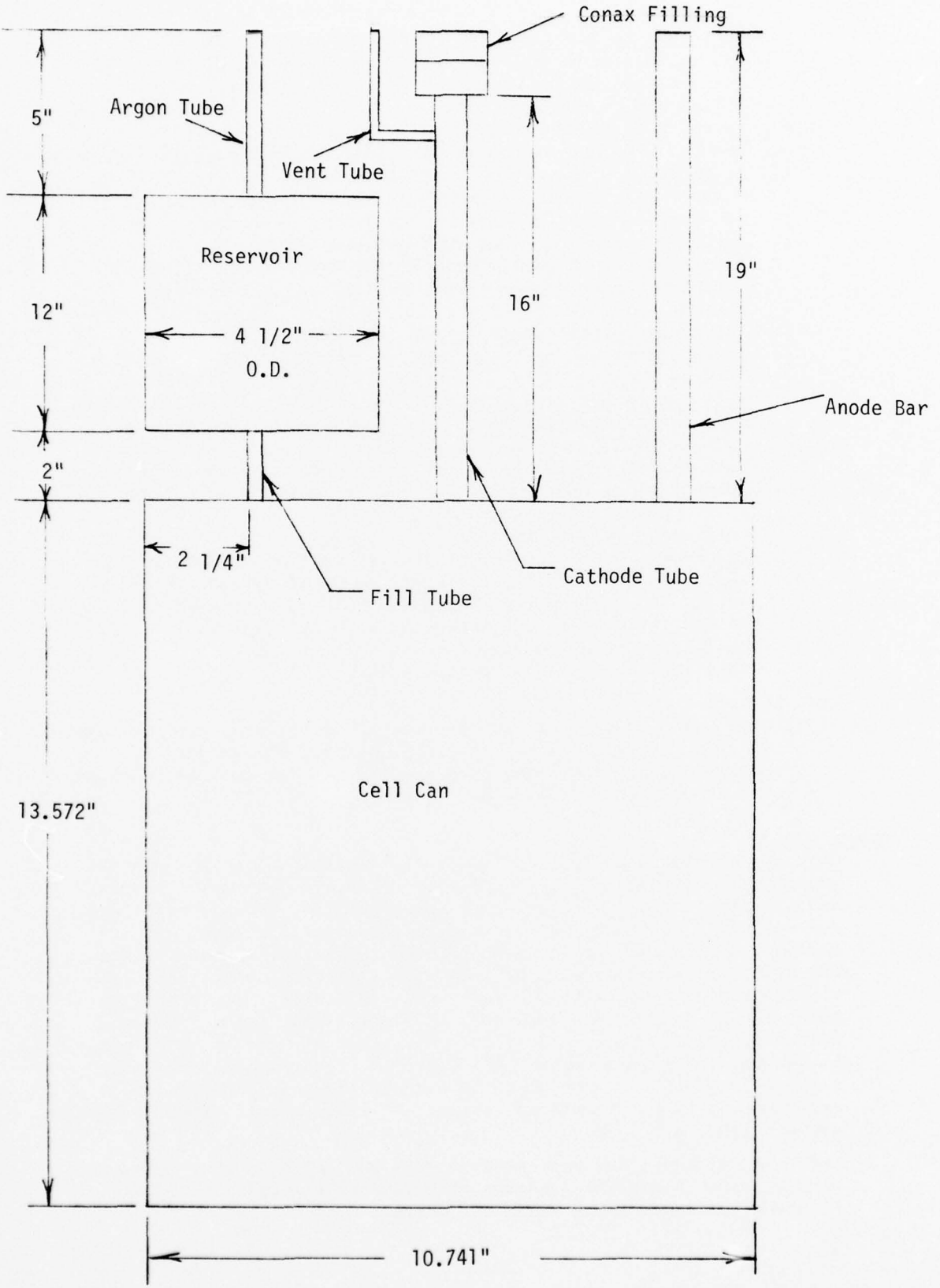
Electrolyte Charging II-E-0

Electrolyte charging is actually accomplished in two steps, each taking place at different stages. The first stage is the placement of the required salt, about 8.5 lbs., into the reservoir (II-D-2-0) before welding the reservoir closed. In order to place this quantity of salt in the reservoir, careful packing of dense material is required. Premelting of the salt in another container of like diameter or slightly smaller and then allowing to cool provides an easy means of accomplishing the objective. Filling with loose particles or powder often does not permit placing the full amount inside. Pouring molten salt into the exact reservoir to be used will allow liquid salt to run into the tube leading from the reservoir to the cell can itself. The salt will cool, solidify, and seal the can. This action will prevent the filling of the cell with helium for the necessary leak testing prior to cell testing. A solid charge is almost a necessity.

The second stage of salt charging is accomplished during the heating up of the cell and reservoir in the cell testing Section (III-0).

Welding Procedures (See Figure 22) II-F-0

1. Body (B80 Amp Setting). Using vice-grip clamps, clamp heat sink below seam and one steel strip on each side of seam above. End of seam should be even as possible. Tack each end and approximately every three inches in between. Using 1/16" filler rod, weld seam. Remove heat sink.
2. Bottom to Body (B80 Amp Setting). Insert special jig into body. Place bottom in body (may require light hammering) until bottom rests on jib. Clamp in place using vice-grip clamps. Tack each side approximately every three inches. Remove clamps and jig. Use 1/16" filler rod for weld. Concentrate heat to body bottom.



MM-1 CELL ASSEMBLY - COLD SEAL TYPE
Figure 22

3. Salt Tube to Reservoir Bottom (B-50-B80 Amp Setting). Insert salt tube into disc making sure end is flush. Using slight motion, weld on the inside of disc. Filler rod is not needed.
4. Vacuum Tube to Reservoir Top. Same as #3
5. Reservoir Bottom to Reservoir (B50-B80 Amp Setting).
6. Conax Fitting to Cathode Tube (B50-B80 Amp Setting). Insert conax fitting into end of tube. While welding, concentrate heat to fitting. Use 1/16" filler rod.
7. Cathode Tube to Body Top (B50-B80 Amp Setting). Insert tube into center hole of top until flush. Using slight motion, weld on inside of top. Filler rod not needed.
8. Reservoir Assembly to Body Top (B50-B80 Amp Setting). Insert salt tube into end hole of top until flush. Weld same as #7.
9. Body Top Assembly to Body (B80 Amp Setting). Place top into body making sure all edges are even (may require light hammering). Use vice grip clamps to hold in place. Tack each side approximately every three inches. Remove clamps. Using 1/16" filler rod, weld, concentrating heat to body top.
10. 1/4 vacuum line to cathode tube.
11. Weld anode bar to lid.
12. Reservoir Top to Reservoir (B80 Amp Setting). Same as #5.
13. Tube Caps (B50-B80 Amp Setting). Drill out salt approximately 1 1/2" from top of tubes. Sand outside surface to be welded. Place cap over tube and weld using slight motion. Concentrate heat to cap.
14. Make leak check. See Section II-G-0.

Welding Notes:

Always move slowly over tacked areas so as to insure proper fusion. Tack welds should be wire brushed prior to welding over. Taper welds away from seam onto the steel so as to eliminate pin holes at the end of the weld.

Leak Testing II-G-0

Concept: Oxygen, nitrogen, and water are detrimental to the operation and life of the cell. A constant objective must be to reduce and minimize the presence of these contaminants. Care, persistence, and quality control during the preparations, fabrications, and assembly will result in the best product in the cell itself. Once the cell has been removed from the dry box it is in an alien environment. No penetration of air can be tolerated. To accomplish this, a cell can and its seal must be hermetically tight. Since helium penetrates more readily than any other element or substance, it is used for leak detection using a mass spectrograph. The only leak detector that can be operated with confidence, convenience, and speed is the unit made by Varian. It also operates without the use of liquid nitrogen.

Before a cell unit has been removed from the dry box, it is pressured with helium. A partial pressure of helium is all that is required to check for leaks in the welds and seals.

Procedure: II-G-1-0

Cold Seal Type II-G-1-a-0

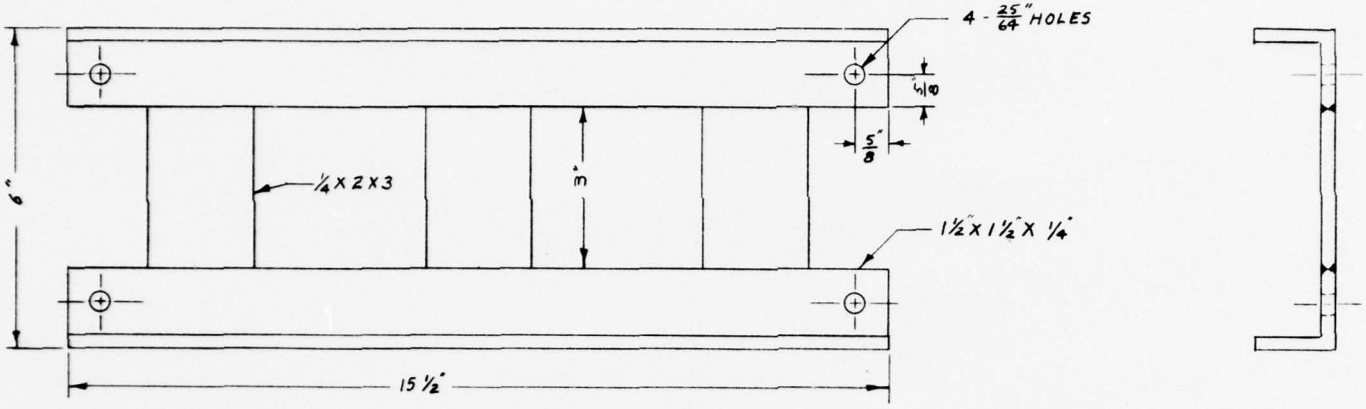
1. After the MM-1 cell is completely assembled and before it is removed from the dry box, tighten the Conax fitting nut as tight as possible using a pair of channel lock pliers and an end wrench. Tightness is usually 15-20 ft.-lb.
2. Cells removed from dry box are pressurized to 5 p.s.i. with helium. Using sniffer probe of leak detector, slowly pass over every welding surface, every seal, and any areas remotely suspicious of being a leak point. Make no assumptions about the quality of weld or seal. Any indication of a leak means that it is mandatory that the cell unit must be returned to the dry box system. Proceed to Step 3 if no leaks are detected.
3. If the cell leak rate is acceptable, torque the Conax fitting nut to 70 ft-lbs. hold the bottom part of the fitting and the tungsten rod completely stationary and in the same relative position to each other at all times during the tightening operation. Neither the bottom of the fitting nor the tungsten rod should be allowed to turn during the tightening of the Conax nut. This will prevent the tungsten rod from turning inside the graphite header and deteriorating the electrical connection between the two.
4. Re-check the leak rate of the cell, and if acceptable, proceed with the cell testing procedure as per usual.
5. Attach cell to Cell Testing Manifold, (see Figure 20, Section III-O) at the Helium Bleeder connection.
6. Evacuate vacuum manifold to about 30". Open Bleeder Valve to evacuate air above cell valve. Repeat this step two additional times.
7. Pressurize vacuum manifold by isolating both manifolds and opening cross-over valve. Pressure to 0 psi with argon.
8. Open cell valve. Manifold pressure should increase due to cell pressure.
9. Evacuate manifolds to 0 psi.
10. Isolate cell valve and manifold and close bleeder valve.
11. Remove cell from Helium Bleeder.
12. Proceed to Cell Testing (Section III-O).

NOTE: Additional precautions must be taken to ensure a leak-free cold seal after Cell Testing. Details are in the latter section.

Cell Testing III-O

General: The thin walls of the cell can may indent or bulge depending on whether a vacuum or pressure exists in the interior. The can must not be permitted to bulge and remain in that state or it will be difficult to assemble cells in a given volume for battery usage. Very slight bulging or indentation is not detrimental to the cell, but major deflections may cause the anodes to crack. Bulging can be prevented by placing an appropriate clamping device (Figure 23) around the cell during cell testing. Indentation can be minimized by evacuating to no more than about 2 in. Hg. Zero gauge pressure is preferred.

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
3/20	78	REDRAWN		L.F.	



NOTE - MAKE TWO AND USE 3/8" DIA. X 3" BOLTS

DESIGN/RELEASE APPROVALS	
APPROVED BY	DATE

DRAWN BY R.E.B	DATE 10-3-77
CHECKED	SCALE HALF
MATERIAL CARBON STEEL	
DO NOT SCALE DRAWING	
TOLERANCE	
FRACTION ±1/64	DECIMAL .XX ±.010 .XXX ±.005
ANGLES ±1/4°	

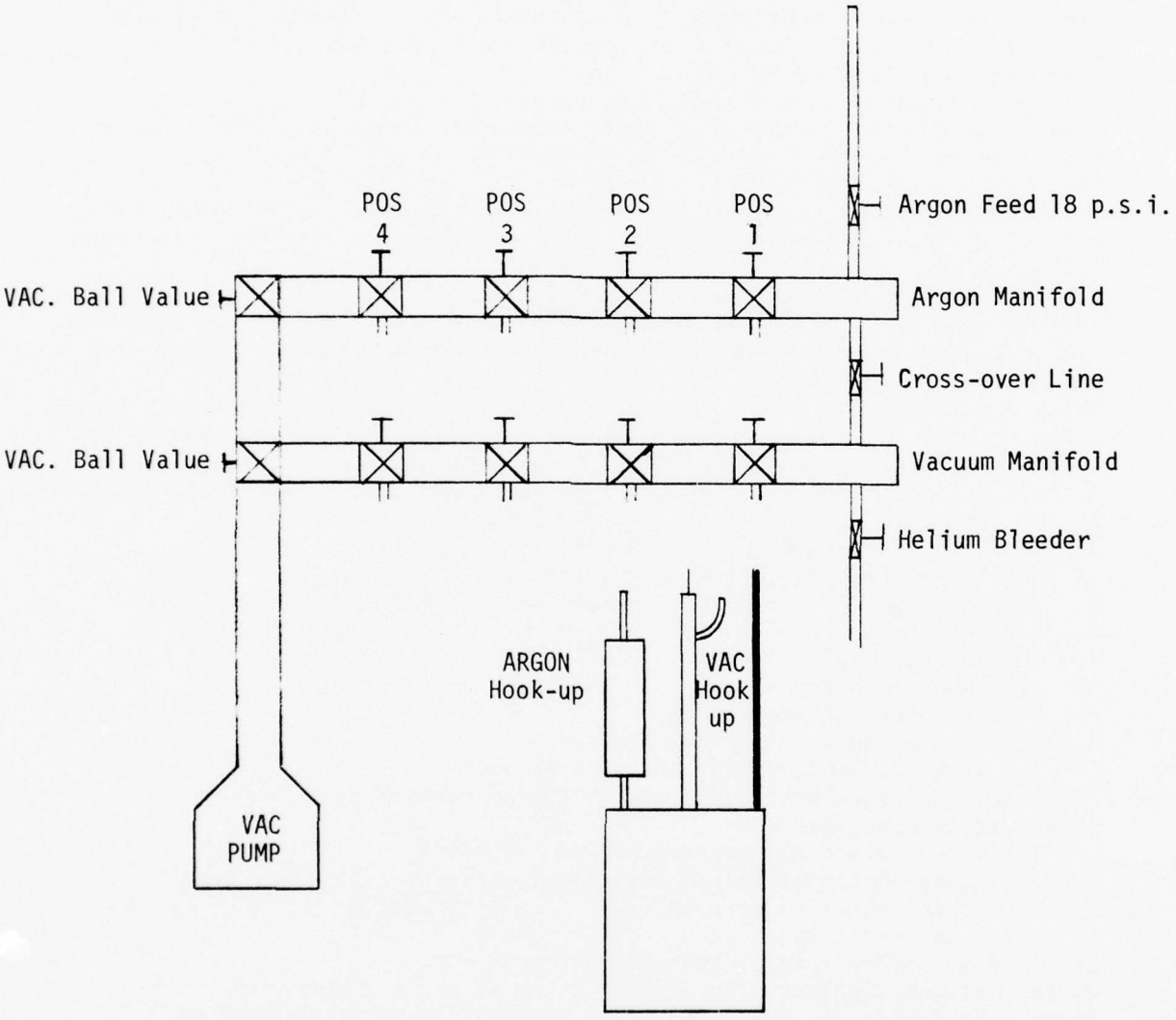
ESB INCORPORATED
TECHNOLOGY CENTER
YARDLEY, PENNSYLVANIA

CELL CLAMP

DRAWING NO. ESB-C107 B

Figure 23 CELL CLAMPING DEVICE

1. Tighten cell clamp (see Figure 23) on cell so that it is snug. Place thermocouple in clamp thermowell.
2. Place cell in a cell testing furnace with the reservoir on the left.
3. Insulate the top of the cell with furnace lids. Seal cracks with asbestos.
4. Attach appropriate manifold lines to the argon hook-up and vacuum hook-up. Pull full vacuum to remove air above cell valves. Repressurize to 0 psi, open both cell valves, (See Figure 24).
5. Attach appropriate power leads to cell terminals. Positive lead attaches to tungsten terminal. Clip on appropriate voltage sensing leads.
6. Plug in appropriate thermocouple jack.
7. Turn on appropriate cycler and power supply.
8. Turn on appropriate temperature controller. Set temperature indicator at corresponding setting. Turn on recorder.
9. Set controller for 425-430°C.
10. The pressure within the cell increases as the temperature increases, bleed off cell pressure from expansion of gas through vacuum manifold. Maintain cell at 0 psi.
11. Cell should heat soak at operating temperature (430°C) for at least 4 hours. Voltage should be steady, at greater than 2.8 volts. Temperature indicator displays referenced temperature. Salt should be melting and flowing into cell during this period.
12. Apply 2 psi argon to cell. Reduce to 0 psi through vacuum manifold. Repeat until salt plugs vacuum hook-up. Remaining pressure should be reduced to 0 psi slowly through argon hook-up. This procedure forces salt into the annular space between the tungsten and the outside tubes to effect a salt seal.
13. Cycler Set-Up.
    a. API high voltage set point 3.0 volts.
    b. API low voltage set point 2.40 volts.
    c. Timer on AND set for desired charge time.
    d. Current limit off.
    e. Charge hold on.
    g. Discharge hold on.
    h. Place cycler in charge mode
        1. set voltmeter to voltage set
        2. adjust charge voltage set to 3.31 volts
        3. press short button and adjust charge current to 36 amps
    i. Place in discharge mode
        1. adjust discharge voltage set to 5.0 volts
        2. press short button and adjust discharge current to 36 amps.
    j. Return voltmeter to cell voltage.
    k. Place in charge mode.
    l. Turn on charge enable, then discharge enable.
14. Cycle cell until essentially equivalent AH values are obtained.
15. After cell testing is completed, cool the cell to room temperature.
16. Re-tighten the Conax fitting nut to 70 ft-lbs. using the same procedure as per step (3). Again it is very important to hold and maintain the relative positions of the tungsten rod and the bottom half of the Conax fitting. The tungsten rod must not be allowed to turn at any time during the tightening operation so that the good electrical connection between the header and the rod is maintained.
17. Return the cell to the dry box and prepare it as per usual for shipment.
18. At this point the cell is ready for further test and the Conax fitting should not require re-tightening at this time.
19. However, after each heat cycle (that is, whenever the cell is cooled to room temperature), check and re-tighten the Conax nut to 70 ft-lbs. as



Manifold is set up to individually evacuate and pressurize cells. Capacity is four cells. Argon applied to reservoir pushes electrolyte into cell body. Vacuum side is for pressure relief. All manifolds and cell lines have compound guages for pressure indication.

CELL TESTING MANIFOLD

Figure 24

per step (3). The Conax fitting can probably be re-tightened 4-6 times before the Conax nut bottoms out and/or the Viton sealant ring loses its sealing properties.

General Operating Procedures IV-0

Atmosphere Requirements IV-A-0

Gases IV-A-1-0

Air must be totally eliminated from the dry box system. The maximum allowable concentration of oxygen at any given time is 1 parts per million. It is assumed that nitrogen will be 4 times the oxygen concentration or 4 ppm. Water content should be established with a dew point at -70°C or lower.

Detection of oxygen can be accomplished by exposing the tungsten filament of a 25W light bulb in the interior of the system. The glowing of the filament continuously for 2.5 days indicates an oxygen level of 1 ppm. Longer time period indicates that the level is 1 ppm or lower. A sudden increase in brightness indicates bulb failure will take place soon. This failure can be attributed to a new leak, such as a cut glove, the introduction of improperly treated or degassed material, an improperly closed antechamber door, a problem with the gettering equipment, etc.

Detection and determination of oxygen can be made by means of an oxygen analyzer capable of reading below 1 ppm.

Nitrogen and oxygen can be determined with the use of a gas chromatograph.

Water vapor can be detected and determined by instruments such as those supplied by Panametrics, Inc. that continuously monitor the dry box environment with respect to moisture.

The atmosphere within the box system must be continuously circulated to facilitate removal of contaminants and to permit the instrumentation to sense the true average atmostphere. Present operation techniques ensures a change rate of about 40 $ft.^3$ per minute.

Removal of Gaseous Contaminants IV-A-2-0

Assuming that a system had nothing passing in or going out through the antechambers, there would be a gradual increase in contamination levels due to diffusion of air thorugh the glove ports. The moisture content will also vary due to the variation in humidity of the outside air exposed to the gloves and to the moisture generated by perspiration of the workers using the glove ports. The gloves used are butyl rubber and are considered to be the least permeable type. Do not use neoprene rubber.

Circulation of the dry box atmosphere is essential. The circulation should be directed through a water removal system, then through an oxygen-nitrogen removal system and then returned to the dry box system. In effect, dry, clean argon gas is introduced at one point, circulated past contamination pickup points, such as gloves, materials, etc., exited at another point, purified, and then returned to continue the cycle. A Photohelic control device is used to maintain about 1 atmosphere pressure at all times.

Water removal can be accomplished by the use of any system containing molecular sieve material that can be recharged by heat and vacuum. Needless to state that the system must be helium tight. Other systems are available.

The most efficient method found to date fortunately removes both oxygen and nitrogen quantitatively and rapidly. The agent is spongue titanium. At 700°C titanium will quantitatively remove oxygen from air. at 800°C it will remove nitrogen. A higher temperature will ensure fast reaction and a reaction bed that is at least above the minimum reaction temperature. Present operation requires a temperature setting of about 930°C. The high temperature of the exit gases requires the use of heat exchangers to cool the argon before re-entry to avoid increasing the overall temperature of the box and causing discomfort for workers.

Also refer to Section IV-C-1-a-0 on Antechambers.

Cleaning of Parts and Degassing IV-B-0

All metal parts for the cell can, salt reservoir, and tubing must be completely degreased and all oxides removed before they enter the dry box. This is necessary for two reasons, (1) to eliminate introducing impurities into the cell and, (2) to minimize welding problems.

Do not start procedure until assured that parts can be placed in dry box immediately after cleaning.

Step 1. Soak metal parts in alkaline cleaning solution for 30 minutes (Northwest Cleaner #47, at 8 oz/gal and 45°C.)

2. Rinse three times in continous water rinse.
3. Dip in acid tank. Remove when all rust has disappeared. (HCl acid, 30%).
4. Rinse three times in continous water rinse.
5. Immediately drop clean parts into reagent grade methanol. Do not leave parts in methanol more than 10 minutes. Note: Methanol is used for one batch only and is then discharded. Once opened to the air methanol absorbs water and moisture from the surrounding air and quickly loses its effectiveness. Immediately go to Step 6.
6. The surface of all parts are now free of all coatings and are active. All parts must be immediately transferred to the dry box antechamber and evacuated. Failure to immediately transfer requires that the cleaning procedure be followed again to ensure cleanliness.

Access Requirements IV-C-0

Material Entry and Exit IV-C-1-0

Antechambers - General IV-C-1-a-0

The entry and exit of materials from the dry box system is one of the critical procedural steps. Failure to follow procedures can endanger the entire system and cause the loss of material in process or, in a detectable manner, reduce the productive life of cell components exposed to the higher oxygen, nitrogen, and moisture conditions. The introduction of unnecessary gaseous contaminants obviously reduces the active life of the moisture extraction media, and the oxygen-nitrogen removal systems. Failure to follow the procedures will not endanger working personnel.

General concepts:

1. Each time that a chamber door is opened to the air of the room, a film or layer of air and moisture is immediately established on all walls and surfaces. The moisture must be removed. Moisture is the most difficult substance to remove. Some installations use mildly warmed chamber surfaces to assist in degassing.

2. Each material being introduced must have its environment converted from air to argon (or helium) before entry. This is accomplished by evacuating and back filling three times.
3. Nonporous materials can be degassed and passed through antechambers quickly. Porous materials or woven materials contain exceptionally large amounts of moisture and are difficult to degas. The volume of water extracted may require frequent oil changes on the vacuum pump unless a ballast-type vacuum pump is used. (Asbestos gloves have taken hours to degas while ceramic insulating brick has required more than one week before entry could be permitted.)
4. It must be remembered that capped containers may explode under vacuum. It is better to open a container, quickly place in antechamber, close and evacuate, than to break or destroy a substance requiring a subsequent clean-up. Caution: Evacuate powders very slowly. Failure to do so will cause powder to blow around.

Procedures and Controls IV-C-1-b-0

All antechambers should be fitted with a pressure-vacuum gauge and a thermocouple-type vacuum gauge equivalent to the unit produced by Hastings-Radist Corporation. The pressure-vacuum gauge is used to indicate return to 1 atmosphere pressure. The vacuum gauge is used to determine the quality of the vacuum and the ultimate vacuum attainable in that portion of the system. The leak rate should be no more than 3×10^{-10} cc/sec. The vacuum value obtained before back filling inert gas should be in the range of 15 to 50 microns for the first two evacuations. The final evacuation should be the value normally expected for the particular chamber but should be less than 45-50 microns. If a gas laden or water laden article has not been completely degassed it will not be possible to reach the values given above.

In an emergency, the first two evacuations need not be more than 200-300 microns.

Always leave the chamber in the purged-three-times-state to safeguard against an inadvertent opening of the interior door and resultant contamination of the dry box atmosphere.

To enter or exit an antechamber the following steps should be observed:

Step 1. Assuming that chamber has been purged-three-times and is under vacuum, it will be necessary to backfill with argon up to 1 atm pressure as indicated by the pressure-vacuum gauge.
2. Open door, place articles in chamber, or remove as indicated.
3. Exiting-close interior door. Entry-close outside door.
4. Evacuate. When pressure is below -30 inches Hg. recheck tightness of door.
5. Evacuate to about 50 microns vacuum.
6. Back fill with argon to 1 atm.
7. Exiting - Open outside door and remove articles.
   Entry - Evacuate for second time to about 50 microns.
8. Exiting - close outside door. Follow steps 4,5, and 6.
   Entry - back fill with argon to about 1 atm.

9. Exiting - Evacuate and leave as is until next use. Recheck ultimate value to ensure that system is OK. Entry - Evacuate for the third time and back fill with argon to 1 atm.
10. Entry - Open interior door and remove articles.
11. Entry - Close interior door. Follow steps 4 and 5. After #5 leave system under vacuum. Recheck ultimate value to ensure that system is OK.

NOTE: As these procedures are followed, it is assumed that the operators will automatically glance at the condition of the door surfaces and the "O" rings to find obvious faults, dirt on surfaces, flattened "O" rings, etc. and will report same for immediate corrective action. Operational success is dependent on this attitude.

Human Entry & Exit (Projected) IV-C-2-0

Antechambers - General IV-C-2-a-0

It is necessary to purge or flush the antechambers in a manner that will insure that oxygen, nitrogen and moisture are excluded from entry into the system. This procedure is complicated by the fact that human personnel are in the antechamber.

The personnel must be in suitable outfits similar to those worn in space exploration. If the suit is identical to the space suits then it should be possible to follow the procedure outlined in IV-C-1-o, provided an air supply, such as a back-pack is available to the wearer. These suits are very cumbersome. Lighter type suits are available on the market (ILC Industries, Inc.) that are less cumbersome, but they cannot withstand vacuum. They also require a means of air supply during transit to the interior.

Exit is simply entry into antechamber, close door, and open exterior door, go out, and close outside door.

Special provisions must be instituted before satisfactory conditions prevail for personnel and product. See IV-C-2-b-0.

Special Provisions IV-C-2-b-0

Much was learned by the Universal-Cyclops Steel Company during the many years of operation of their INFAB facility near Pittsburgh, Pennsylvania. They operatored a facility measuring 42 ft. by 97 ft. and 23 ft. high. They maintained the argon atmosphere at less than 1 ppm oxygen at all times. The metallurgical furnaces, rolls, etc. were operated by remote control with the assistance of personnel in space suits.

Universal-Cyclops found that the moisture on the surface of the suits was too high and was detectable as soon as the suited-person entered the system. To eliminate the problem, a dressing room was attached to the system so as to include the entry-exit doors. The air in the room was dry. The suits were not permitted to be exposed to normal room air. This room was operated similar to a "clean room". The personnel entered the room through double doors, dressed in the space suit and then entered the antechamber. In the chamber wall was a plug-in connection for air. The air hose from the suit was plugged in and the door was closed. No vacuum procedure could be used so they flushed the chamber rapidly with argon, and then the interior door was opened for entry. While inside the system the operator had numerous plug-in points for air and air exhaust,and the umbilical tubes were several feet long. Today it would be possible to flush the antechamber with argon and monitor the oxygen level until the value was essentially 1 ppm.

EMERGENCY EXITS: At some time an emergency may arise with personnel within the system that requires an immediate exit. Crash-out, one way doors were provided at strategic points so that an operator could literally crash-out if seconds or minutes were critical. In 10 years of operation the crash-out doors were never used. Three persons had to be assisted toward an exit. Two were ill and the third had not opened his air line after entry and plugging-in. Opening a crash-out door will destroy the system atmosphere, etc.

Procedure and Controls IV-C-2-c-0

(This section is projected and is subject to change due to changes in equipment).

ENTRY

Step 1. Check suit for leaks. Perform test in dry air dressing room. Use helium leak detector. Do not use suit if any leaks are detected.
2. Put on suit in dry air dressing room. Monitor humidity.
3. Enter antechamber. Plug in air and exhaust hoses.
4. Close door.
5. Flush chamber with argon until oxygen analyzer indicates 1 ppm.
6. Open interior door.
7. Disconnect air and exhaust hoses and proceed to next air and exhaust hose connection and plug in.
8. Close interior door and ensure tightness.
9. Proceed to work area, reconnecting hoses as necessary.

EXIT

Follow above steps in reverse order including the first step, leak check.

Windows IV-D-0

Glove Arrangement IV-D-1-0

The glove arrangements as supplied by vendors in the field are satisfactory for most purposes. In the design of a given window location consideration must be given to access to materials, doors, etc. Overhead conveyors may require adjustments, replacement ontrack, etc. and therefore an occasionally placed glove should be located about 15% higher (on centers) to allow personnel to reach the problem area. Too many higher gloves reduces the visibility of workers and increases the chance for leaks.

Material Specs. IV-D-2-0

Glass windows are impervious to gases. Some vendors no longer supply glass. Glass can be broken or creacked readily.

Polycarbonate type panels withstand impact and moderate temperatures and are considered to be standard.

Lucite or Plexiglass is subject to craxing and distortion due to continuous low heat application and is therefore not considered as acceptable.

Glove Work Stations IV-E-0

Use IV-E-1-0

Gloves are the means of reaching through the walls of the system and performing the required actions within the box. These same gloves are subject to abrasion and cuts due to the various required actions within the box. It is recommended that objects are handled as often as possible with tools and clamps rather than actual contact between glove and object. If the activity is unusually detrimental to the glove it is advisable to place another glove hand over the window glove. The glove hand can be retrieved from a replaced glove or it could be a cloth glove.

A warning is necessary when working with warm or hot objects. The heat transfers suddenly through the rubber and appears to be intense. It is strongly recommended that the glove be covered with an asbestos glove.

Always be conscious of the possibility of the object being handled can cause a leak by pricking, cutting, or abraiding.

Inspection IV-E-2-0

Gloves should be visually inspected frequently to detect leaks. Inspect by pulling a small segment between the hands. A hole or cut will be obvious and indicates the need for replacement. Failure to replace will overtax the recovery systems and may cause permanent effects on materials being processed. (Tire patches are satisfactory when leaks are found in other than finger areas.)

Use a healium leak detector over each square inch of surface if a leak is suspected but cannot be found by visual inspection. (The Varian leak detector will indicate that all of the glove surfaces leak unless the sensitivity is reduced.)

Replacement IV-E-3-0

Glove replacement is a critical operation. Improper procedure or improper replacement can result in air contamination.

Numerous devices are available to permit glove replacement without affecting system operation or the atmosphere. Many are cumbersome. Figure 25 illustrates the device recommended. The procedure that follows is for that device. (Be sure thumb position is up.)

Procedure

1. Attach stopper hose to vacuum line.
2. Close vacuum valve and purge valve, evacuate line
3. Seat stopper firmly in glove port.
4. Open vacuum valve to evacuate glove and seat stopper.
5. Open purge valve to equilibrate pressure; close purge valve.
6. Remove retaining clamp and rings from glove port flange; remove glove.
7. Install new glove in reverse order of Step 6.
8. Evacuate glove by opening vacuum valve. Close valve.
9. Purge glove by opening purge valve. Close valve.
10. Repeat steps 8 and 9 four times
11. Remove stopper from glove port.

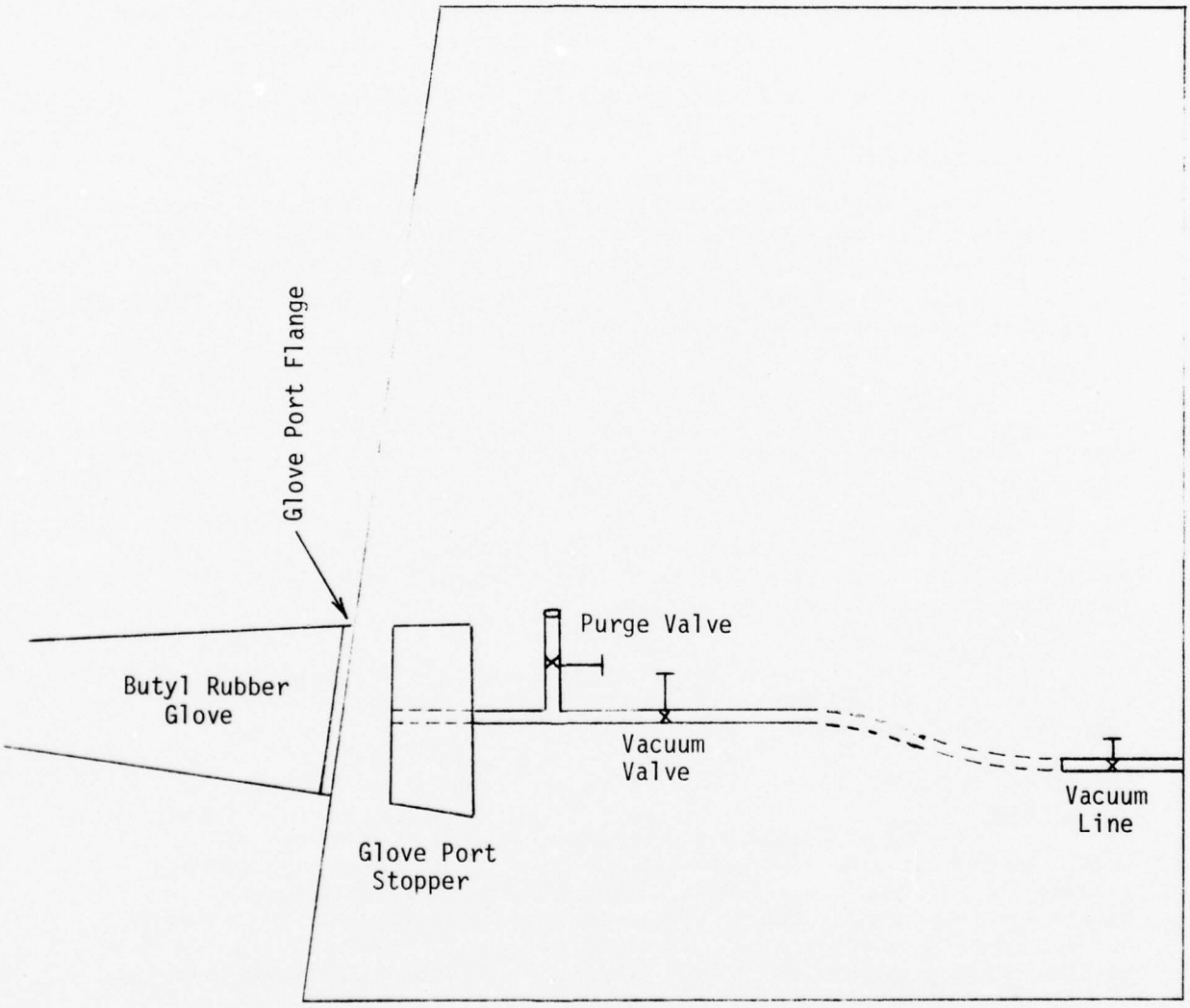
Quality Specifications IV-E-4-0

Butyl Rubber, heavy weight, dry box gloves, 8-9" diameter. Purchased by dry box vendors or Charleston Rubber Co.

Molten Salts IV-F-0

Specifications IV-F-1-0

Salts must be free of moisture and must be of ultra high purity. The individual salts cannot be purchased with these requirements. The only reliable method is the electrolysis of the molten salts. Two approaches can be followed: (1) purchase reagent grade salts, KCl and LiCl, dry under vacuum, melt in inert atmosphere and electrolyze by cycling for three days under slight vacuum conditions. The electrodes can be the regular Li-Al anodes and heat-treated carbon cathodes. Hydrogen and oxygen will be evolved and must be removed via a vacuum exhaust system. Method (2) purchase salt from the lithium production cells of lithium metal producers. These producers must have a purified salt electrolyte to obtain quality lithium metal from their cells. The composition used by most of the producers contains more LiCl than the eutectic compsoition. The producers' composition is exactly the composition desired for cell formation, and cell operation.



DEVICE FOR GLOVE REPLACEMENT

Figure 25

Special Compartment - Formation Tank IV-G-0

A special purpose dry box was designed and constructed by Vacuum Atmospheres Company based on requirements generated while operating the pilot line.

Concept: To provide a dry box working area suitable for forming cathodes in molten KCl-Li-Cl salts. Glove ports to be available on both sides. The roof of the box to be raised to allow for the travel of a hoist from one end of the box to the other without the hoist subtending any work area or height. The hoist to be accessible for repair or removal. A formation tank or tanks must be mounted flush with the floor of the dry box. The usual accessories are expected for atmosphere control, etc.

Movement of Materials IV-H-0

Overhead IV-H-1-0

Overhead hoists are considered to be useful for the movement of the MM-1 size cells and components. It is a must for the insertion and removal of cathodes from the formation tank. (See Section IV-G-0).

Standard overhead hoists and trolleys are acceptable provided the precautions given in the Introduction are followed.

Belt IV-H-2-0

Magnetic belt conveyors can be used to transport or transfer parts from one place to another. The units can be sectionalized to permit entry through the antechambers. Conveyors must not interfere with the operation of section doors or antechamber doors.

Antechambers IV-H-3-0

Standard type trays as supplied by Vacuum Atmospheres Company and others that can be pulled either direction through the chamber are necessary for ready access and egress.

Section Doors IV-H-4-0

Section doors are necessary for sealing off a particular section of dry box for repair, maintenance, safety or isolation for a special purpose. Standard item.

Safety and Cautions IV-I-0

Lithium IV-I-1-0

The metal, lithium, is very active, and at the same time can be worked in dry air. Working with lithium in an inert atmosphere normally presents no problems other than the fact that it tends to stick to other metals like soft butter sticks to the butter-knife. In case of accidents, the consequences vary from one extreme to the other. The following sections outline the appropriate procedures necessary to avoid a dangerous situation.

Li- In Chamber IV-I-1-a-0

Inside the dry box, bulk or foil lithium can be handled by any normal procedure used for a soft metla. it can be handled by means of the rubber gloves or ordinary tools. Scrap pieces should be placed in a separate container marked "Lithium For Disposal". Small pieces or powdered metal should be included. Pick up of such material can be accomplished by the use of a small brush and pan "butler" outfit which allows the fine material to be swept into the pan and then into the "Lithium For Disposal" container. When small accumulations of metal are realized, the container should be brought outside for disposal as per Section IV-1-c-0.

To prevent unnecessary loss of lithium, it is advisable to keep all metal in closed containers.

In the event of an accident, such as the loss of a glove or improper use of antechambers that has permitted the dry box to be filled with humid air, no combustion is to be expected from bulk metal. The surface may become contaminated with hydroxide and carbonates. Powders may react and generate heat. No combustibles, such as paper, are present in the box and fire is not expected unless an excess quantity of powder makes it possible to generate a high heat which, in turn, causes other materials to ignite.

Outside Chamber IV-I-1-b-0

Lithium metal can be stored outside the dry box in original sealed containers. All opened or punctured cans must be immediately transferred to the dry box to avoid contamination, or safety hazard.

Bulk lithium metal will react slowly with atmospheric moisture. The attack is not obvious by eye, but viewing a section of metal under a microscope will reveal an effervescent surface.

Powdered lithium in air can be dangerous, and is a safety hazard, particularly in contact with items such as wet paper.

Do not handle lithium metal or powder with the hands. The moisture of the hands will cause a reaction and possible burns.

Disposal IV-I-1-c-0

Disposal can be accomplished by careful reaction with water in gram quantities in a lab hood free of combustibles or in a large open area outside the building, with protection of the worker with gloves, apron, and face shield. A metal container filled with cold water can be charged with occasional sprinklings of metal. Observe water temperature to avoid boiling and splashing. Normally no flames are evident, but the addition of an unalloyed anode sandwich to the water will cause flames to be generated.

Lithium-Aluminum Alloy IV-1-2-0

The anode alloy has the same problems as the lithium metal but the magnitude of the problems are much less. The alloy is brittle and can be cracked or broken whereas lithium metal is soft and pliable.

In Chamber IV-1-2-a-0

The alloy can be readily handled with ordinary tools. Avoid handling with gloves due to possibility of a puncture. No precautions are necessary but it must be remembered that a major influx of oxygen and moisture to the dry box renders all exposed alloy suspect with respect to purity. No flame or fire has been reported as a result of water on the alloy. The heat of reaction is large.

Outside Chamber IV-1-2-b-0

Alloy sections examined under a microscope exposed to room atmosphere will show on the surface due to reaction with moisture. Alloy sections exposed to air should not be used for cell purposes and should be discarded. (See Disosal).

Disposal IV-1-2-c-0

Anode alloy is readily decomposed with water as a result of the lithium forming the hydroxide, which subsequently dissolves the aluminum.

For disposal, several anodes can be placed in a 30 or 50 gal. drum in a vertical position. Small increments of cold water can be added (400-500 mls) by an operator that has rubber gloves, lab coat or apron, and face protection. Monitor the temperature of the water in the reactor. Avoid boiling. Eventually cover the anodes with water or fill the reactor to the top. Disposal of solution depends on local ordinances.

Other Metals IV-1-3-0

No precautions other than normal are necessary other than to caution that warm or hot metals can cause the rubber gloves to become overly warm.

Hot Materials IV-1-4-0

Molten Salts IV-1-4-a-0

Molten salts, at temperature, appear to be water-like. They are non-corrosive in the truly anhydrous state. "Moist" salts will attack carbon steel and stainless steels including 347 grade,

Experience on the pilot line has shown that molten salt leaks are small spot leaks that spread slowly and do not create unbearable situations. This may be in part due to the fact that all lines, tanks, and furnaces are insulated and the insulation absorbs the salt. Equipment failures result, and indicate a problem, but the danger to personnel is minimal.

The disassembly and repair of equipment that contains salt should be performed wearing gloves and face mask to avoid contacting salt or breathing the dust. Prolonged exposure without protection may cause garlic breath.

Molten salts can be contained in SS-347 or 316L and possibly SS-321. All welds must pass x-ray examination. No satisfactory valves have been found. Movement of salt has been accomplished by applying argon gas pressures and/or vacuum, hold the fluid at the desired point and then solidifying a section of salt by cooling.

Compounds IV-I-5-b-0

No special precautions are required.

Tellurium IV-1-5-0

Tellurium Metal IV-1-5-a-0

Tellurium is a toxic metalloid.

Exposure to tellurium is not normally expected except in disposal of spent materials, etc. Normal precautions should be taken for adequate ventilation and non-exposure to skin during disposal.

Tellurium Compounds IV-1-5-b-0

Tellurium is a metalloid that forms metallic salts. The salt used in this cell system is tellurium tetrachloride ($TeCl_4$).

$TeCl_4$ should be stored in unopened bottles outside the dry box and when opened should be immediately brought in to the inert dry box.

$TeCl_4$, when used, is placed in a reactor and sublimed to condense in and on the carbon cathode. If sublimed in a vessel outside of the dry box system, provisions must be made to exhaust fumes in case of a gasket failure and escape of $TeCl_4$ vapors.

APPENDIX A

OPERATION OF CELL CYCLERS

TABLE OF CONTENTS

I. Set-Up

II. Controls

III. Calibration Procedures

IV. Operation

V. Cell Cycler Test Facility

VI. Schematics

Esterline Angus Chart Recorder

Kepco Power Supply

OPERATION OF CELL CYCLERS

I. Set-Up

The cell cyclers are composed of two units: 1) The Power Supply, and 2) The Cycler Control.

The power supply is a Kepco model ks - 8 - 100M and has an output of 0-10 v.d.c. at 0-100 amps. The cycler control unit is an original design engineered by Standard Oil of Ohio for this project. Minor modifications were made in the circuitry to allow for the higher currents needed for the larger design MM-1 cells.

II. Controls

1. Charge Hold Timer - A (0-5) minute timer that can establish a time - hold period before charging.
2. Charge Timer - A (0-10) hour timer that establishes a time limit on the length of charge time of a cell.
   NOTE: See charge timer switch (16) for conditions
3. Discharge Hold Timer - A (0-5) minutes timer that can establish a time - hold period before discharging.
4. Voltmeter - Indicates voltage of cell from cell sensing leads (5 volts full scale). 1A and 1B high and low limits on meter, controls the upper and lower voltage set points.
5. Ammeter - Indicates current to cell during charge and discharge cycle. Limit operates as a low limit.
6. Voltmeter - A digital panel voltmeter (0-20v.d.c.) used to accurately monitor the cell voltage or the cycler set - up voltage.
7. Ammeter - A digital panel ammeter (0-200mv) used to accurately monitor the cell current or the cycler set-up current.
8. Voltage Set/Cell Voltage Switch - A two position toggle switch used to change the digital panel voltmeter to monitor either the cell voltage or the set-up voltage.
9. Voltmeter Switch - An on - off toggle switch used to control the digital panel voltmeter.
10. Ammeter Switch - An on - off toggle switch used to control the digital panel ammeter.
11. Power Switch - An on - off toggle switch used to turn the main power on for the control unit.

12. Circuit Breaker - A three amp circuit breaker used to protect the input to the cycler control unit.

13. I Limit Switch - An on - off toggle switch for activating current limit set point on ammeter (5). (NOTE: Red light above switch will light if in ON position).

14. Charge Hold Timer Switch - An on - off toggle switch for the charge hold timer. Permits the cell to stay in an open circuit mode before charging for the amount of time set on the charge hold timer. (NOTE: Red light above switch will light if in the ON position.

15. Discharge Hold Timer Switch - An on - off toggle switch for the discharge hold timer. Permits the cell to stay in an open circuit mode before discharging for the amount of time set on the discharge hold timer. (NOTE: Red light above switch will light if in the ON position.

16. Charge Timer Switch - A three position selector switch showing AND, OFF, and OR.

The AND position - this position permits change from a charge mode to a discharge mode when the following conditions are met:

(a) Requires the cell voltage be greater than the set point upper limit on the voltmeter (4).

(b) Requires the time set on the charge timer (2) to be finished.

(c) If the 1 limit switch (13) is on. The current has to be less than the limit set point on the ammeter (5).

NOTE: Only conditions A and B have to be met if the 1 limit switch (13) is in the OFF position (Red light above 1 limit switch (13) is not lit). All three conditions A, B, and C have to be met if the 1 limit switch (13) is in the ON position. (Red light above 1 limit switch (13) is lit).

The OFF position - this position permits change from a charge mode to the discharge mode when the cell voltage exceeds the upper set point limit on the voltmeter (4).

NOTE: IF the 1 limit switch is ON the current must be less than the limit set point on the ammeter and the voltage greater than the set point on the voltmeter in order to switch from the charge to the discharge mode.

The OR position - this position permits change from a charge mode to a discharge mode when either of the following conditions are met:(AorB)

(a) Requires the cell voltage be greater than the set point upper limit on the voltmeter (4).

NOTE: If the 1 limit switch is ON the current would have to be less than the limit set point on the ammeter and the voltage greater than the set point on the voltmeter in order that the above condition be met.

OR

(b) Requires the time set on the charge timer (2) be completed.

17. Charge Hold Button - Red push button light and switch indicates when cycler is in the charge hold mode and being held for the amount of time set on the charge hold timer (1).

18. Charge Button - Red push button light and switch indicates when the charging mode is set on the cycler.

19. Charge Indicator Light - Green light indicates when the charging mode is being performed.

NOTE: Charge hold light, red charge light, green charge light, and charge enable switch all have to be ON in order that the charge operation take place.

20. Charge Enable Switch - An on - off toggle switch that will determine if cycler and power supply is charging to the cell or in a standby condition used for setting up.

21. Discharge Hold Button - Red push button light and switch indicates when cycler is in the discharge mode and being held for the amount of time set on the discharge hold timer (3).

NOTE: When the discharge hold button light is lit and the red discharge button and green discharge light are not, then the cell will be in open circuit for the allotted time.

22. Discharge Button - Red push button light and switch indicates when the discharging mode is set on the cycler.

23. Discharge Indicator Light - Green light indicates an active discharging mode.

NOTE: Discharge hold light, red discharge light, green discharge light, and discharge enabled switch all have to be on in order that the discharge operation take place.

24. Discharge Enable Switch - An on - off toggle switch that determines whether cycler and power supply is discharging the cell or in a standby condition.

25. Charge Voltage Adjust - A ten turn locking control for setting the output voltage of the power supply in the charge mode.

26. Charge Current Adjust - A ten turn locking control for setting the output current of the power supply in the charge mode.

27. Discharge Voltage Adjust - A ten turn locking control for setting the output voltage of the power supply in the charge mode.

28. Discharge Current Adjust - A ten turn locking control for setting the current rate of the power supply in the discharge mode.

29. Current Set Button - A push button used on the calibration procedure to short out the output of the power supply in order to adjust the current.

III. Calibration Procedure

A. Set -

Charge Enable Switch (20)	-OFF
Discharge Enable Switch (24)	-OFF
I Limit Switch (13)	-OFF
Charge Hold Timer Switch (14)	-OFF
Discharge Hold Timer Switch (15)	-OFF
Charge Timer Switch (16)	-OFF
Charge Voltage Adjust (25)	-Full Counterclockwise
Charge Current Adjust (26)	-1/4 Turn Clockwise
Discharge Voltage Adjust (27)	-Full Counterclockwise
Discharge Current Adjust (28)	-1/4 Turn Clockwise
Voltmeter Switch (9)	-ON
Voltmeter Switch (8)	-Voltage Set Position
Ammeter Switch (10)	-ON
Voltmeter (4)	-Low limit to 0 High limit to 5
Ammeter (5)	-Set to maximum

B. Power Switch (11) -ON

C. Kepco Power Supply -ON (NOTE: Allow 30 minutes warm up time)

D. Esterline Angus chart recorder -ON

E. Push Charge Hold Button (17) (NOTE: Red light should light)

F. Setting Charge Voltage:

1. Adjust charge voltage adjust (25) to desired voltage by turning clockwise and reading voltage on the digital voltmeter.
2. Lock charge voltage adjust (25).
3. After locking, recheck voltage set.

G. Push Discharge Hold Button (21) (NOTE: red light should light)

H. Setting Discharge Voltage:

1. Adjust discharge voltage adjust (27) to desired voltage by turning clockwise and reading voltage on the digital voltmeter.
2. Lock discharge voltage adjust (27).
3. After locking, recheck voltage set.

I. Push Charge Hold Button (17) (NOTE: Red light should light)

J. Setting the charge current:

1. Push the shorting button (29) and keep it pushed down until adjustment is finished.
2. Adjust the charge current adjust (26) by turning clockwise and reading the mv. on the digital voltmeter to the desired current. The scale conversion is:

50 mv - 200amps
So: 1 mv - 4amps
2 mv - 8amps
5 mv - 20amps
10 mv - 40amps

3. Lock charge current adjust (26)
4. Recheck setting by repushing the short button and examing the digital voltmeter.

K. Push the discharge hold button (21) (NOTE: Red light should light)

L. Setting the discharge current:

1. Push the shorting button (29) and keep it pushed down until adjustment is finished.
2. Adjust the discharge current adjust (28) by turning clockwise and reading the mv, on the digital voltmeter to the desired current. The scale conversion is:

50 mv - 200amps
So: 1 mv - 4amps
2 mv - 8amps
5 mv - 20amps
10 mv - 40amps

3. Lock discharge current adjust (28)
4. Recheck setting by repushing the short button and examining the digital voltmeter.

NOTE: The circuitry of the cycler is designed to work within a specified load range duping DISCHARGE. These two ranges are:

1. 35 amps minimum to 100 amps maximum.
2. 70 amps minimum to 200 amps maximum.

These tolerances are EXTREMELY CRITICAL and MUST

be maintained to avoid serious damage to the cyclers circuitry.
These two settings are made internally and must be known BEFORE beginning a discharge cycle. Check with supervisor before operating.

THE UNIT IS NOW READY FOR OPERATION

IV. Operation

A. Do not proceed unless steps A through M have been completed on the Calibration Procedure.

B. Set - Charge Enable - OFF
Discharge Enable - OFF

C. Set the low limit set point on the voltmeter (4) for the desired termination of the discharge mode.

D. Set the high limit set point for the possible termination of the current mode.

E. Set the current limit set point on the ammeter (5) for the possible termination of the current mode.

F. Select charge timer AND - OFF - OR position (16).
NOTE: If timer is in AND or OR position, adjust the setting on timer for possible termination of charge mode.

G. Turn on Charge Hold and Discharge Hold switches (17 and 21)

H. Adjust timers of charge hold and discharge hold to 5 minutes (1 and 3).

I. Turn on 1 Limit Switch if desired condition is to go into discharge mode when less than the current limit setting. (See controls section, 1 limit, and Charge Timer.)

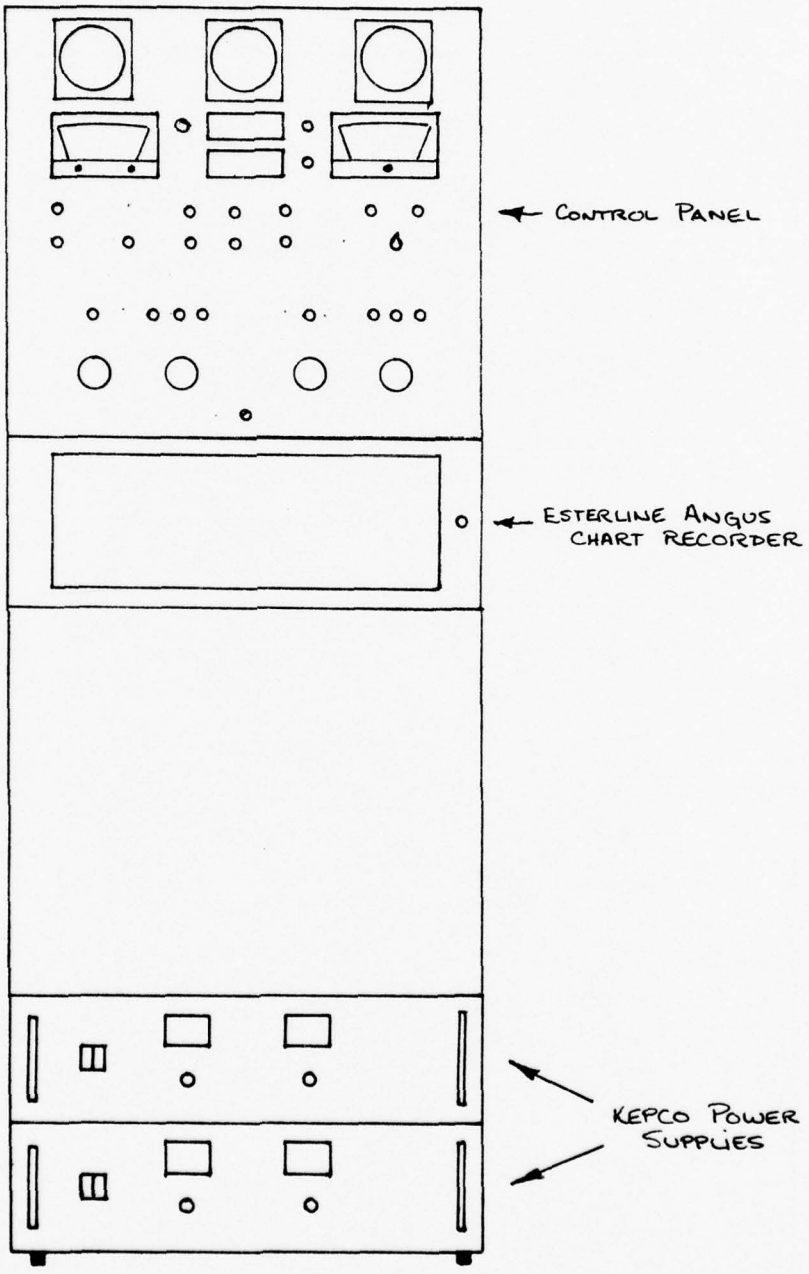
J. Connect cell to power leads from cycler.

K. Connect voltage sensing terminals to cell.

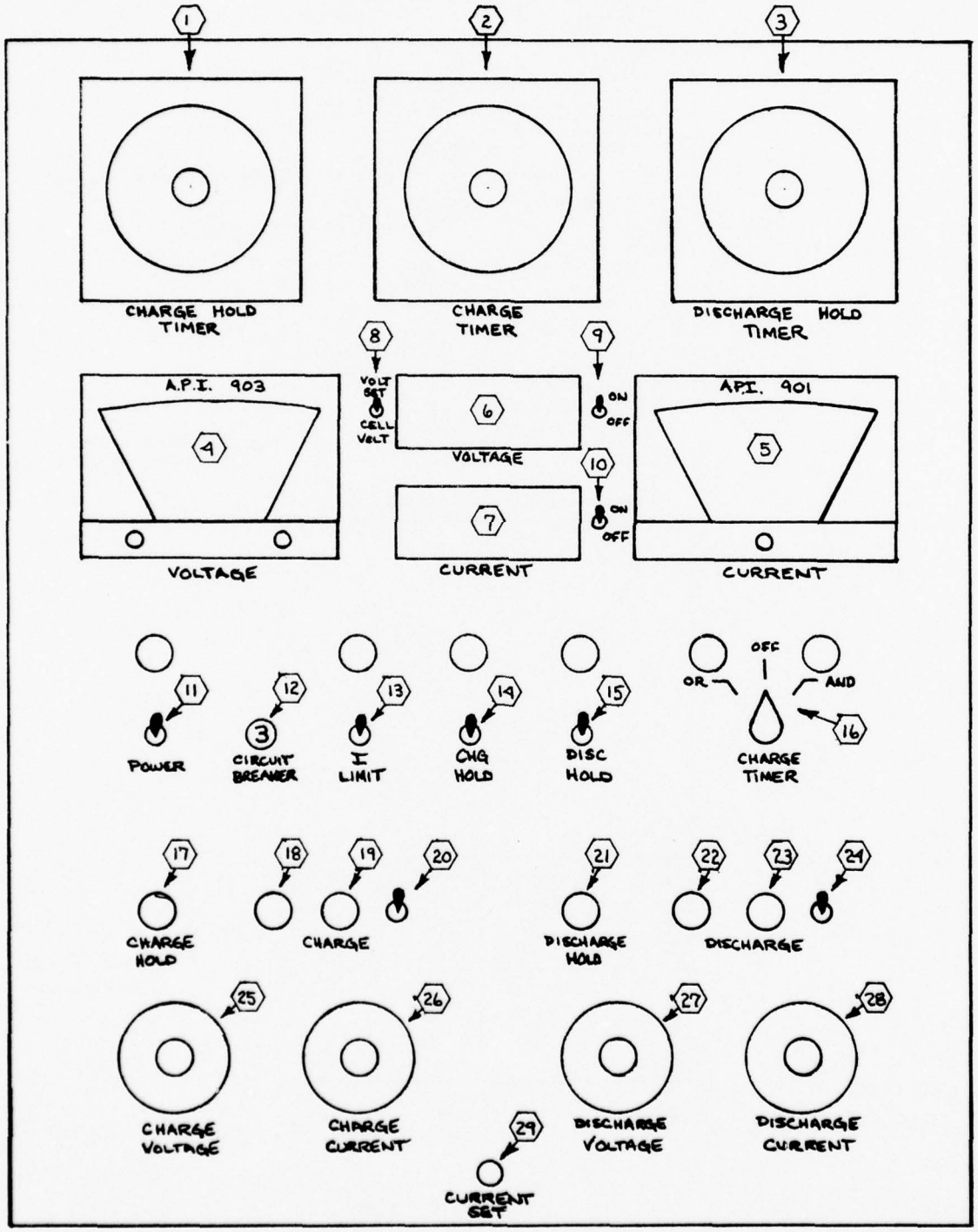
L. Set - Charge Enable - ON
Discharge Enable - ON

M. Make check of final adjustments of operating conditions as required by cell testing procedures.

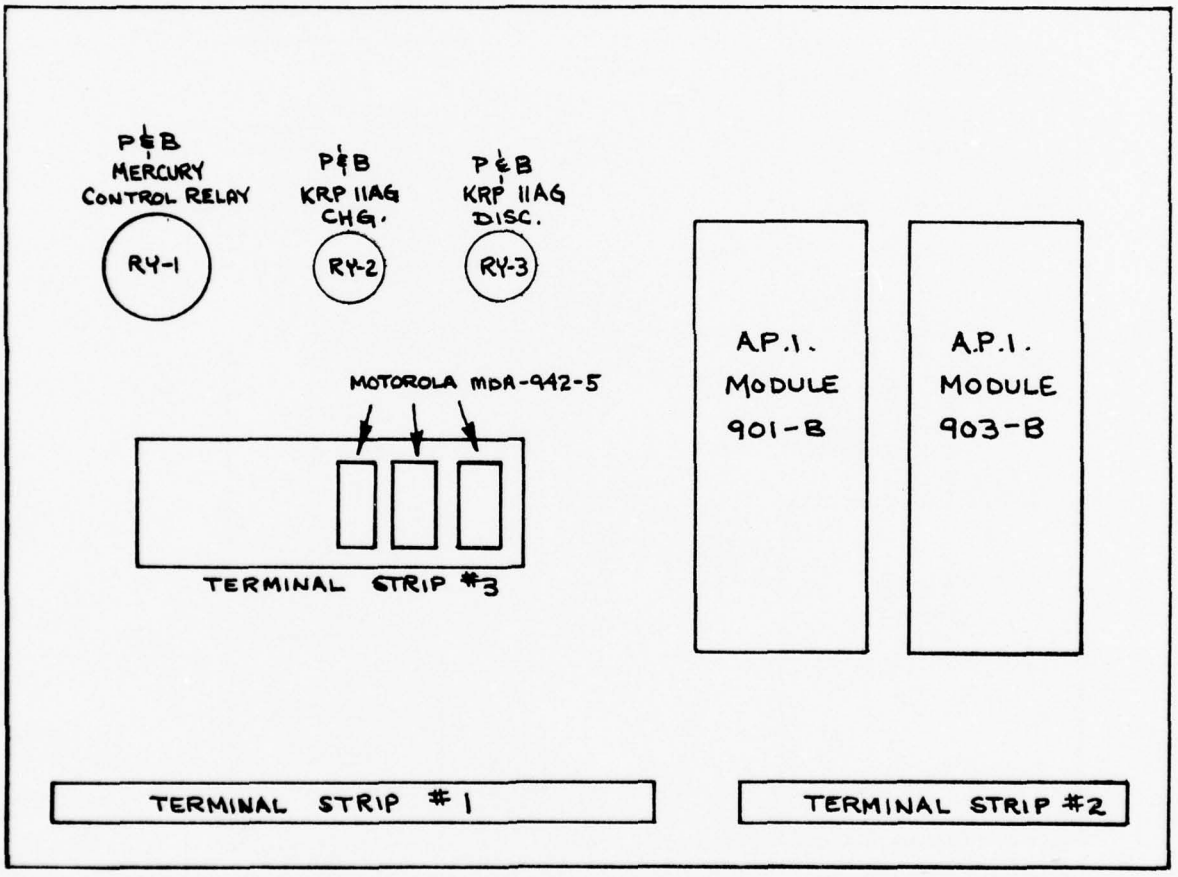
COMPLETE CELL CYCLER 2-11-77 S.T.



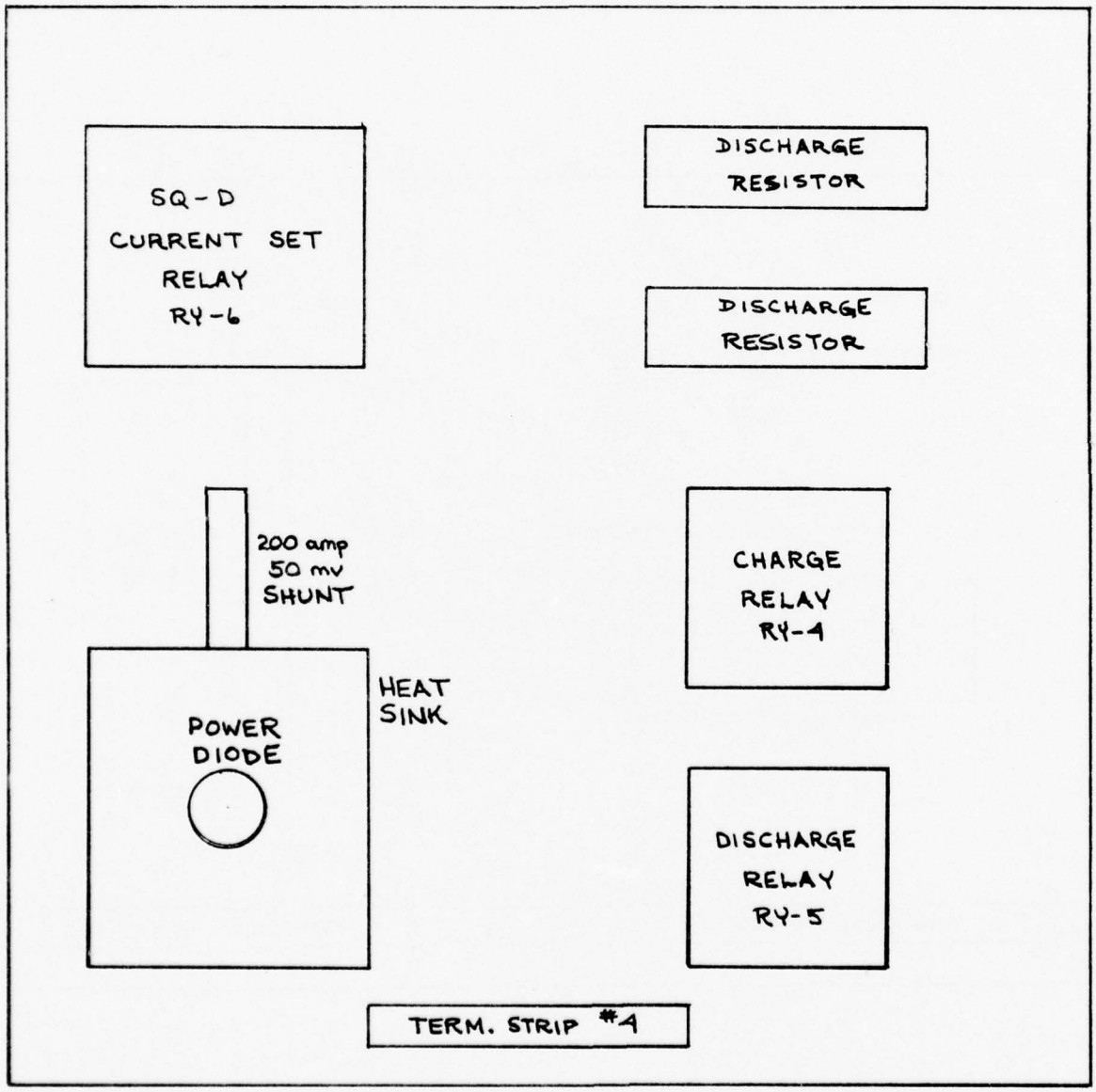
CONTROL PANEL 2-11-77 S.T.



CONTROL CHASSIS 2-11-77 S.T.

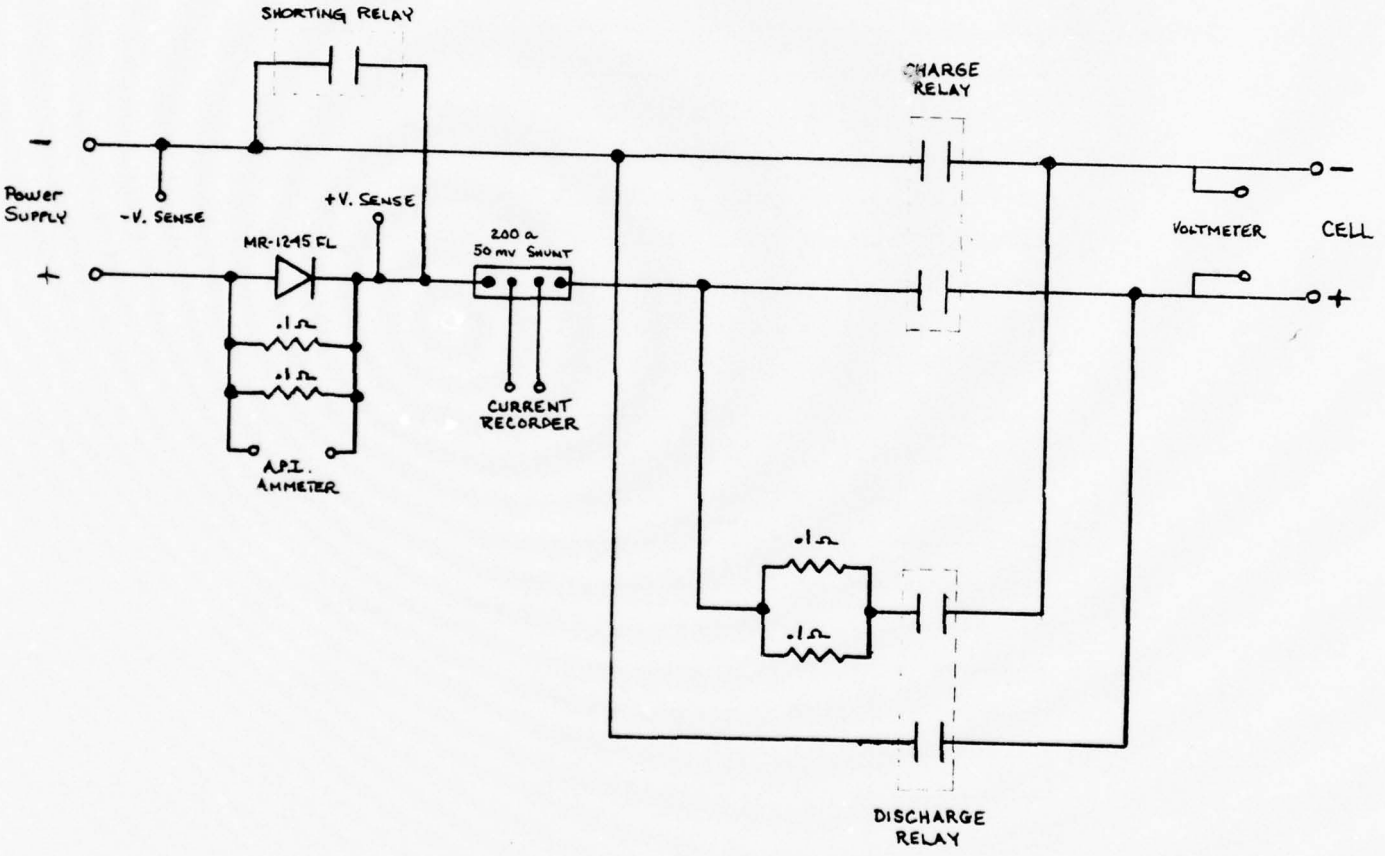


POWER PANEL 2-11-77 S.T.

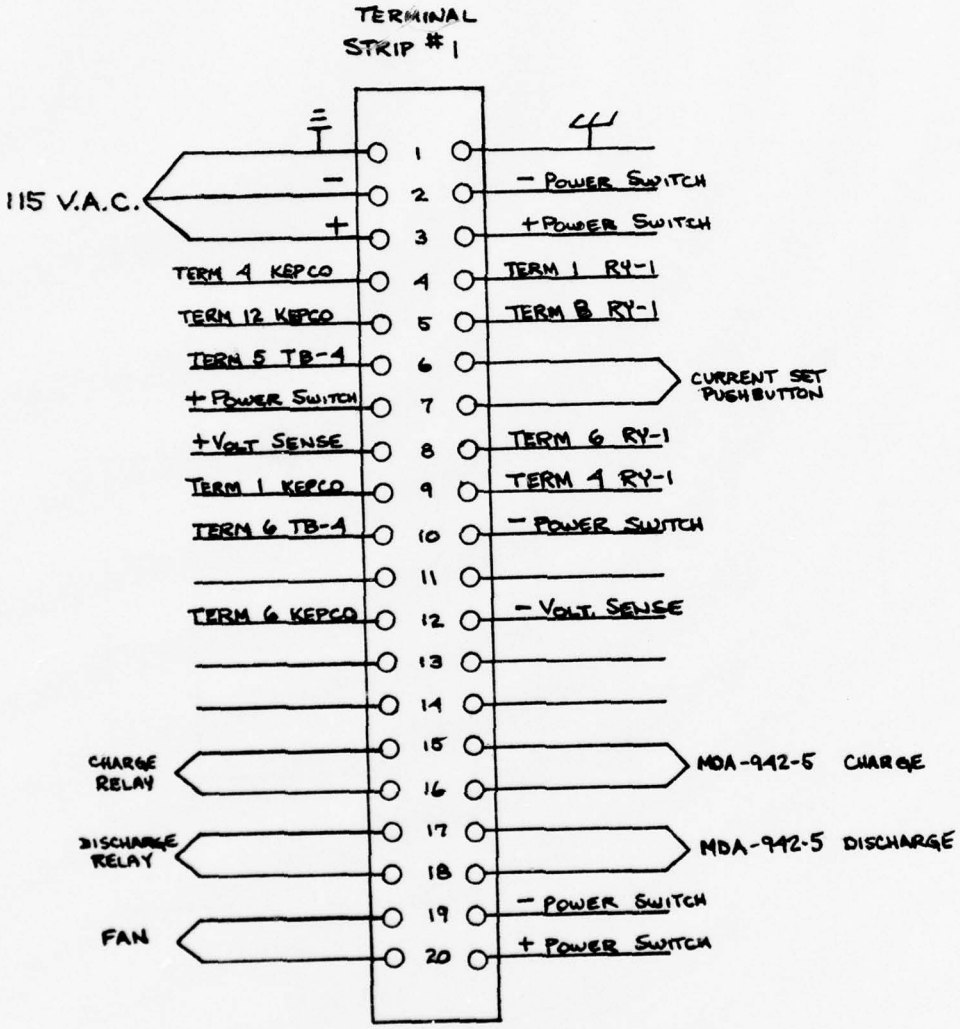


CYCLER Power Circuit

2-11-77 S.T.

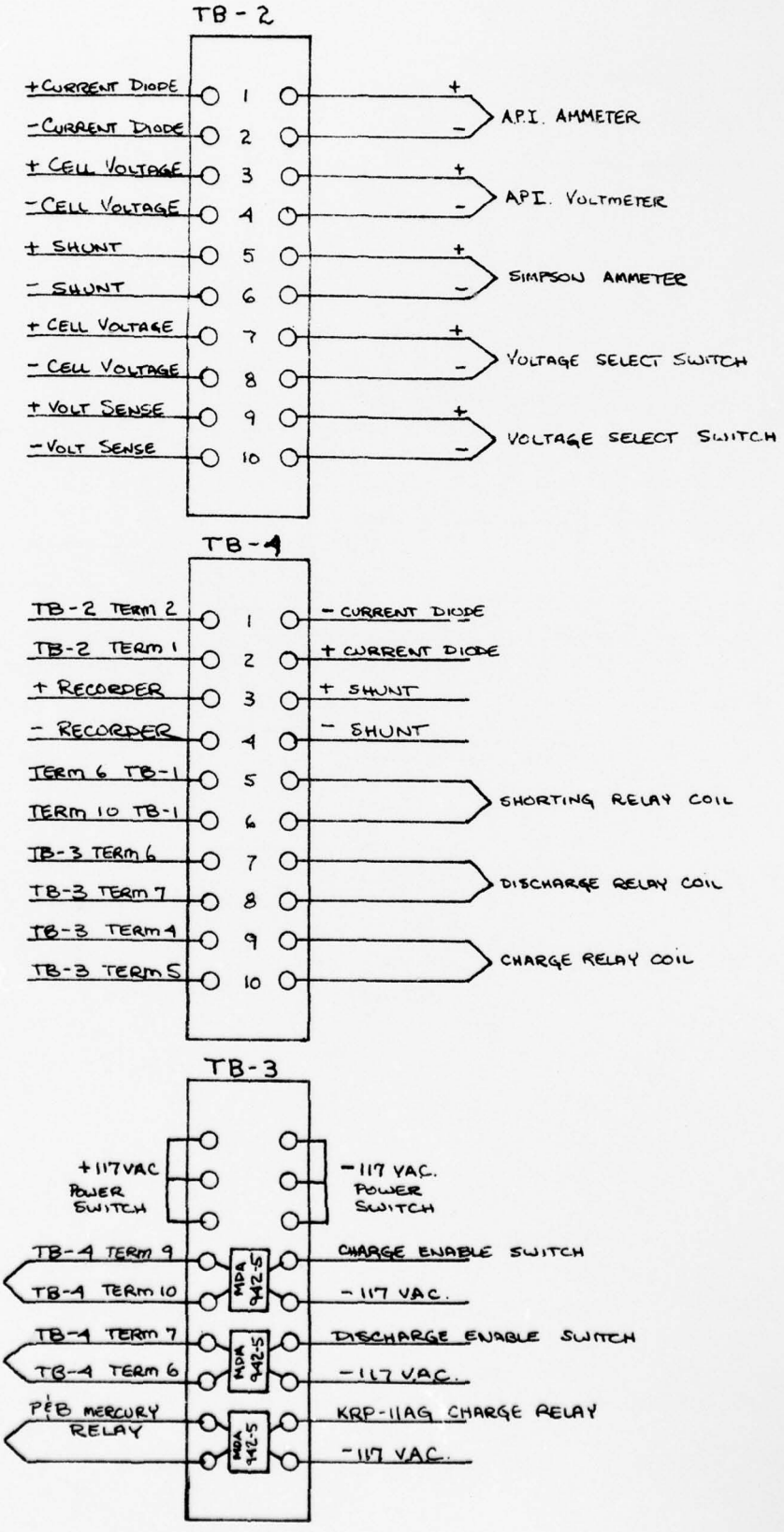


TERMINAL CONNECTIONS 2-11-77 S.T.

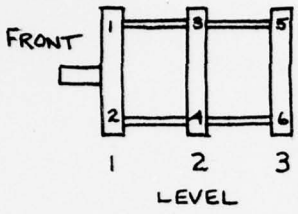


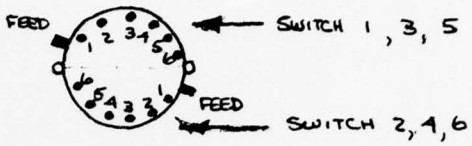
TERMINAL CONNECTIONS

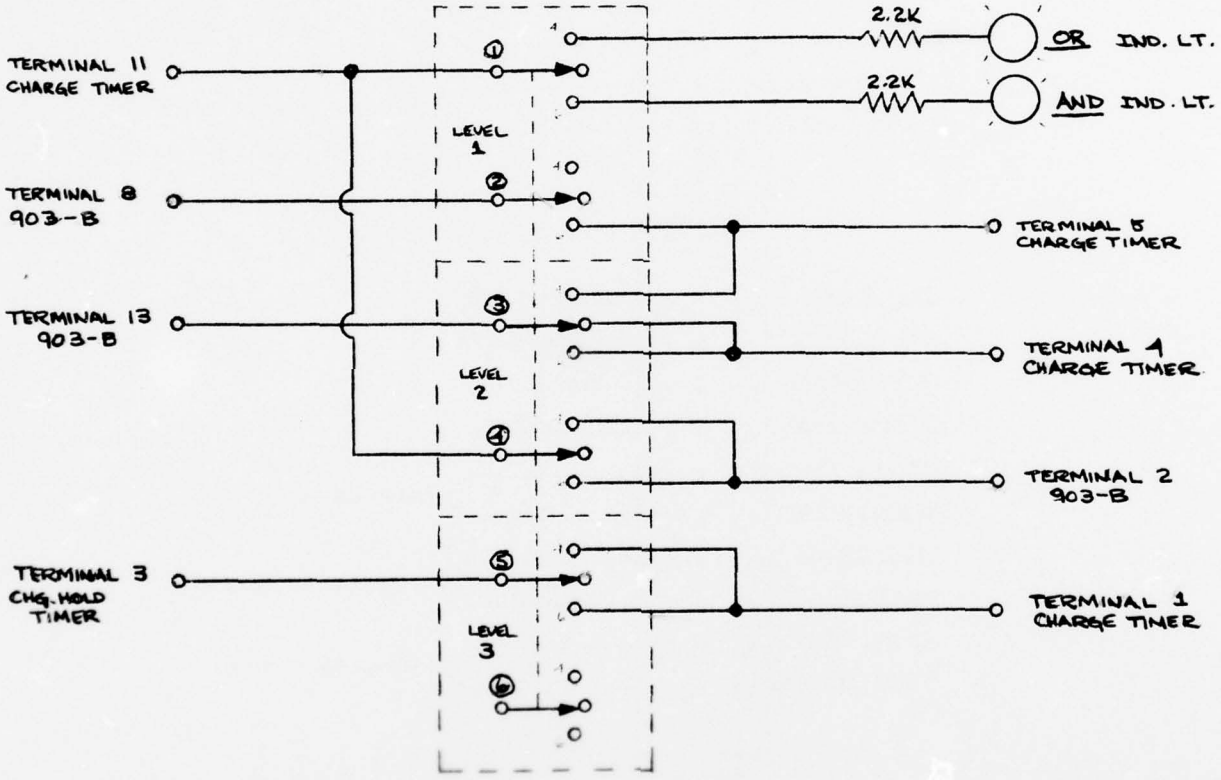
2-11-77 S.T.



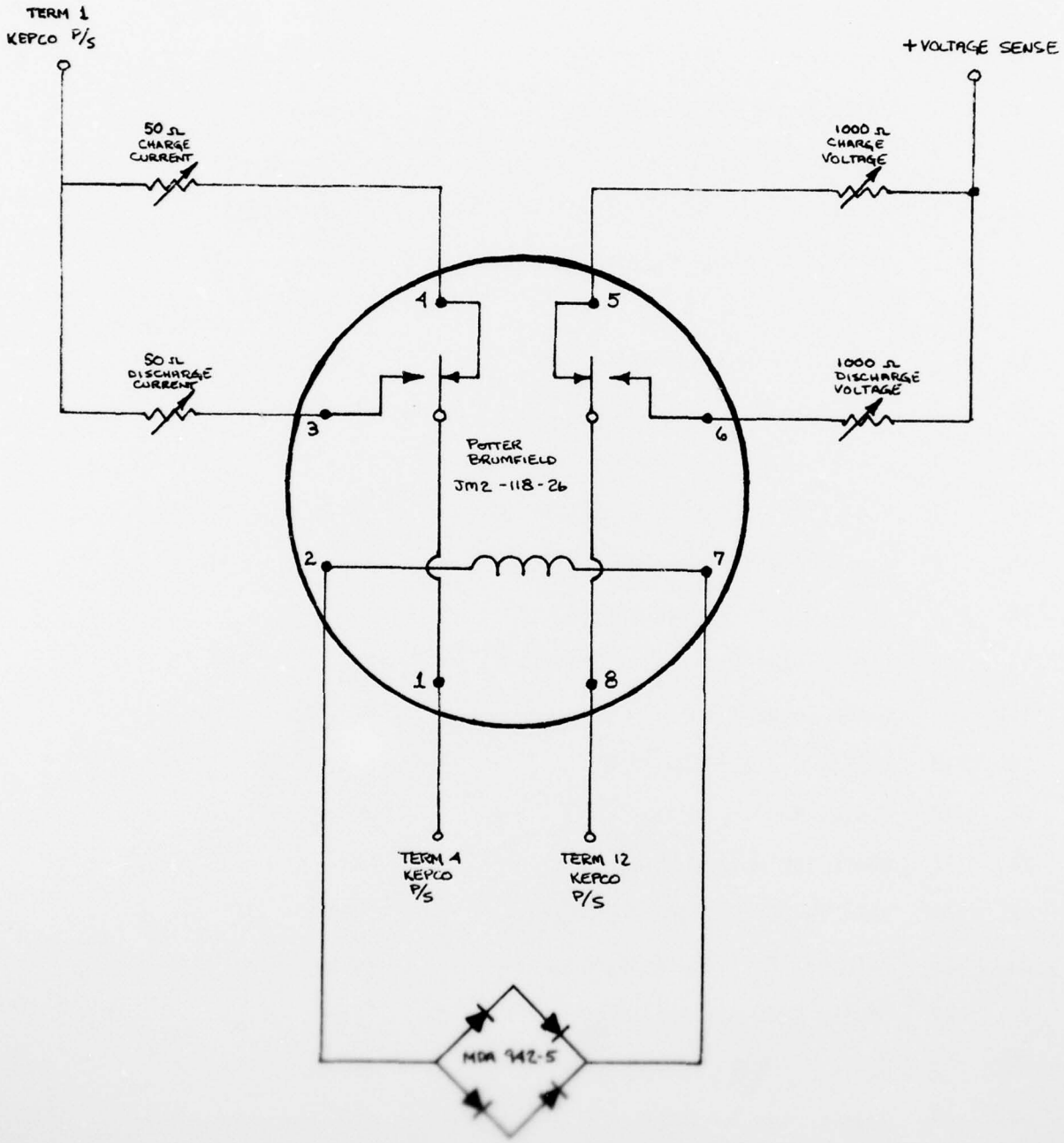
CHARGE TIMER SWITCH AND/OFF/OR 2-11-77 S.T.







MERCURY RELAY CONTROL CIRCUIT 2-11-77 S.T.



MATERIALS LIST - CELL CYCLER

1.	1	A.P.I. Double Set Point Meter	502-L 1000A 52-3602-8000
2.	1	A.P.I. Module	903-B 2710-830-201
3.	1	A.P.I. Single Set Point Meter	502-L 1000A 52-3602-7000
4.	1	A.P.I. Module	901-B 2710-820-201
5.	2	Eagle Cycle - Flex Timers	HP-53A6
6.	1	Eagle Cycle - Flex Timer	HP 59A6
7.	1	Simpson Panel Voltmeter 0-20 V.D.C.	2850 - 22977
8.	1	Simpson Panel Ammeter 0-200 millivolts	2850 - 22984
9.	1	Simpson Portable Panel Shunt 200A 50mv	06715
10.	1	Wakefield Heat Sink	NC 441-K
11.	1	G.E. Silicon Diode 450A	IN -3738
12.	1	Bud Electric Cabinet	CR - 2075
13.	4	Bud Electric Rack Panels	PA - 1111
14.	1	Wood Electric Circuit Breaker 3A	374 - 203 - 101
15.	1	Cinch Jones Terminal Strip	20 - 141
16.	1	Cinch Jones Terminal Strip	10 - 141
17.	1	Cinch Jones Terminal Strip Cover	MS - 20 - 141
18.	1	Cinch Jones Terminal Strip Cover	MS - 10 - 141
19.	6	McGill D.P.D.T. Switches	0111 - 0001
20.	3	J.B.T. Mini Switches	JMT 221
21.	1	Centralab Rotary Switch	PA - 2021
22.	2	Dale RH-250 .1 Ohm Resistors	7618
23.	2	Dale RH-50 .1 Ohm Resistors	6916
24.	12	Ohmite 2200 Ohm Resistors	4631
25.	8	Dialco Indicators Lights	183-9813-14-604
26.	4	Dialco Push Switches	513-0301-604

Materials List - Cell Cycler (Continued)

27.	6	Dialco Lenses	185 - 1871
28.	4	Dialco Lenses	183 - 1471
29.	2	Dialco Lenses	185 - 1872
30.	12	G.E. Indicator Lamps	387
31.	1	Rotron Caravel Fan	CL-2L2
32.	1	Rotron Screen Guard	476323
33.	3	Motorola Full Wave Rectifiers	MDA - 942 - 5
34.	2	Potter & Brumfield D.P.D.T. Relays	KRP - 11AG
35.	1	Potter & Brumfield Mercury Relay	JMZ - 118 - 26
36.	1	Grayhill Pushbutton Switch	2201
37.	3	Potter & Brumfield Octal Sockets	146 - 103
38.	2	H.B. Electric DC Contactors D.P.S.T.	HB - 36D - 9600
39.	6	I.T.T. Contact Protectors	15A5PA5
40.	2	Heli-Pot 10 Turn 1000 Ohm Potentiometers	AR-1K-L.25
41.	2	Heli-Pot 10 Turn 50 Ohm Potentiometers	AR-50-L.25
42.	4	Duo-Dial Vernier Deals	RB
43.	2	Dale Resistors 45,000 Ohm 1/2 Watt 1%	MFS-i/2-T1
44.	2	Ohmite Trimpots 5000 Ohm	CLU - 5021
45.	1	SQ-D Relay D.P.S.T. Relay 200A	8960 - W0 - 11
46.	20ft.	4/0 Welding Cable Airco	1322 - 1340
47.	10ft.	#2 Welding Cable Airco	1322 - 1302
48.	4	Jackson 4/0 Terminals Lugs	0706 - 0013
49.	12	Jackson #2 Terminals Lugs	0706 - 0010
50.	1	Esterline Angus Chart Recorder	L1102S-V24-M08-E5015-61-PD-Y-V8-W8
51.	2	Kepco Power Supplies 100A	KS - 8 - 100M
52.		Misc. Hardware	

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2-11-77 S.T.

CABLE SPECIFICATIONS - AIRCO WELDING CABLE

#1322-1302 NEOPRENE COVERED #2 CABLE
CURRENT RATING = 250 amps
CONDUCTOR O.D. = .320"
CABLE O.D. = .535"
665 #30 A.W.G. WIRES
CIRCULAR MILL AREA = 66,360
.000163 Ω per foot at 20°C

#1322-1340 NEOPRENE COVERED #4/0 CABLE
CURRENT RATING = 600 amps
CONDUCTOR O.D. = .580"
CABLE O.D. = .850"
2109 #30 A.W.G. WIRES
CIRCULAR MILL AREA = 211,600
.000051 Ω per foot at 20°C

Cycl-Flex OPERATION

SCHEMATIC DIAGRAM

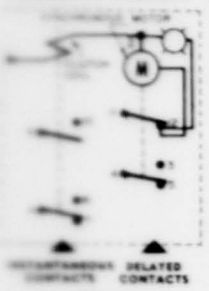
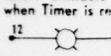


FIG. 2

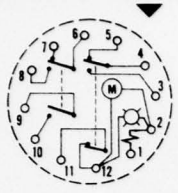
Instantaneous Contacts 9-10 and 6-8 close when the clutch coil is energized. Contact 6-7 opens. Contact 9-10 opens and 6-7 closes when coil is de-energized.

Delayed Contacts 4-3 close and contacts 4-5 open when the orange pointer reaches "O." Contact 11-12 opens slightly later. Contacts 11-12 and 4-5 reclose when Timer is reset.



Neon Pilot Light is built into dial to indicate timer motor is running.

ACTUAL TERMINALS AND WIRING DIAGRAM ON REAR OF TIMER CASE



Connect Jumpers Between Terminals To Obtain The Different Circuit Actions Shown On Pages 3 and 4.

FIG. 3

SELECT FROM THESE 2 START-RESET ACTIONS

BASED UPON CONTROL SWITCH OPERATION

HP5 ___ Cycl-Flex ON DELAY

CLOSE SWITCH TO START

Energized clutch coil starts timing.
De-energized coil resets Timer.
Timer resets on power failure.

See Ordering Information *Page* 5

HP5 ___ -01 Cycl-Flex OFF DELAY

OPEN SWITCH TO START

De-energized clutch coil starts timing.
Energized coil resets Timer.
Timer does not reset on power failure.

	RESET (Timer off)	TIMING	TIMED OUT
CLUTCH	OFF	ON	ON
MOTOR	OPTIONAL	ON	OFF
9-10	O	X	X
6-8	O	X	X
6-7	X	O	O
4-5	X	X	O
4-3	O	O	X
11-12	X	X	(X) O

TIMER CONTROL FUNCTIONS

INSTANTANEOUS CONTACTS

DELAYED CONTACTS

FIG. 4

	RESET	TIMING	TIMED OUT
CLUTCH	ON	OFF	OFF
MOTOR	OPTIONAL	ON	OFF
9-10	X	O	O
6-8	X	O	O
6-7	O	X	X
4-5	X	X	O
4-3	O	O	X
11-12	X	X	(X) O

FIG. 5

3 symbols in sequence denote circuit condition in RESET-TIMING-TIMED OUT

EXAMPLES: X-X-O, O-O-X, X-O-O

DELAYED OPENING OF SWITCH 11-12 FOR

- Timer Motor Cut-Off
- Clutch Holding Circuit Release
- Time of End of Timing (Obtained by connecting 11-12 in series with 4-3. Do not use with Fig. 10.)

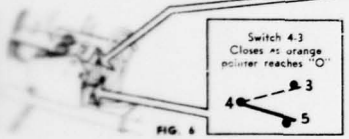


FIG. 6

Switch 11-12 is set to operate after switch 4-3 to shut off Timer motor. The delay between these switches is directly proportional to the Timer dial.

DIAL	DELAY ADJ
10 sec.	.05 to .15 sec.
30 sec.	.15 to .45 sec.
60 sec.	.3 to .9 sec.
150 sec.	.8 to 2¼ sec.

DIAL	DELAY ADJ
5 min.	1½ to 4½ sec.
10 min.	3 to 9 sec.
30 min.	9 to 27 sec.
60 min.	18 to 54 sec.
150 min.	45 to 135 sec.

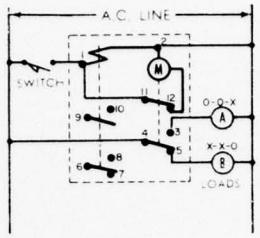
Note: Timers are shipped with switch 11-12 operating within the above limits. A selected setting within these limits can be made. Use an Allen wrench (.050"AF) to adjust switch actuating screw.

Cycl-Flex CONTROL CIRCUITS

BULLETIN 125

ON DELAY — HP5 SERIES Cycl-Flex TIMER

SUSTAINED CONTROL SWITCH — Close Switch to Start — Open to Reset.



Simple Delayed Closing and Opening of Load Circuits.

Additional Load Circuit Operations Obtained by Connecting Contacts in Series.

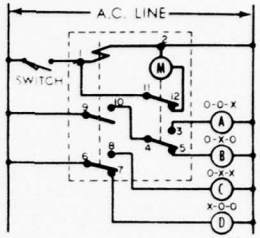
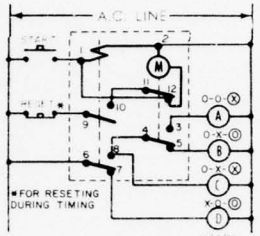


FIG. 7 NOTE — EXTERNAL WIRING SHOWN IN GRAY FIG. 8

MOMENTARY CONTROL SWITCH—Close to Start—Resets Automatically



Push Button Start. Remains in 3rd switch position indicated by (X) or (O) for ½ to 1½% of the dial range.

Use when the control switch may not always be opened before end of timing. This circuit insures shutting off timer motor at end of timing.

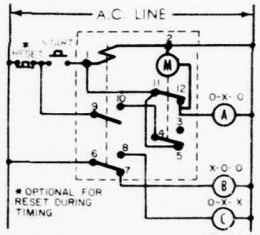
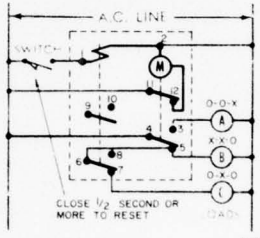


FIG. 9 NOTE — EXTERNAL WIRING SHOWN IN GRAY FIG. 10

OFF DELAY — HP5-01 SERIES Cycl-Flex TIMER

OPEN CONTROL SWITCH TO START — CLOSE TO RESET.



Simple Delayed Closing and Opening of Load Circuits.

Additional Load Circuit Operations obtained by connecting contacts in series or parallel.

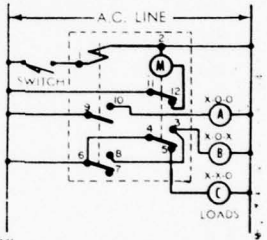


FIG. 11 NOTE — EXTERNAL WIRING SHOWN IN GRAY FIG. 12

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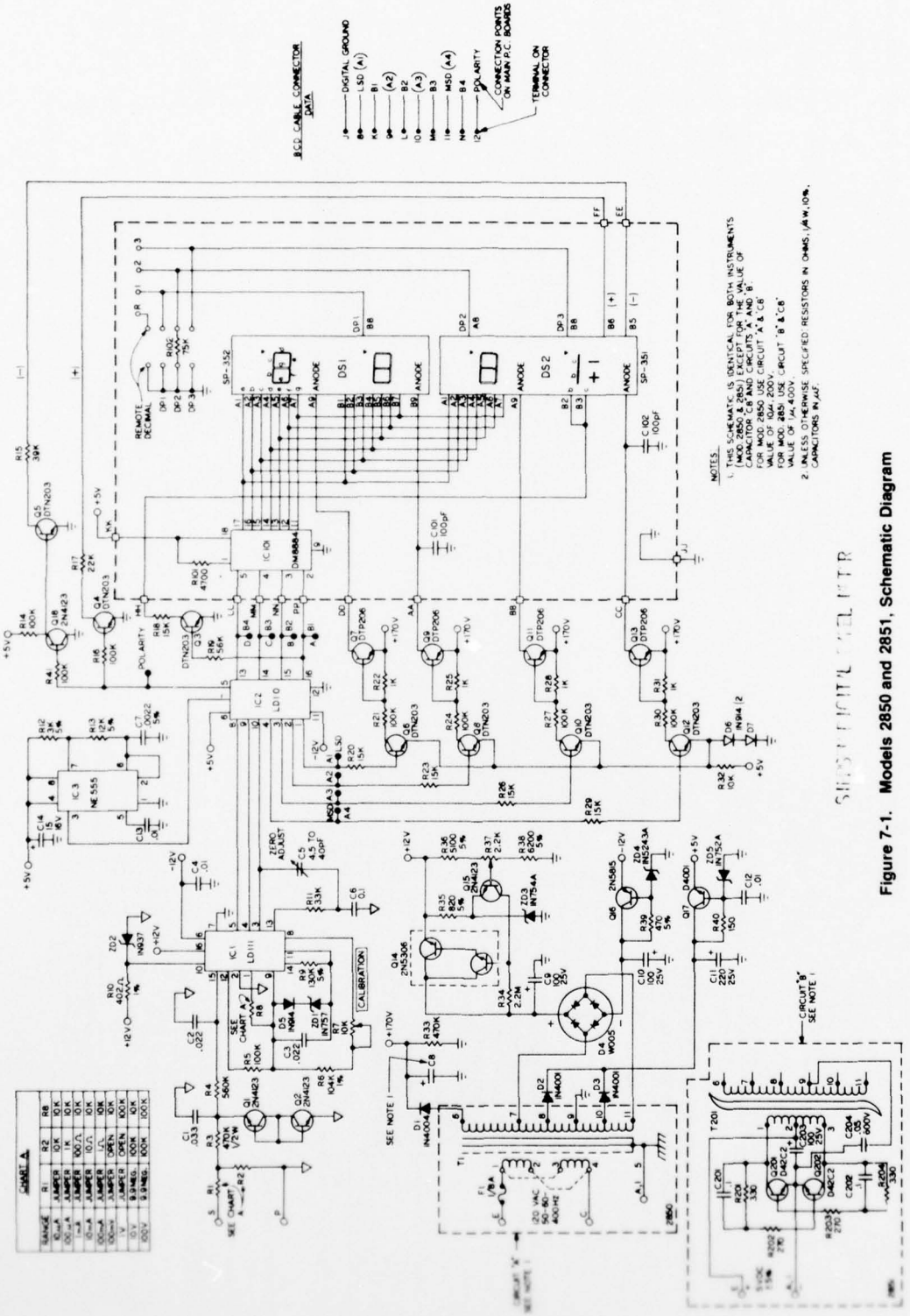


Figure 7-1. Models 2850 and 2851, Schematic Diagram

955--18
January, 1965

API INSTRUMENTS CO.
7100 Wilson Mills Road
Chesterland, Ohio

INSTRUCTIONS FOR MODEL 901-B AND 903-B

OFF-ON OPTICAL CONTROL MODULES

API optical control modules are designed for use with contactless optical meter-relays. Major advantage of the optic relay is its increased reliability due to the elimination of meter contacts and the use of solid state electronics in the control module.

Theory of operation

The module is actuated by a resistance change in the photo-resistor arm of an AC bridge within the meter-relay. As the resistance of the cell increases at contact point, the bridge output phase reverses to cut off a silicon controlled rectifier (SCR). When the SCR stops conducting, the load relay in series with the SCR drops out, initiating control action. The module also supplies regulated power for the optic meter-relay lamp.

Operating voltage

Model 901-B and 903-B control modules are designed for operation from a 115 or 230 volt, 50/60 cycle line. Variation in line voltage beyond + 10% of nominal voltage may cause a shift in operating point and is not recommended.

Dead band

Dead band is the difference in control point when approaching the control point; first with increasing signal and then with decreasing signal. This change in control point is usually required to prevent hunting or constant operation of the load relay with very small changes in the input signal. A 1-megohm dead band resistor is normally supplied as standard. For greater dead band, this resistor may be reduced.

Limit control

Standard modules are wired for use either as off-on controls or as limit controls with external reset circuitry.

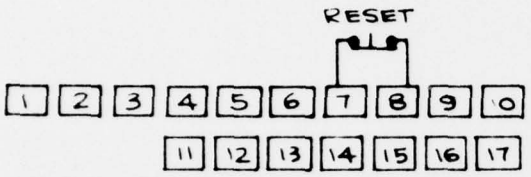


Fig. 1, Model 901-B

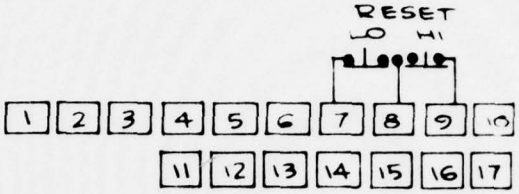


Fig. 2, Model 903-B

For limit control, connect a normally closed external switch (or switches) as shown in Fig. 1 or 2 above (50 milliamperes @ 50 VDC switch load). When the indicator pointer passes the set pointer, the load relay will drop out and stay de-energized until the reset switch is opened. The circuit must be reset to initiate operation after AC power is turned on. If desired, a time delay relay could be used for an automatic start-up cycle.

Do not install switches if off-on control action is required.

Signal Input

With standard meters signal inputs are to be connected directly to the meter studs.

Load Contacts

All optical meter-relay modules are supplied with Form C (SPDT) load contacts rated at 5 amperes, 115 volts AC, 2.5 amperes, 230 volts AC, or 5 amperes, 26.5 volts DC. (All ratings for resistive loads.) Standard modules utilize fail-safe relays which are energized until the variable reaches the set point going up scale for a high set point instrument, and down scale for a low set point. Both relays are energized when the signal is between the two set points of a double set point instrument. For controlling a load, the NO and C contacts should be used as in Fig. 3. For alarm circuits, the NC and C contacts should be used per Fig. 4.

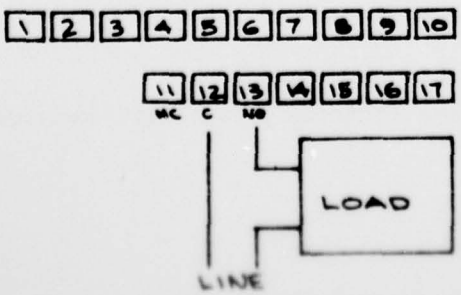


Fig. 3, Typical Wiring for controlling a Load

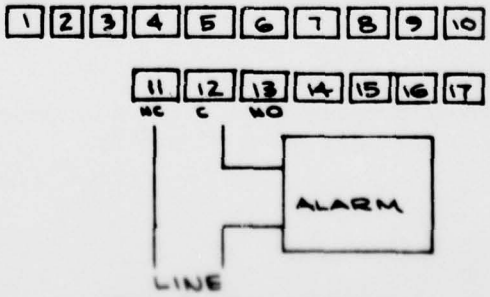


Fig. 4, Typical Wiring for Alarm Circuit

All modules utilize a fail-safe energized load relay which will drop out with a failure in AC line, transformer, SCR, relay coil, meter-relay lamp, meter photo-resistor, or any open circuit in the connectors or cable between the control-pak and the meter.

Interlock or Cycling Control 903-B Only

901-B is a single set point, non-cycling control.

A standard API double set point optical control may be connected externally so that it cycles between high and low set points producing control actuation on a wide signal differential.

Normally energized load contacts - connect as shown in Fig. 5a. The contacts will de-energize on reaching the high set point and energize again on reaching the low set point.

Normally de-energized load contacts - connect as shown in Fig. 5b. Contacts will energize on high set point and de-energize on low set point.

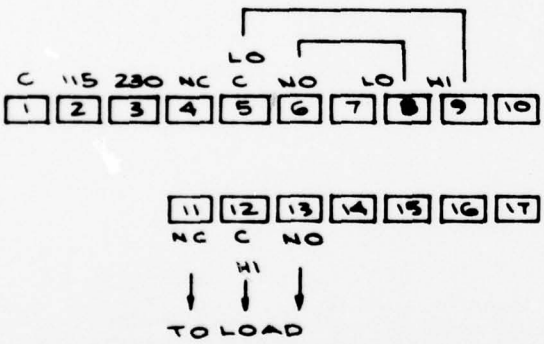


Fig. 5a, Model 903-B

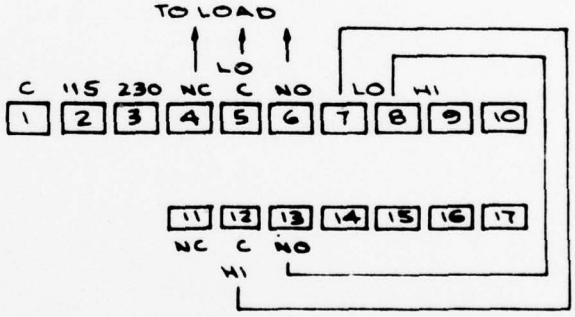


Fig. 5b, Model 903-B

Installation

Mount the optical meter-relay per instructions for that model. A nominal 3 foot cable is provided on the module to permit easy location of the module adjacent to the meter. This cable may be lengthened by using wire which inserts nc more than 0.125 ohms per conductor into the lamp circuit. Mounting dimensions for the module are shown in Fig. 6, on page 4.

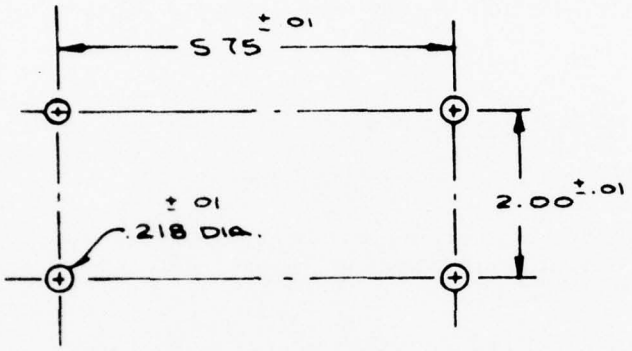


Fig. 6, Mounting Dimensions

Connect AC line either 115 or 230 volts to the module. It may be desirable to provide an external line switch if the unit will not be operated continuously. If the load is greater than the module contact ratings (see page 2), an external heavy-duty relay or contactor is required. If limit control provisions are required, wire external reset switch as instructed in the limit control section (see page 2). Plug cable connector into the male connector on the optical meter-relay and lock connectors together.

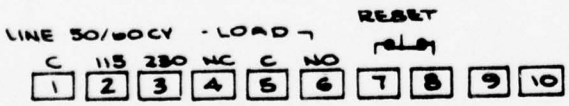


Fig. 7, Model 901-B

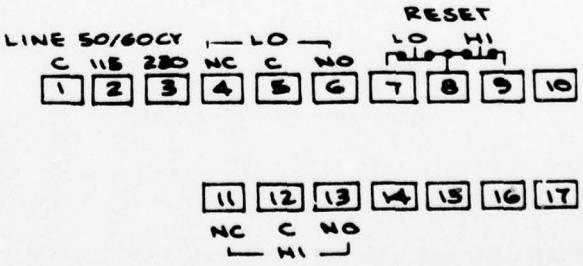


Fig. 8, Model 903-B

CAUTION:

Before energizing the control, carefully recheck all connections. Accidental connection of voltages over 10 volts DC from the reset limit control terminals to chassis or ground may damage the SCR and render the control inoperative.

Service

If your optical control does not function correctly, recheck the steps in the installation instructions.

All products are warranted against workmanship and material defects for a period of one year from date of shipment. Units out of warranty are repaired on a time and material basis. Contact the Customer Service Department at our Chesterland plant for help if trouble is encountered.

API INSTRUMENTS CO.
(formerly Assembly Products, Inc.)
7100 Wilson Mills Road
Chesterland, Ohio

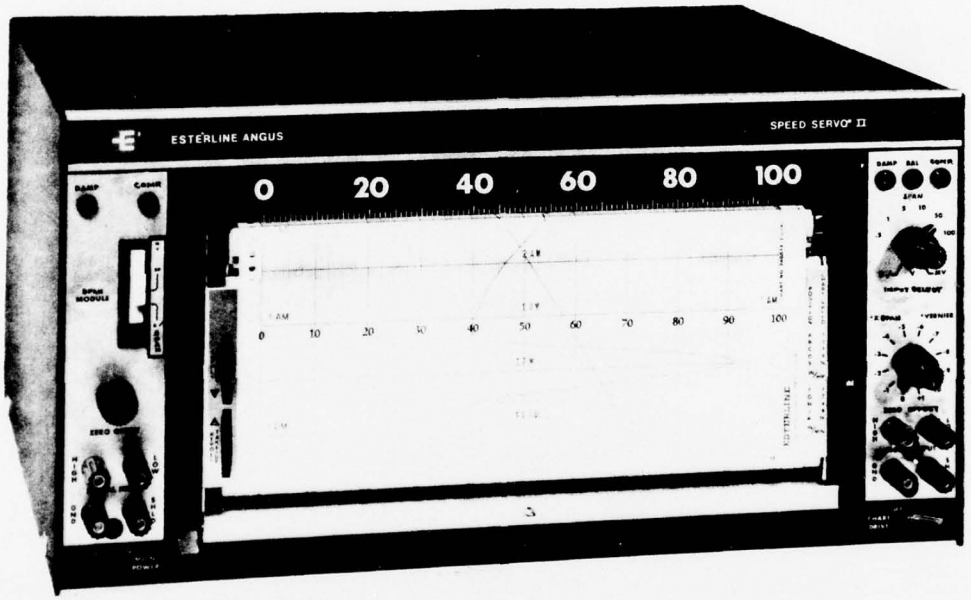
Tel: 216-423-3131

909375

OPERATING INSTRUCTIONS

FOR Speed Servo® II

STRIP-CHART RECORDERS



NOTE: FOR A COMPLETE TECHNICAL DESCRIPTION OF YOUR SPECIFIC INSTRUMENT, SEE THE DATA SHEET WHICH IS SUPPLIED WITH THIS MANUAL. SPECIAL DRAWINGS AND SUPPLEMENTARY INSTRUCTIONS THAT MAY BE REQUIRED FOR YOUR RECORDER WILL BE LISTED ON THE DATA SHEET AND WILL ACCOMPANY THIS MANUAL.

ESTERLINE ANGUS

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WARRANTY—Only the products manufactured by the Seller and sold hereunder are warranted as free from defects of materials and workmanship and in conformance with specifications. There are no other oral, statutory, or implied warranties. Seller's obligation hereunder shall be and is limited to servicing or replacing f.o.b. its plant in Indianapolis, Indiana or such other point as Seller may designate, or refunding the purchase price of any such product manufactured by the Seller which proves to be defective in material or workmanship or which fails to conform to specifications therefor, provided that (1) written notice of such defect or failure is received by Seller from Purchaser within one year after the date of shipment of such products manufactured by the Seller, and (2) such defects, in the opinion of Seller, shall not have arisen from improper use. The absence of such written notice of defect, or failure, or lack of conformance to specifications within the specified time shall constitute a waiver of any claim. Seller may, after receipt of notice, require purchaser to send said products, transportation prepaid, to Seller for its examination and inspection.

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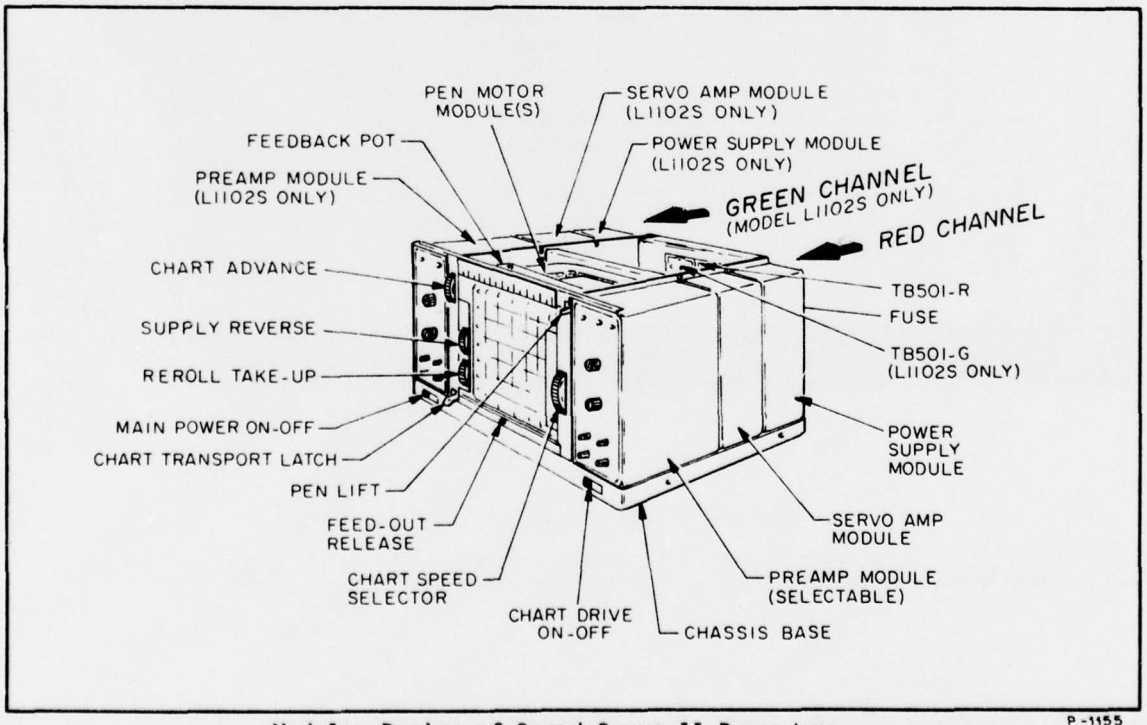
DESCRIPTION

NOTE: If conflicting supplemental information is supplied, it shall supersede the following instructions.

Speed Servo II recorders are constructed for bench-top operation and permanent installations in relay racks, switchboards, or panels. They are precision null-balance instruments suitable for all industrial, laboratory, and general field applications. Their high sensitivity, fast wide-chart response, and interference-free operation places them among the most versatile and reliable instrumentation available to data acquisition science.

The recorders are available in two basic configurations. One is the Model L1101S, which is a single-channel, single-pen unit with one potentiometric measuring system and one servo pen motor. The other is the Model L1102S, which is a two-channel, two-pen crossover recorder having two separate measuring systems and two pen motors. The figure below reveals the basic construction of these instruments.

The Model L1101S Speed Servo II has one pen element with a red scale pointer, and red is the standard color of ink employed in this single-channel instrument. To identify the servo systems employed in the Model L1102S, one is designated the "red channel" and the other the "green channel". As a standard practice, red ink is used in the red channel and green ink in the green channel. The scale pointer on the front of each pen is colored to correspond with the color of ink used in the respective channel.



Modular Design of Speed Servo II Recorders.

TECHNICAL SPECIFICATIONS

ANALOG INPUT (Optional):
- Millivoltage Spans* - - - - - - - - - - - - - - - - .5MV to 100MV (Plug-in Modules).
- Voltage Spans* - .5V to 100V (Plug-in Modules).
- Multirange Spans* - - - - - - - - - - - - .5, 1, 5, 10, 50, 100MV and .5, 1, 5, 10, 50, 100V (Panel Selector).
- Temperature Ranges - - - - - Available for Thermocouple Types E, J. K, R, S and T*

SOURCE IMPEDANCE - Up to 10K Ohms (Maximum).

INPUT IMPEDANCE(Minimum) - - - - - - - - - 20 Megohms for all Millivoltage Spans, or 1 Megohm for all Voltage Spans.

MAXIMUM COMMON MODE - 120V AC or ±500V DC.

STRAY REJECTION:
- Transverse (Normal Mode @60Hz) - - - - - - - - - - - - - - - - - - > 50 db. (Minimum).
- Longitudinal (Common Mode) - > 120 db. (Minimum).

ZERO OFFSET(Optional):
- Calibrated PreAmp - - - - - - - - - - - - - 1 x Span to 10 x Span Suppression, and 1 x Span Elevation (Switch and Vernier)*
- Uncalibrated PreAmp - - - - - - - - - - - - - Vernier Adjust >±100% of Chart Span.*

ACCURACY:
- Millivoltage Spans - - - - - - - - - ±0.25% of Span (or 3.5μV Whichever is Greater)†
- Voltage Spans - ±0.35% of Span†

DEADBAND - 0.1% of Chart Span.

STEP RESPONSE TIME - < 0.3 Sec. F.S.

AMBIENT TEMPERATURE RANGE - - - - - - - - - - - - +60°F to +90°F for Specified Accuracy.

MAXIMUM DRIFT - 0.15 microvolts/°C.

POWER REQUIREMENTS:
- Model L1101S - 120V ±10%, 50/60Hz, 30VA.††
- Model L1102S - 120V ±10%, 50/60Hz, 50VA.

WARM-UP TIME - 30 Minutes for Specified Accuracy.

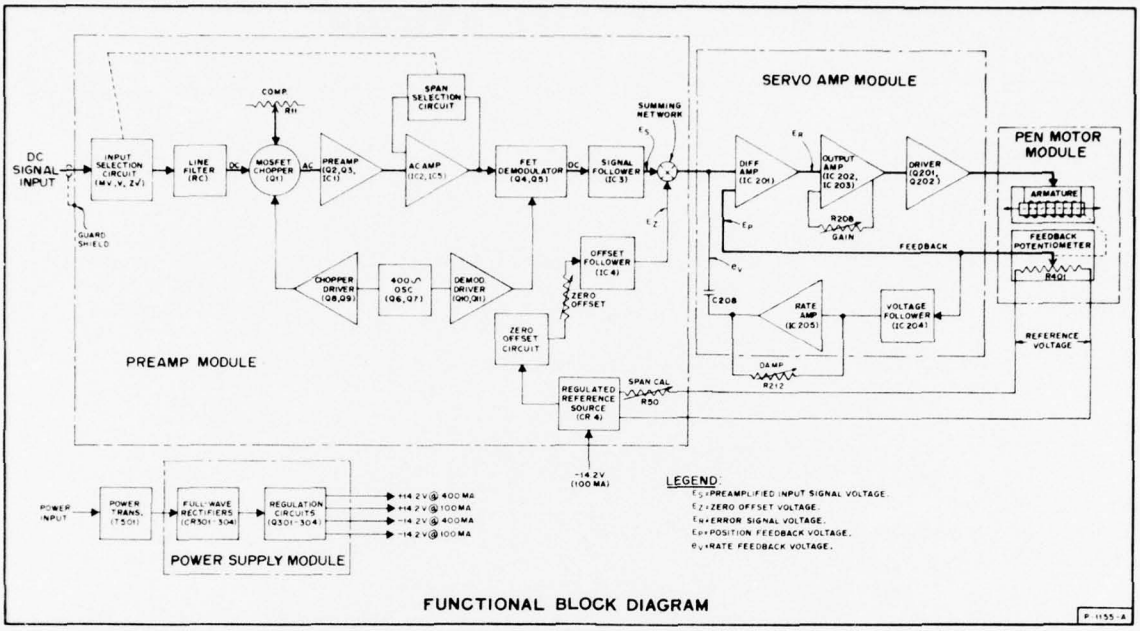
CHART FEED RATES(Optional)
- 1 or 5 Speed Drives - - - - - - - 3/8"/Hr to 1"/Sec.**Dialable on Five Speed Units.
- 2 or 10 Speed Drives - - - - - - - 3/4"/Hr to 1"/Sec.**Dialable on Ten Speed Units.

INSTRUMENT SIZE - (See Dimension diagrams).

* Maximum recorder inputs: 1.5V on millivoltage spans; 100V on voltage spans.
** For rates in MM, multiply inches by 25.
† Add ±0.1% of offset for input signal ranges greater than span.
†† 240V operation available with step-down transformer.

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THEORY OF OPERATION

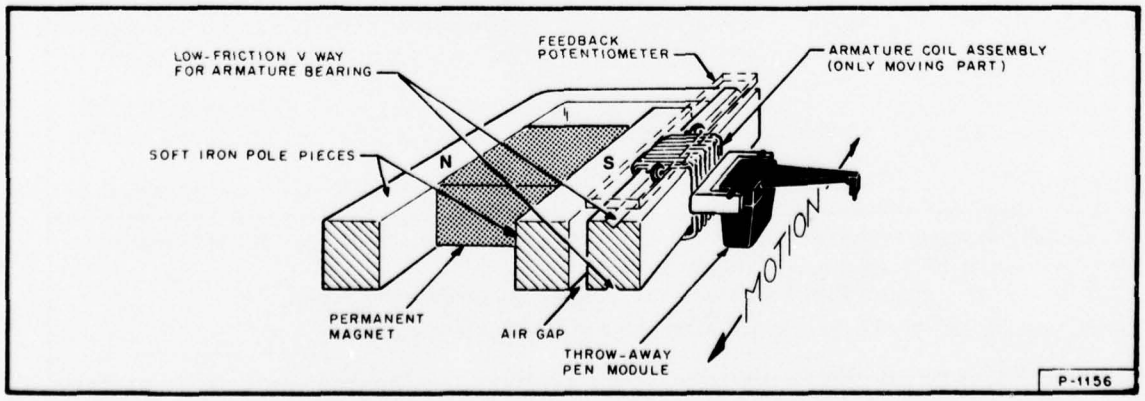


FUNCTIONAL BLOCK DIAGRAM

Each measuring system used in these recorders operates on a null-balance servo principle. The servo feedback signal is supplied by a precision potentiometer which is automatically adjusted by movements in the pen motor armature.

In the basic servo loop, the unknown input voltage is compared with an internal feedback voltage--representing pen position; the difference or error signal thus developed is amplified and is then used to drive the pen motor in a direction that causes the system to balance. The pen accurately records this movement over a calibrated span on the chart.

The complete servo loop and function modules for one recording channel are shown in the block diagram above. The boxes within broken lines indicate the four basic components--PreAmp module, Servo Amp module, Pen Motor module, and Power Supply module. Conservative design and closely-regulated voltages in these circuits assure long and stable operation. In the Model L1102S, inner-channel interference is eliminated by isolating the electronic circuits through the use of shielding and the careful placement of modular components.



Linear-Motion Pen Motor and Writing System.

INSTALLATION

Unpacking Instructions

The following standard items have been inspected and carefully packed in the Speed Servo II shipping carton. Optional items are only supplied if originally ordered.

ITEM	QTY.
Recorder Chassis (with top cover or within rack/panel case)	1
Door Assembly (option)	1
Cutout-trim Pieces (Panel-Mount only)	2
Service Kit (Inking Accessories)*	1
Recording Chart *	1
Hardware Bag* (Rack-Panel Case Option)	1
Manual (Operating Instructions)	1
Manual (Servicing Instructions - Option)	1

* May be protected within formed ends of packing material.

Remove the packing material carefully and check off all items listed on the packing slip as they are unpacked. If special items were ordered, they will appear on the packing slip. After all items have been removed, make a complete inspection for physical damage. If the shipment *has been* damaged in transit, notify the carrier and Esterline Angus immediately.

CAUTION: *Do not* attempt to operate a damaged instrument.

Bench Instruments

The Speed Servo II bench-style recorder requires no special installation procedures; however since these models come equipped with resting feet, they may be permanently mounted to a bench, table or shelf by merely removing the feet and using the feet-mounting holes to anchor the base of the chassis to a stationary surface. Mounting screws are accessible from the bottom-center of each foot. Refer to the physical dimensions illustration in this manual for the location of these mounting holes. The deeper, rack/panel case can optionally be supplied with feet (and door). This style, however, has only three feet--one is centered 3/4" from the rear of the case, and two (16" apart) are fastened to the bottom of a forward shroud (door-foot adapter). If permanent bench mounting is desired, the feet may be removed as described for the standard bench-style recorder.

Rack/Panel Instruments

Speed Servo II recorders designed for either rack or panel installation should be mounted upright in a clean, well-lighted location that is free of excessive dust, steam, moisture, smoke or corrosive fumes. The recorder should not be subjected to extremes of temperature or humidity. The cooling of internal components is accomplished solely by convection, and therefore installation of the recorder must provide for adequate air circulation. In addition, it should not be mounted close to large transformers or near conductors carrying high currents.

The depth of the case is 15-5/16" from the back surface of its mounting flanges; space behind these flanges (including the mounting panel thickness) must be sufficient to accommodate this dimension--also, additional space for wiring may be required. Allow 16" (min.) clearance in front of the panel for chassis insertion and removal. If a door option is supplied, allow 20" clearance for the door to swing completely open.

RACK-MOUNTING PROCEDURES:

(1) Remove one hex-head bolt and one lockwasher from each lower-rear side of the case, and retain hardware. Carefully remove chassis from the front of the case.

CAUTION: Do *not* tip case forward with chassis installed and bolts removed.

(2) Position case in rack with case flanges on outer side of rack mounting strips.

(3) Align slots in case flanges with desired holes in rack mounting strips and mount case using screws (supplied) and suitable nut fasteners.

(4) Install chassis through front of case and secure using hardware that was removed in step (1) above. This step is not necessary when a door attachment is supplied; see Door Installation Procedures.

NOTE: If the instrument will be subjected to vibration or shock, it is recommended that additional support be fabricated at the rear of the case.

PANEL-MOUNTING PROCEDURES:

(1) Form panel cutout and drill four 1/4" holes on each side of the cutout as illustrated in the case mounting diagram in this manual.

NOTE: If panel holes are to be threaded, a No. 6 drill (.204"), and 1/4-20 tap is recommended.

(2) Remove one hex-head bolt and one lockwasher from each lower-rear side of the case, and retain hardware. Carefully remove chassis from the front of the case.

CAUTION: Do *not* tip case forward with chassis installed and bolts removed.

(3) Support case and insert into front of panel cutout until case flanges are about an inch from the panel surface.

(4) Place one panel-cutout trim piece over top of case, directly *behind* flanges, with lip of trim piece *toward* panel (see case mounting diagram). Slide trim piece back toward panel until lip is under top edge of cutout and trim is flush against panel surface.

(5) Position second panel-cutout trim piece around bottom-front of case and behind flanges (see case mounting diagram). Press trim back towards panel surface until lip slips between bottom of case and lower edge of cutout. Slide case back firmly against trim pieces and panel.

(6) Align slots in case flanges with drilled holes in panel and mount case using bolts and nuts applicable to the panel thickness and material.

CAUTION: Panel must be of adequate strength to support instrument. Fabricate additional supports, if necessary.

(7) Install chassis through front of case and secure using hardware that was removed in step (2) above. This step is not necessary when a door attachment is supplied; see Door Installation Procedures.

Door Installation Procedures

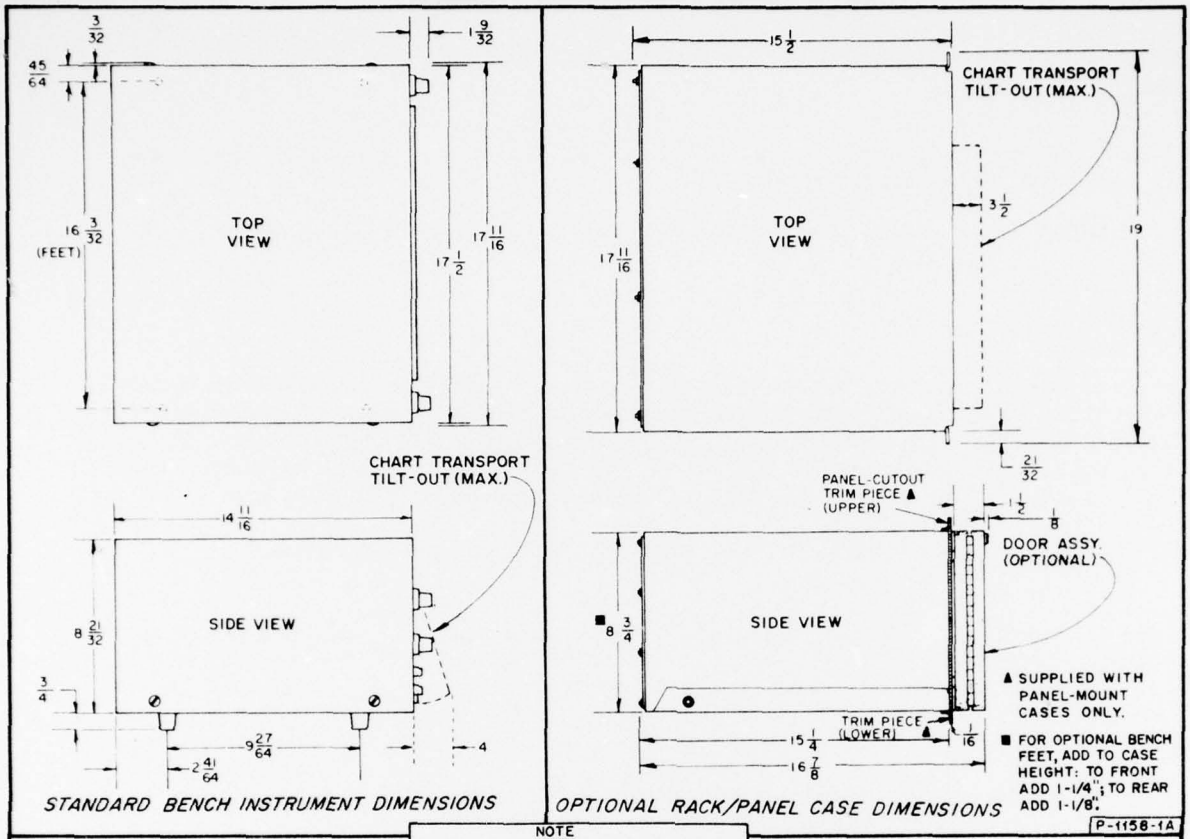
When optional door attachment is supplied, attach assembly as follows:

NOTE: Chassis must be installed prior to attaching door assembly to case.

(1) After case is firmly mounted to rack or panel, depress release button on front of door and swing door away from adapter frame. If case has feet for bench usage, butt rear of case against firm support prior to attaching adapter frame.

(Continued)

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Case Mounting and Dimension Diagrams.

(2) Supporting open door, position back of adapter frame against front flanges of case.

(3) Insert socket-head screws (supplied) into recessed holes of adapter frame and tighten with Allen wrench (supplied).

NOTE: Door assembly must be removed to permit removal of chassis from case.

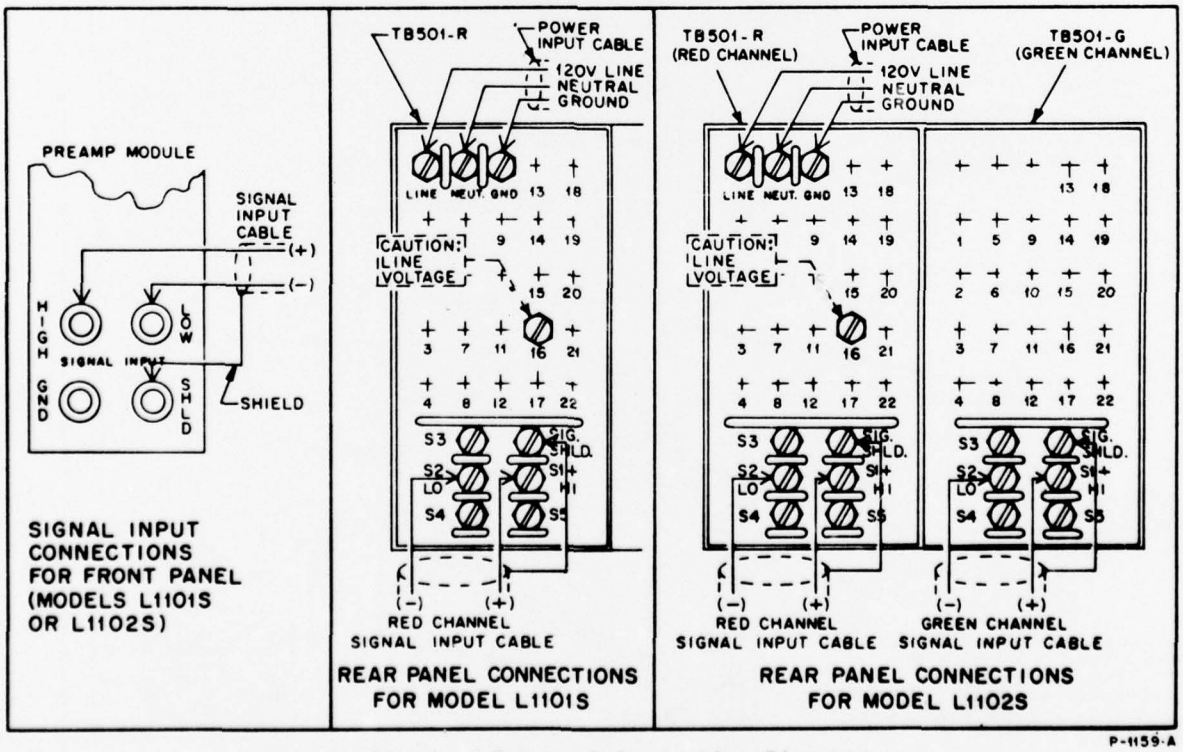
Electrical Connections

The Internal Wiring Diagram furnished in this manual identifies all external terminal connections for signal and power inputs, as well as for the wiring of standard options that may be supplied with the recorder. Input power and accessory ratings will be specified on a nameplate which is located on top of the chassis base directly below the chart transport module. These ratings are also listed on the Data Sheet.

CAUTION: Common-mode voltage must not exceed a maximum of 120V AC or 500V DC.

The input analog signal may be connected to either the universal binding posts on the front of the instrument or to the appropriate screw terminals on the rear of the unit. These inputs are connected in parallel, and therefore only one location must be used for each recording channel. Turn off instrument power, remove rear terminal cover, and make connections to recorder as illustrated in the appropriate diagram below.

NOTE: Refer to Internal Wiring Diagram for connections of optional features.



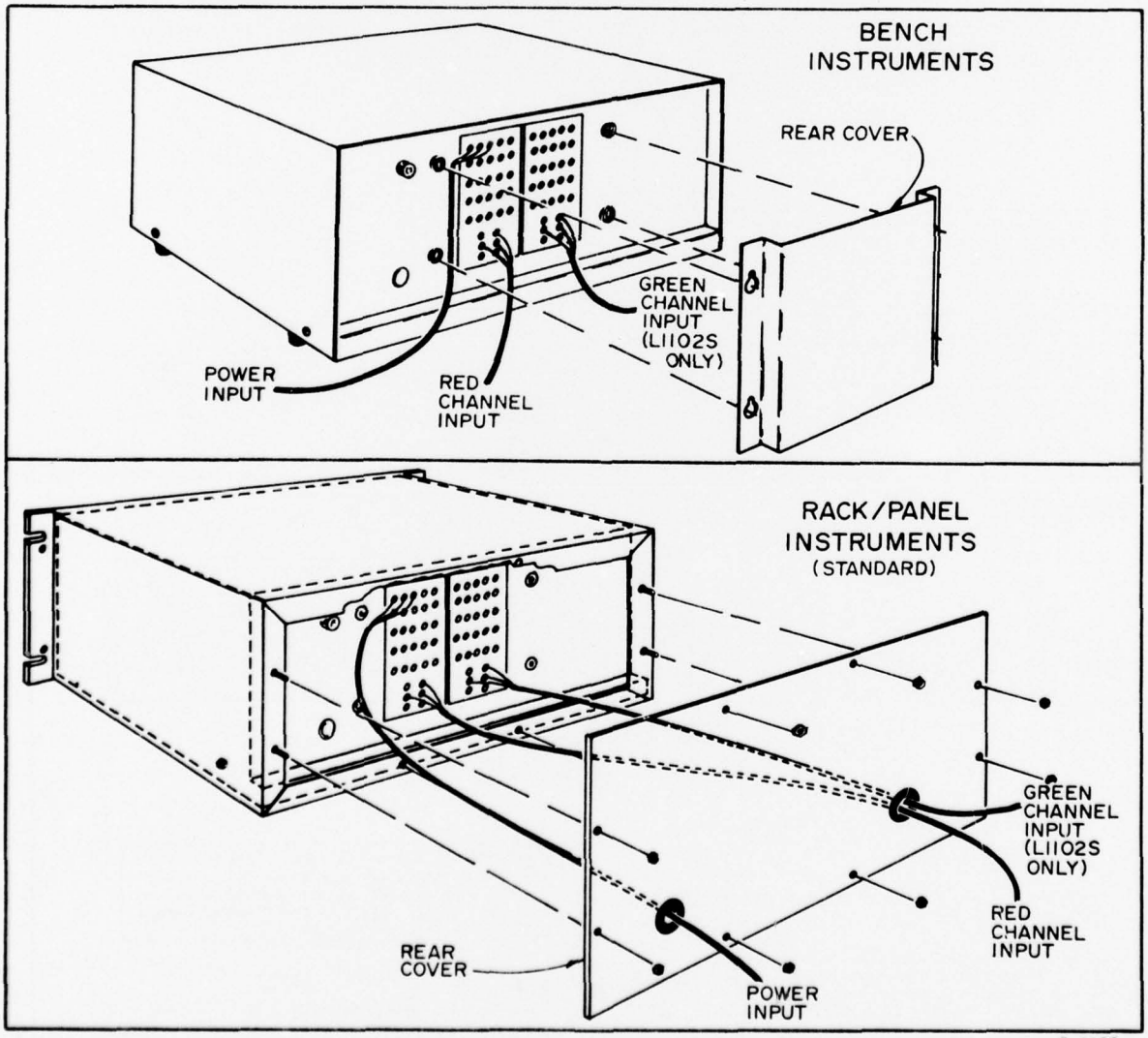
Standard External Connection Diagrams.
(Refer to Supplemental instructions when other configurations are supplied).

Rear Panel Wiring

To gain access to the rear connections of a bench-style instrument, loosen the four screws securing the terminal block cover, lift the cover upward and remove it from the rear panel. On rack- or panel-mounted instruments, remove eight nuts from the rear mounting studs and completely remove the rear cover from the case. After wiring, this cover plate must be replaced for the case to maintain its designed rigidity.

An external ground connection should be established at only one point on the instrument--preferably at the power input terminals. Signal input cables should be routed away from power and accessory leads to avoid interference problems. Typical methods of wiring a rear panel are illustrated in the diagrams below. See that all connections are clean and tight, replace rear cover, and check operation. If signal interference is encountered, refer to Grounding and Shielding instructions in the Service Manual.

WARNING: Dangerous potentials may be present on rear-panel terminals. Exercise appropriate caution when power is applied to instrument.



Typical Methods of Wiring Rear Panels.

CHARTING PROCEDURES

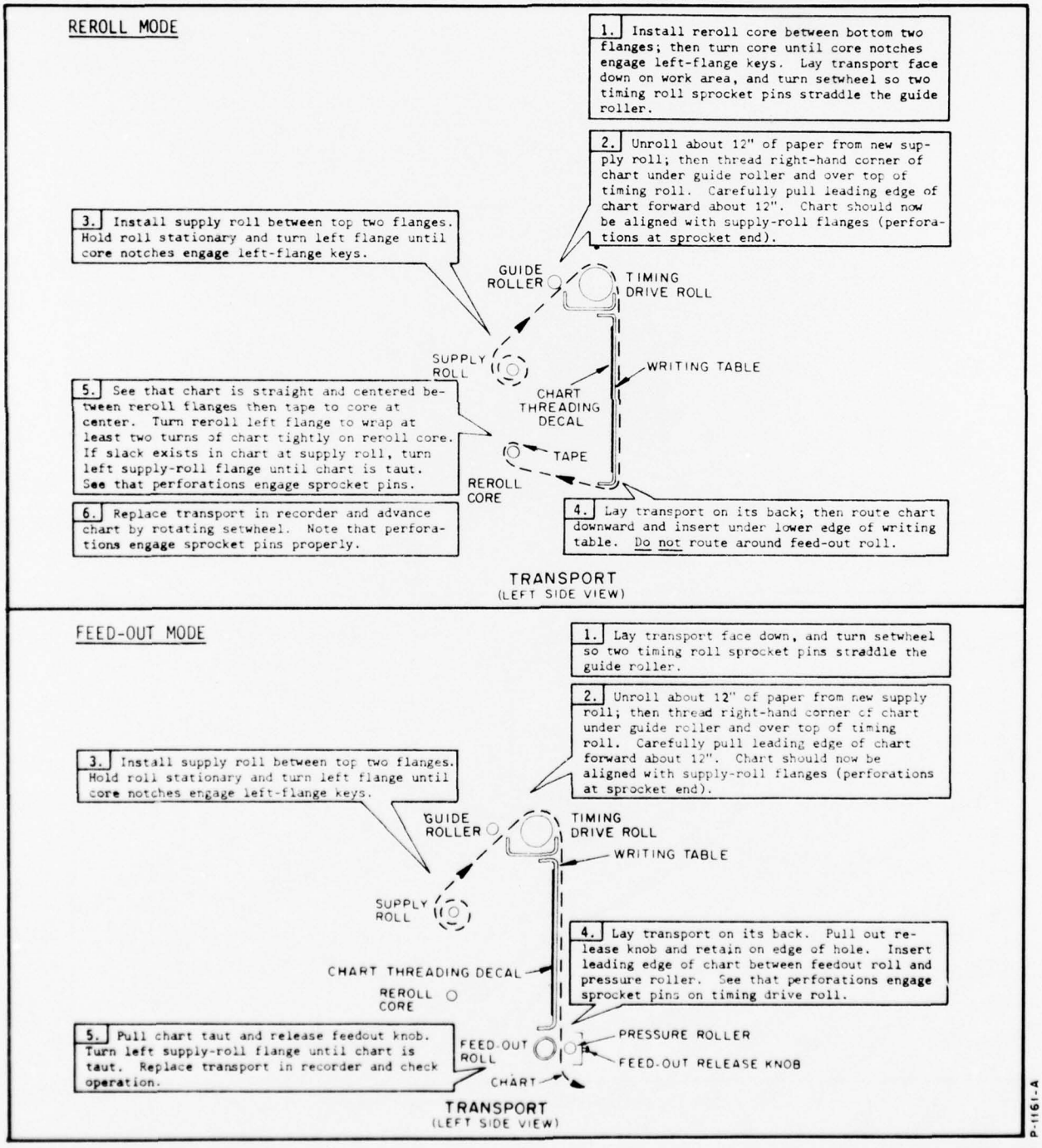
Perform charting procedures as follows:

(a) Raise recording pens by moving pen lifter lever to its up position; then pivot bottom of the scaleplate out and upward.

(b) Hold down on the transport latch (lower left), swing transport module out and upward to a horizontal plane, and remove transport by pulling straight out from the recorder.

(c) Strike perforated end of new supply roll on flat surface so that fibre core is flush with paper. See that fibre has not frayed into open ends of core.

(d) Thread chart paper as shown below for one of the two following modes of operation:



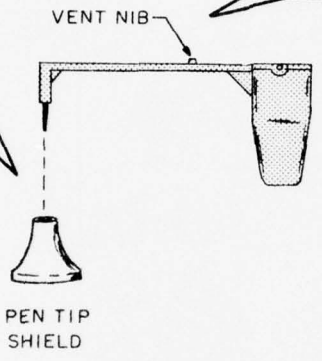
INKING PROCEDURES

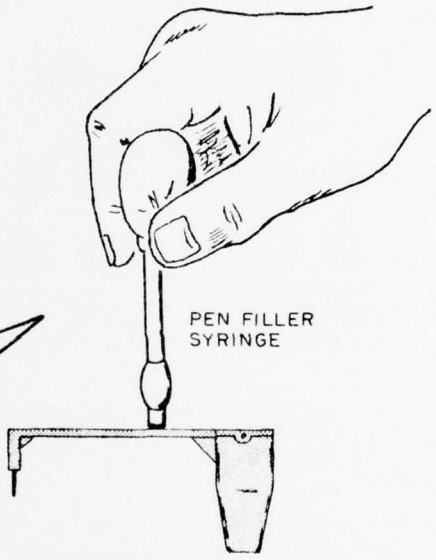
The disposable pen modules contain their own ink supply and are furnished in a separate service kit -- together with a pen filler syringe. One pen module for each active channel must first be vented, primed and then installed in the instrument prior to recording operations. To activate an analog inking system, proceed with the following steps:

1 To remove pen tip shield, support module near pen tip and pull shield straight downward. Retain shield.

NOTE: TO PREVENT DRY-OUT, REPLACE SHIELD IF RECORDER WILL REMAIN INACTIVE FOR MORE THAN 24 HOURS.

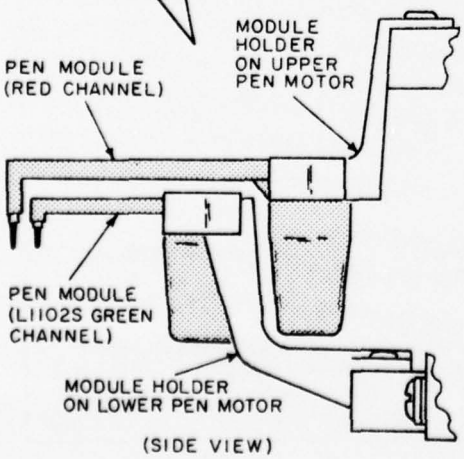
2 To open air vent hole, slice or clip small nib from top of pen module.



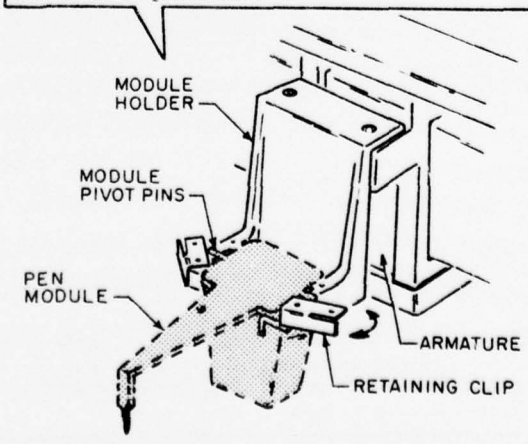


3 If ink does not appear at pen tip, place syringe over air hole in module and slowly compress bulb until pen is primed.

4 Tilt out and remove scaleplate from recorder. With chart transport in position and pen lift down, install pen module(s) as shown below.

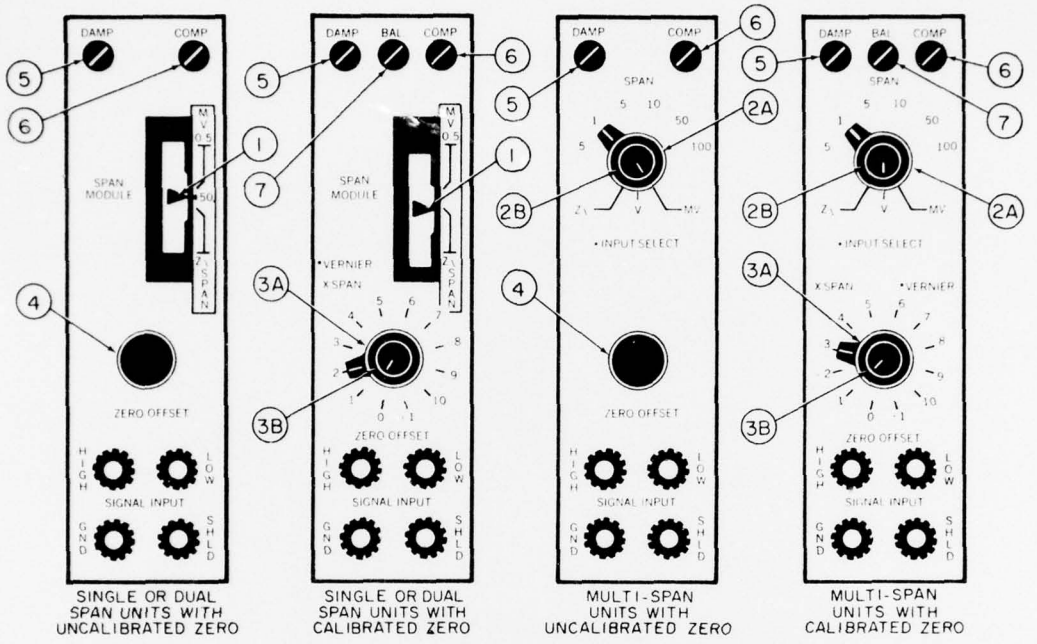


5 Open retaining clips at each side of holder. Place pen module on holder so that pivot pins seat in holder notches. DO NOT USE FORCE. Close retaining clips and check recorder operation.



P-1162-A

OPERATING CONTROLS



(1) **Span Module Switch:** A two- or three-position slide switch that is part of the plug-in Span Module furnished with single- or dual-span units. It is used to select the basic full-scale span of the recording channel and, in its "Z√" position, sets up the input circuitry for a zero check.

(2) **Span Selector Switch:** A dual-concentric switch supplied on all multi-span preamp modules. **(2A) Span:** Six-position rotary type that selects the basic full-scale span for both millivolt and volt measurements. **(2B) Input Select:** Three-position rotary switch used to select the following input modes: (Z√) Zero Check, (V) Voltage Actuation, and (MV) Millivoltage Actuation.

(3) **Zero Offset:** A concentric adjustment that is provided on all units having the calibrated zero option. **(3A) X Span:** twelve-position rotary switch. In its -1 thru -10 positions, this switch is used to suppress zero from 1 to 10 times span; or, in its +1 position, it will elevate zero one full span. No calibrated offset is provided when this switch is in its "0" position. **(3B) Vernier:** A 10-turn potentiometer that provides zero positioning between offset switch steps. It must be set fully CCW for any fixed step value.

(4) **Zero Offset:** A covered screwdriver adjustment furnished on all preamps having the uncalibrated zero provision. This 10-turn pot affords uncalibrated control over zero suppression or elevation. Offset limits are ±100% of chart span zero (control knob optional).

(5) **Damp Adjust:** This miniature potentiometer is supplied on all preamp modules and is used to regulate pen-motor damping on step input signals.

(6) **Comp. Adjust:** A miniature potentiometer which is provided on all units. This calibration adjustment is used to compensate for inherent amplifier offset potential that may become objectionable at low signal levels.

(7) **Bal. Adjust:** This is a miniature pot furnished on only those preamps having the calibrated zero option. It serves as a calibration balancing adjustment to compensate for end resistance in the feedback potentiometer. The Bal. Adjust may be used to slightly shift the entire span for an accurate zero reference position.

P-1163

Standard Optional Preamps.
(Refer to supplemental instructions when other configurations are supplied).

OPERATION

The following instructions assume that proper power connections have been made to the recorder, a chart supply roll has been installed in the transport, and that the inking system is ready for operation.

All operator controls are accessible from the front of the Speed Servo II recorder. On Model L1102S instruments, pre-amplifier controls for the red channel pen are located on the right side, and green channel controls are on the left side. Internal service adjustments are pre-set at the factory -- *DO NOT DISTURB*.

WARNING: Front-panel control shafts and knob setscrews may be at a dangerous common-mode potential.



Operating Procedures

(1) Without an input signal applied, energize the recorder by placing the Main Power switch in its "ON" position. This switch is located in the lower left-front corner of the instrument.

NOTE: A 30-minute warm-up period is recommended for amplifier stabilization and for specified accuracy.

(2) Lower the recording pen(s) on to the chart by placing the Pen Lift lever in its lower position. This lever is located at the right end of the scaleplate.

(3) Check recorder zero by placing Span Module switch (or Input Select switch) in its "Z√" position. With "0" offset, the recording pen should come to rest at the zero reference point on the chart.

NOTE: Refer to Zero Calibration instructions for a more accurate zero check.

(4) Determine measurement span to be recorded and place Span Module switch (or Span Selector switch) in the appropriate span position. If zero suppression or elevation is desired, adjust offset controls as required.

CAUTION: Once an offset adjustment is made, DO NOT disturb control setting.

(5) Apply input signal to recorder (see "Electrical Connections").

CAUTION: Input signal level must not exceed 1.5 volts on millivoltage spans, or 100 volts on voltage spans. Common-mode potentials are limited to 120V AC or ±500V DC.

(6) Place the Chart Drive switch in its "ON" position. This switch is located in the lower right-front corner of the instrument.

NOTE: On two-speed drives, this switch may be placed in either its "Fast" or "Slow" position as desired. On multi-speed drives, a feed rate is also selected by a thumb wheel located on the front of the chart transport.

(7) Set Damping adjustment (Damp) for optimum response. On step input signals, this control should be adjusted for a fast jitter-free response with minimum overshoot and deadband. Do *NOT* disturb internal gain adjustments.

Zero Calibration (Single-span units only)

Permit instrument to warm up for 30 minutes. Remove input signal and connect shorting jumper between the High, Low and Shield input terminals. It is also recommended that the chart be in motion when making adjustments. Refer to the "Operating Controls" illustration in this manual and proceed with channel zero calibration as follows:

NOTE: For greater accuracy when a high-impedance signal source is to be measured, the source resistance (or equiv. dummy load) should remain across the input terminals without use of the shorting jumper.

(A) UNITS WITH UNCALIBRATED ZERO OPTION:

1. Place Span Module switch (1) in its span operating position and observe pen zero position.
2. Adjust Zero Offset control (4) until pen is positioned precisely on chart zero point.
3. Remove shorting jumper, apply input signal, and check operation.

(B) UNITS WITH CALIBRATED ZERO OPTION:

1. Place Zero Offset switch (3A) in its "0" position and adjust Vernier (3B) fully counterclockwise (ccw).
2. Place Span Module switch (1) in its span operating position and observe pen zero position.
3. Carefully turn Bal. adjust (7) until pen is positioned precisely on chart zero point.
4. Remove shorting jumper, apply input signal, and check operation.

Zero Calibration (Dual or multi-span units only)

Permit instrument to warm up for 30 minutes. Remove input signal and connect shorting jumper between the High, Low and Shield input terminals. It is also recommended that the chart be in motion when making adjustments. Refer to the "Operating Controls" illustration in this manual and proceed with channel zero calibration as follows:

NOTE: For greater accuracy when a high-impedance signal source is to be measured, the source resistance (or equiv. dummy load) should remain across the input terminals without use of the shorting jumper.

(A) UNITS WITH UNCALIBRATED ZERO OPTION

1. Place Span Module switch (1) or Span selector switch (2A) in its highest span position. On multi-span units, also place Input Select switch (2B) in its MV position.

2. Adjust Zero Offset control (4) until pen is positioned precisely on chart zero point.

3. Place Span Module switch (1) or Span selector switch (2A) in its lowest span position.

4. Carefully turn Comp. adjust (6) until pen is resting precisely on the same zero point as that obtained in step 2 above.

5. Repeat above procedure until zero points coincide accurately. Remove shorting jumper, apply input signal, and check operation.

(B) UNITS WITH CALIBRATED ZERO OPTION:

1. Place Zero Offset switch (3A) in its "0" position and adjust Vernier (3B) fully counterclockwise (ccw).

2. Place Span Module switch (1) or Span selector switch (2A) in its highest span position. On multi-span units, also place Input Select switch (2B) in its MV position.

3. Carefully turn Bal. adjust (7) until pen is positioned precisely on chart zero point.

4. Place Span Module switch (1) or Span selector switch (2A) in its lowest span position.

5. Carefully turn Comp. adjust (6) until pen is resting precisely on the same zero point as that obtained in step 3 above.

6. Repeat above procedure until zero points coincide accurately. Remove shorting jumper, apply input signal, and check operation.

Zero Offset Elevation

When negative input signals below the lower limit of a given span are to be recorded, electrical zero may be shifted up-scale (elevated) from chart or scale "0" to 100% of the recording span. Electrical zero may be elevated by the following procedure:

NOTE: These instructions are applicable to instruments with left-hand zero calibration. Reverse deflection references for right-hand zero.

(1) The precise amount of zero elevation required for any given application will equal the low-end value of the desired signal range. Determine this elevation point on the chart or scale--disregarding the negative sign.

NOTE: If scale calibrations are not directly proportional to the operational span, calculate an equivalent percentage point on the scale.

(2) Place Span Module switch (1), or Input Select switch (2B), in its Z√ position. On calibrated units, also place Zero Offset X Span switch (3A) in its "0" position.

(3) Adjust Zero Offset control (4), or Vernier (3B), until recording pen moves up-scale to the point determined in step 1 above.

(4) Place Span Module switch (1), or Span and Input Select switches (2A) and (2B), in the span-operating position. The instrument will now record analog inputs over the offset range selected.

NOTE: If an elevation of one full span is desired on a calibrated unit, place X Span switch (3A) in its"+1"position and Zero Offset Vernier (3B) fully counterclockwise (CCW).

Example: Assume a 5MV recorder span; nominal source output of +1.05MV; and a desired measurement range of -1.45MV to +3.55MV. Disregarding the sign, the required elevated offset equals 1.45MV. Set preamp switches as directed in step 2, and adjust offset control for a pen position of 1.45MV on a 5MV span (equivalent to 29% of scale width). Select 5MV operating span, and the recorder will now operate over the input signal range of -1.45MV to +3.55MV.

Zero Offset Suppression

When positive input signals above the upper limit of a given span are to be recorded, electrical zero may be shifted down-scale (suppressed) from chart or scale "0" to 100% of the recording span. In addition, zero may be suppressed in pre-calibrated steps of from 2 x span to 10 x span when the calibrated zero option is supplied.

Electrical zero may be suppressed by one of the following procedures:

NOTE: These instructions are applicable to instruments with left-hand zero calibration. Reverse deflection references for right-hand zero.

(A) UNITS WITH UNCALIBRATED ZERO OPTION:

1. Place Span Module switch (1), or Span and Input Select switches (2A) and (2B), in the span-operating position.

2. Using a known-accurate voltage standard, apply an input signal to the recorder that is equal to the low end value of the desired measurement range. The recording pen should deflect to an equivalent position on the chart span.

   NOTE: If scale calibrations are not directly proportional to the operational span, calculate an equivalent percentage point on the scale.

3. Adjust Zero Offset control (4) until the recording pen moves down-scale and comes to rest precisely on the "0" reference line of the chart. Scale "0" now electrically represents the low end of the desired measurement range.

4. Disconnect voltage standard from input terminals and connect signal source to be monitored. The instrument will now record analog inputs over the offset range selected.

Example: Assume a 50V recorder span; nominal source output of +60V; and a desired measurement range of +35V to +85V. The required suppressed offset equals 35V. Apply a 35V reference signal to the recorder, and adjust Zero Offset control for a "0" pen position on the chart. Disconnect the reference source and the recorder will now operate over the input signal range of +35V to +85V.

(B) UNITS WITH CALIBRATED ZERO OPTION:

NOTE: The operator must remember that the Vernier only decreases the amount of offset selected by the X Span switch, and that the maximum input signal is limited to ±100V.

1. Determine a span multiple which, in terms of signal value, will encompass the low end of the desired measurement range. Multiply the given span value by this multiple figure and then substract the lower end value of the desired range (use resultant in step 3 below).

   NOTE: If the desired span multiple is a whole number found on the offset switch, turn Zero Offset Vernier (3B) fully CCW and proceed to step 4.

2. Place Span Module switch (1), or Input Select switch (2B), in its Z✓ position. Place Zero Offset X Span switch (3A) in its "0" position.

3. Adjust Zero Offset Vernier (3B) until the recording pen moves up-scale to a point equal to the resultant calculated in step 1 above.

   NOTE: If scale calibrations are not directly proportional to the operational span, calculate an equivalent percentage point on the scale.

4. Place X Span switch (3A) in a suppression position equal to the span multiple determined in step 1 above.

   CAUTION: Do not disturb Vernier setting.

5. Place Span Module switch (1), or Span and Input Select switches (2A) and (2B), in the span-operating position. The instrument will now record analog inputs over the offset range selected.

Example: Assume a 10MV recorder span; nominal source output of +53MV; and a desired measurement range of +48MV to +58MV.

	GIVEN SPAN		SELECTED MULTIPLE		SIGNAL VALUE		RANGE LOW END		RESULTANT
Calculations:	10MV	x	5	=	50MV	-	(+48MV)	=	2MV

Adjustments: Set preamp switches as directed in step 2, adjust Vernier for a pen position of 2MV on a 10MV span (equivalent to 20% of scale width). Place X Span switch in its "-5" position, select 10MV operating span, and the recorder will now operate over the input signal range of +48MV to +58MV.

OPERATOR CALIBRATION

Calibration Check

NOTE: Refer to instrument Service Manual for complete calibration instructions. Procedures given in this manual are also not applicable to recorders with Integrator option (see supplemental instructions).

(1) Permit instrument to warm up, then position recording pen at the "0" point on the chart span as directed under Zero Calibration instructions.

(2) Set Span Module switch (or Span/Input Select switches) for the operational span used for your specific measurement application.

(3) Using a known-accurate voltage source*, apply a full-span DC signal to the input terminals of the recorder.

(4) The recording pen should now deflect to full-scale on the chart -- within the accuracy limits given in the Technical Specifications.

NOTE: Since the recorder has been calibrated at the factory for an accurate chart span of 10 inches, allowances may be necessary if the width of the chart paper changes due to different environmental conditions.

Should the above calibration check indicate that recording accuracy is not within acceptable tolerance, the operator may "touchup" calibration by proceeding with the instructions in the following applicable paragraphs. If inaccuracies are excessive or a mal-function is suspected, refer to the Service Manual for complete calibration and servicing procedures.

Adjustments (Uncalibrated zero option only)

(1) Disconnect signal input leads, turn on power, and permit instrument to warm up 30-minutes. On dual- or multi-span units, perform Zero Calibration procedures to ensure the proper setting of the Comp. adjust.

(2) Using 2-wire shielded cable, connect precision voltage source* across the High and Low input terminals of the recorder with Low and Shield terminals shorted by copper wire.

(3) Set Span Module switch (or Span/Input Select switches) for the operational span desired.

(4) With no signal applied (source at zero), adjust Zero Offset control until recording pen is precisely positioned on the full-scale line of the chart.

(5) Apply a negative (-) full-scale DC signal to the recorder. Recording pen should come to rest precisely on the "0" line of the chart. If it does not, gain access to internal preamp adjustments by removing top cover from instrument.

(6) Carefully adjust SPAN CAL pot (R50) until pen is resting precisely on chart "0". This screwdriver adjustment is located on top of the preamp module. Repeat steps 4 through 6 until no further adjustment is necessary.

CAUTION: As opposed to common practice, the ZERO control is adjusted to position the pen at the upper limit of the chart span, while the SPAN control is used to position the pen at the lower limit.

CAUTION: Do *NOT* disturb other internal adjustments.

(7) Reduce input signal to zero and adjust Zero Offset control until pen comes to rest on chart "0" again.

(8) Apply a positive (+) full-scale DC signal; the pen should deflect to the full-scale line on the chart. Repeat above steps as necessary.

Adjustments (Calibrated zero option only)

The following adjustment procedures assume that recorder offset circuitry is functioning properly. If internal adjustments have been accidently disturbed, refer to the Service Manual for complete calibration instructions.

(A) SPAN ADJUSTMENT:

1. Disconnect signal input leads, permit instrument to warm up, and turn the Zero Offset Vernier fully counterclockwise (CCW). On dual- or multi-span units, perform Zero Calibration procedures to ensure the proper setting of the Comp. adjust.

2. Set Span Module switch (or Span/Input Select switches) for the operational span desired.

3. Place Zero Offset switch in its +1 position (Vernier CCW).

4. Recording pen should come to rest precisely on the full-scale line of the chart (10" from "0" line). If it does not, turn the Bal. adjust for a full-scale pen position.

5. Place Zero Offset switch in its "0" position. Do not disturb CCW setting of Offset Vernier.

6. Recording pen should come to rest precisely on the "0" line of the chart. If it does not, gain access to internal adjustments by removing top cover from instrument.

7. Carefully adjust SPAN CAL. pot (R50) until pen is resting precisely on chart "0". Repeat above steps as necessary.

CAUTION: Do *NOT* disturb other internal adjustments.

(B) OFFSET ADJUSTMENT:

1. Place span switch in its span operating position and Zero Offset switch in its "0" position. Turn Vernier control fully counterclockwise (CCW).

NOTE: On multi-span units, set selector for 100MV (basic span). On dual-span units, place Span Module switch in its highest span position (basic span).

2. Connect precision voltage source* across the High and Low input terminals of the recorder with Low and Shield terminals shorted by copper link or buss wire.

* Esterline Angus Model V-2000 or equivalent. DC source must have .05% accuracy or better.

3. With no signal applied (source at zero), turn the Bal. adjust until the recording pen is positioned at the 5% point on the chart span.

4. Place the Zero Offset switch in its "-10" position. Do not disturb CCW setting of Vernier.

5. Apply a DC input signal equal to ten times the basic span. Recording pen should come to rest at the 5% point on the chart span (±1.05%). See Table 1.

NOTE: If pen position is within ±2% of the 5% chart span point, proceed with step 6. If pen position is not within ±2%, refer to complete calibration procedures in Service Manual.

6. Gain access to internal preamp adjustments by removing top cover from bench instrument. For a rack or panel installation, remove door (if supplied) and slide out chassis from front of case.

7. Carefully adjust .5V CAL. pot (R21) until pen is positioned within ±1.05% of the 5% point on the chart span. This screwdriver adjustment is located on the exposed. side of the preamp module.

CAUTION: Do *NOT* disturb other internal adjustments.

8. Check accuracies for other positions of the Zero Offset switch. Example: Repeat above procedures but now place switch in its "-9" position and then apply a signal equal to nine times the span; etc. See Table 1 for accuracy limits.

NOTE: If accuracies are not within acceptable tolerance, refer to Service Manual for complete calibration instructions.

9. Disconnect reference source, place Zero Offset switch in its "0" position (Vernier CCW), and turn the Bal. adjust until the recording pen is positioned on chart zero. Resume operation.

TABLE 1
CALIBRATED ZERO OFFSET ACCURACIES

OFFSET SWITCH SETTING	±% OF CHART SPAN		
	BASIC SPAN▲	OTHER MV SPANS	OTHER VOLT SPANS
+1	.15	.25	.35
0	0	.1	.1
-1	.15	.25	.35
-2	.25	.45	.65
-3	.35	.65	.95
-4	.45	.85	1.25
-5	.55	1.05	1.55
-6	.65	1.25	1.85
-7	.75	1.45	2.15
-8	.85	1.65	2.45
-9	.95	1.85	2.75
-10	1.05	2.05	3.05

▲ The "basic span" for multi-span preamps is 100MV; for single- or dual-span preamps, it is the highest span offered by the plug-in module originally supplied.

PARTS AND SUPPLIES

COMMON REPLACEMENT ITEMS†

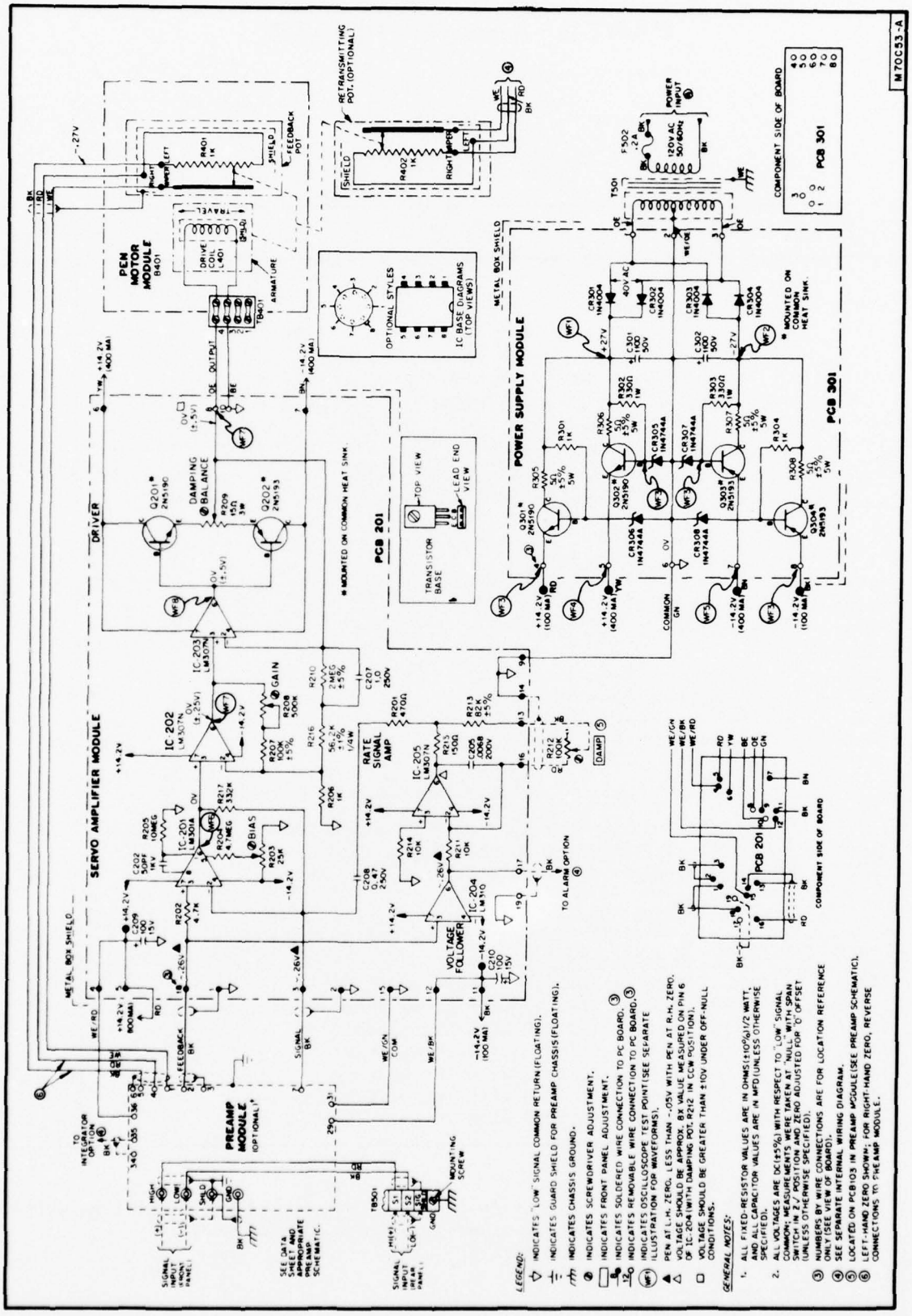
EA PART NUMBER	DESCRIPTION	QUANTITY 1-Chan.	QUANTITY 2-Chan.
*	Strip Chart, Roll	A/R	A/R
201434	Reroll Core, Chart (Fiber)	1	1
*	Change Gears, Optional	A/R	A/R
70B41*	Module, Writing System (Single/upper pen. Red ink)	1	1
70B46*	Module, Writing System (Lower pen. Green ink)	-	1
14359-2	Fuse, 2A Slo-Blow (Type 3AG)	1	1
FAG2-.2	Fuse, .2A Slow-Blow	1	2
8935G	Cord, Power (3-Wire, 7A @125V)	1	1
8935-J	Adapter, Power Plug (with ground wire)	Optional	
70A147	Foot, Base (Standard Bench-Style only)	4	4
NX90808	Screw, Foot Mtg.	4	4
NX2108	Nut, Foot Mtg.	4	4
SP1908	Washer, Foot Mtg.	4	4
45024	Foot, Base (Optional Rack/Panel-Type Case only)	3 A/R	3 A/R
NX90808	Screw, Foot Mtg.	3	3
73A58	Spacer, Front-Foot Mtg.	2	2
713A10	Spacer, Rear-Foot Mtg.	1	1
S832C5B1	Screw, Rear-Spacer Mtg.	1	1
70A343	Carrying Case, Instrument	Optional	
M70A1	Manual, Operating Instructions	1	1
M70A1S	Manual, Servicing Instructions	Optional	
	PEN MODULE PACKS		
71A31	Eight Writing-Sys. Modules (Red-single/upper pen)	A/R	A/R
71A29	Eight Writing-Sys. Modules (Green-lower pen)	-	A/R
71A30	4-Red (upper pen) and 4-Green (lower pen) Modules	-	A/R
	ACCESSORY KITS (Complete Inking Supplies)		
71A18	Kit, Service (L1101S without options)	1	-
71A19	Kit, Service (L1102S without options)	-	1
71A20	Kit, Service (L1101S with Event Pen)	1	-
71A21	Kit, Service (L1102S with Event Pen)	-	1
71A22	Kit, Service (L1101S with Integrator)	1	-
71A23	Kit, Service (L1102S with Integrator)	-	1
71A24	Kit, Service (L1101S with Intgr. & Event Pen)	1	-
71A25	Kit, Service (L1102S with Intgr. & Event Pen)	-	1

A/R : As Required.

* Refer to instrument Data Sheet for part number of specific item supplied.

† A complete illustrated parts breakdown is included in Service Manual No.. M70A1S.

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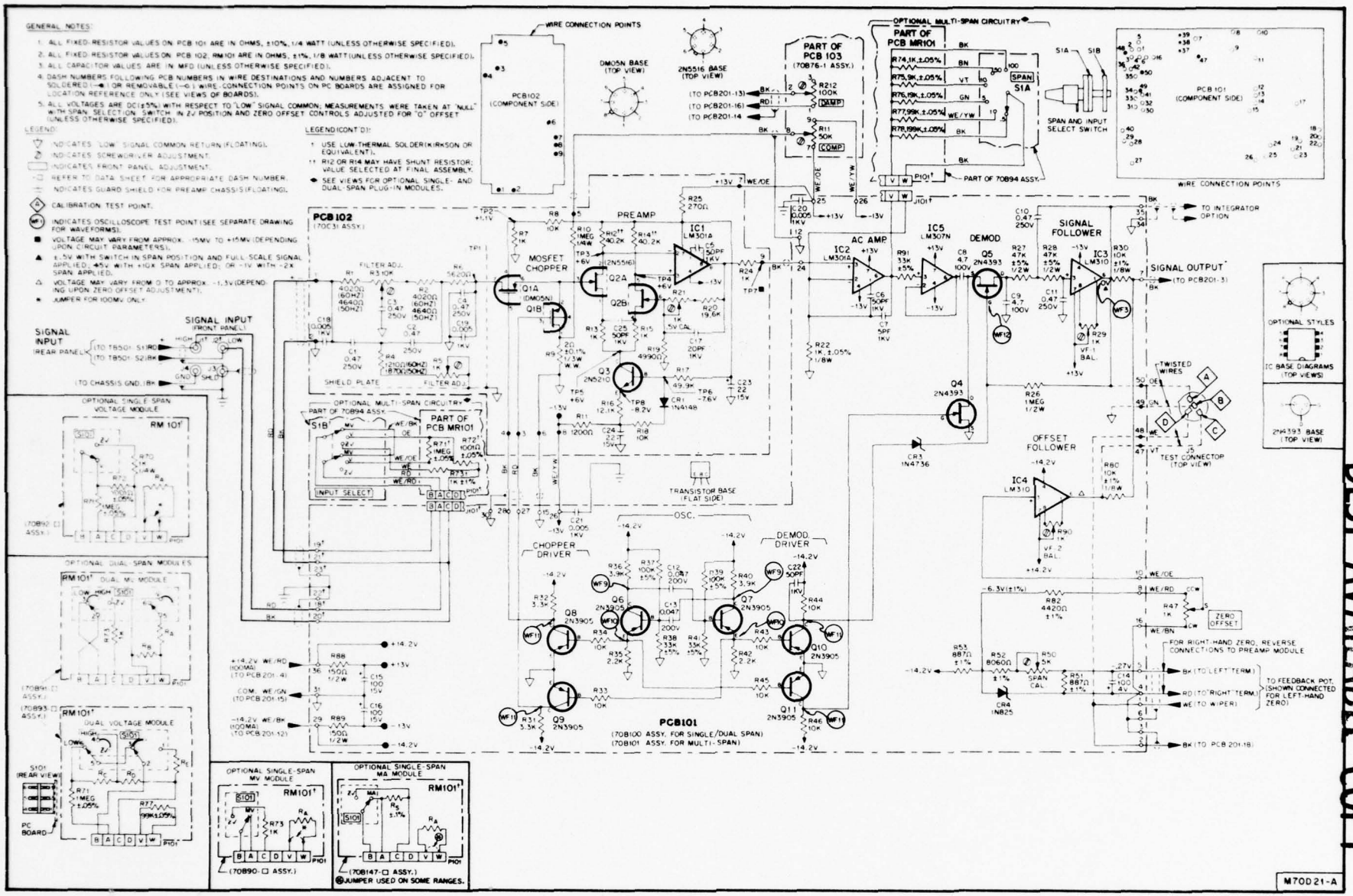
SERVO SYSTEM SCHEMATIC

LEGEND:

- ◇ INDICATES 'LOW' SIGNAL COMMON RETURN (FLOATING).
- ⏚ INDICATES GUARD SHIELD FOR PREAMP CHASSIS (FLOATING).
- ⏚ INDICATES CHASSIS GROUND.
- ② INDICATES SCREWDRIVER ADJUSTMENT.
- □ INDICATES FRONT PANEL ADJUSTMENT.
- ● INDICATES SOLDERED WIRE CONNECTION TO PC BOARD. ③
- ○ INDICATES REMOVABLE WIRE CONNECTION TO PC BOARD. ③
- 1/2○ INDICATES OSCILLOSCOPE TEST POINT (SEE SEPARATE ILLUSTRATION FOR WAVEFORMS).
- ▲ PEN AT L.H. ZERO, LESS THAN −.05V WITH PEN AT R.H. ZERO. VOLTAGE SHOULD BE ±.05V. R2 VALUE MEASURED ON PIN 6 OF IC-204 (WITH DAMPING POT, R212 IN CCW POSITION).
- □ VOLTAGE SHOULD BE GREATER THAN ±10V UNDER OFF-NULL CONDITIONS.

GENERAL NOTES:

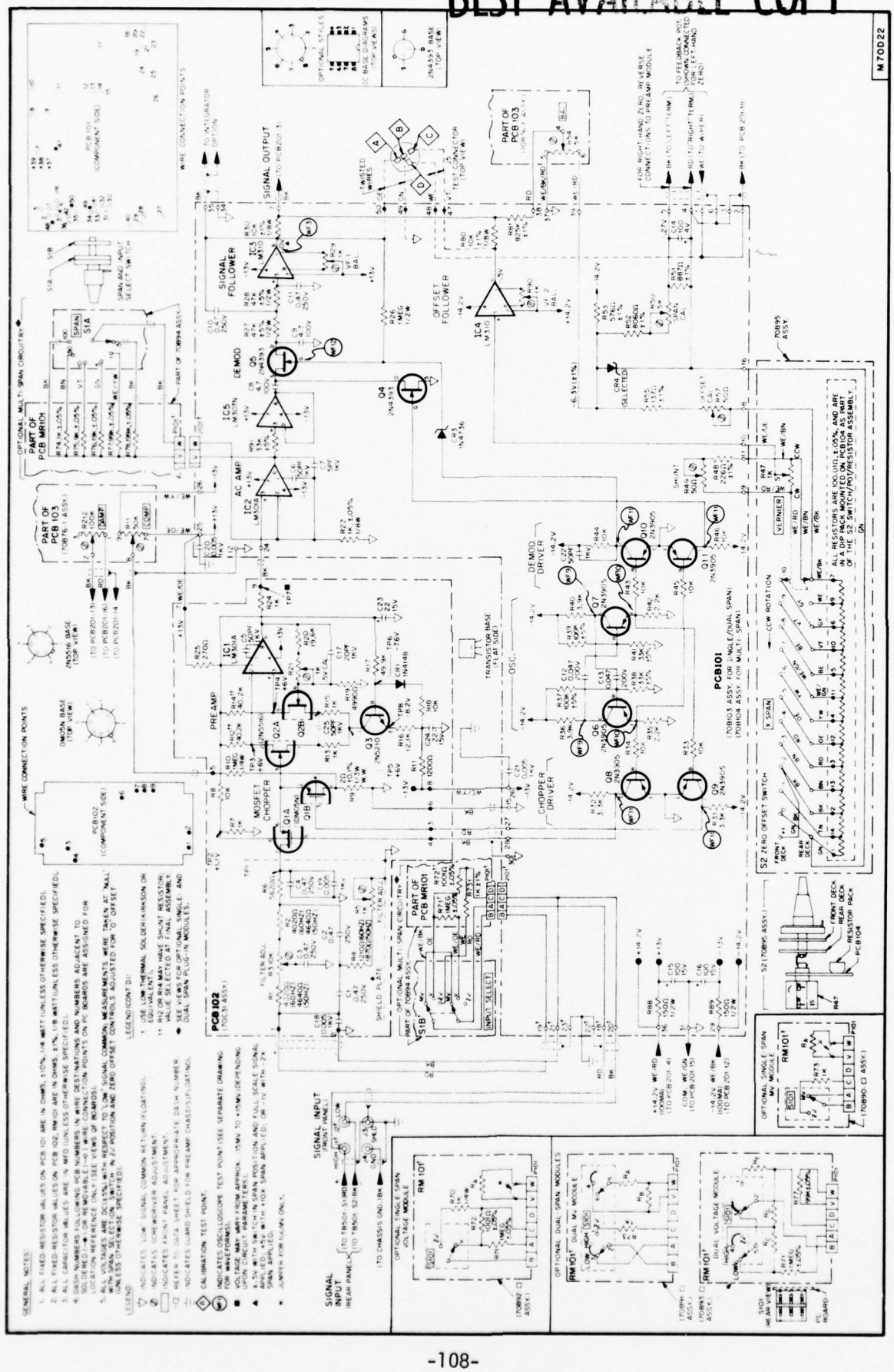
1. ALL FIXED-RESISTOR VALUES ARE IN OHMS (±10%), 1/2 WATT, AND ALL CAPACITOR VALUES ARE IN MFD (UNLESS OTHERWISE SPECIFIED).
2. ALL VOLTAGES ARE DC (±5%) WITH RESPECT TO 'LOW' SIGNAL COMMON; MEASUREMENTS WERE TAKEN AT 'NULL' WITH SPAN SWITCH IN 2V POSITION AND ZERO ADJUSTED FOR '0' OFFSET (UNLESS OTHERWISE SPECIFIED).
3. NUMBERS BY WIRE CONNECTIONS ARE FOR LOCATION REFERENCE ONLY (SEE VIEW OF BOARD).
4. SEE SEPARATE INTERNAL WIRING DIAGRAM.
5. LOCATED ON PCB103 IN PREAMP MODULE (SEE PREAMP SCHEMATIC).
6. LEFT-HAND ZERO SHOWN; FOR RIGHT-HAND ZERO, REVERSE CONNECTIONS TO PREAMP MODULE.



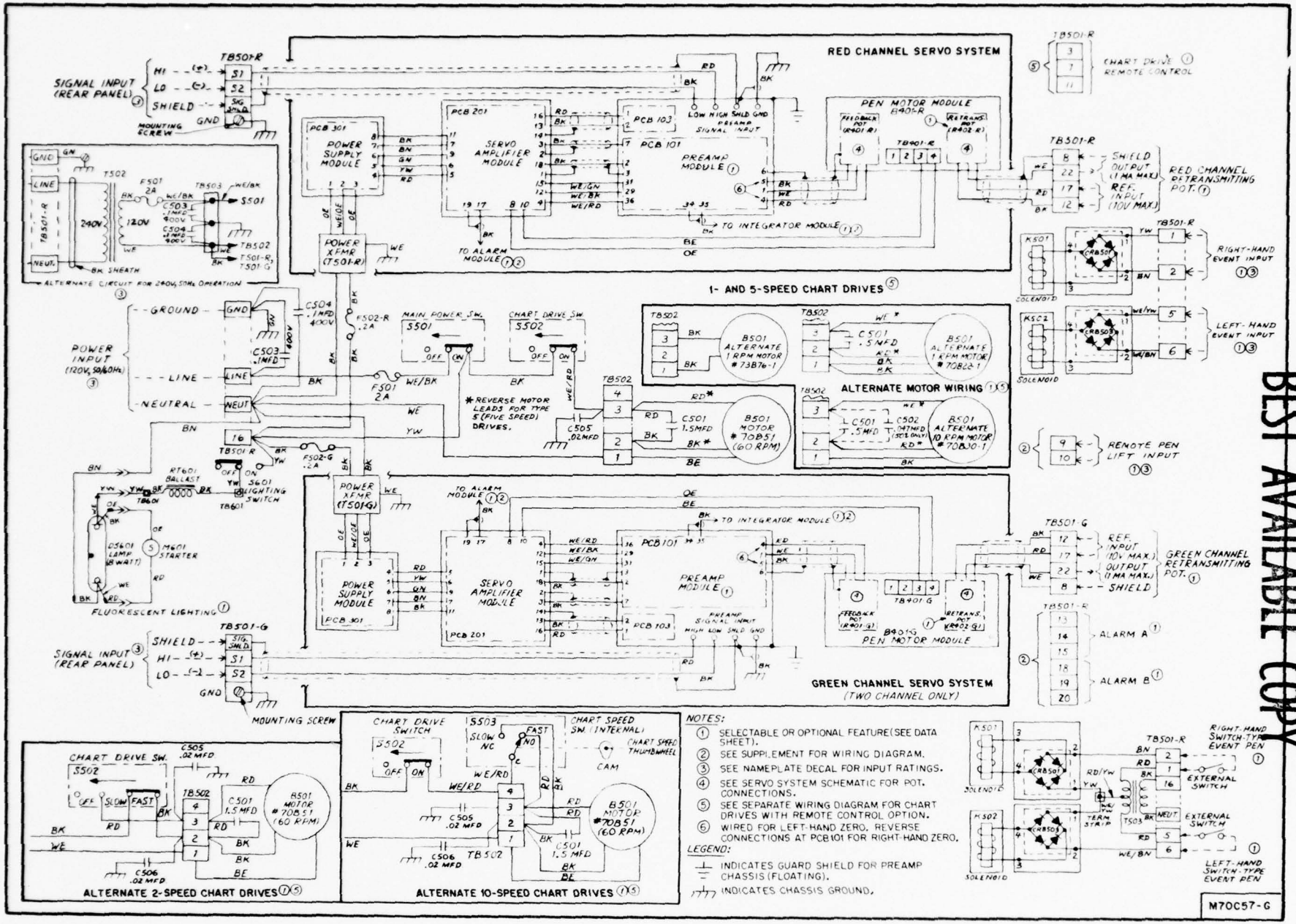
PREAMPLIFIER SCHEMATIC (UNCALIBRATED ZERO)

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PREAMPLIFIER SCHEMATIC (CALIBRATED ZERO)



INTERNAL WIRING DIAGRAM

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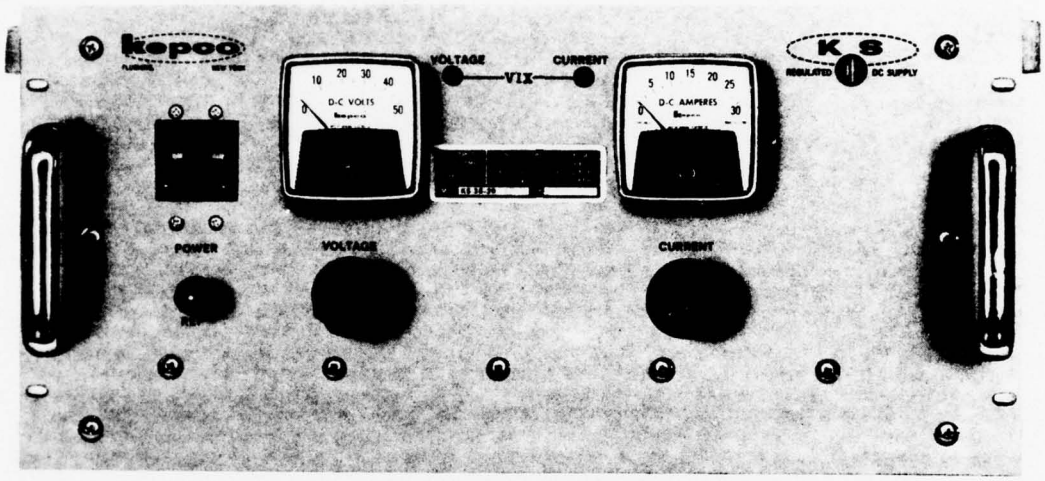


FIG. 1-1 KS POWER SUPPLY, (TYPICAL) FRONT VIEW

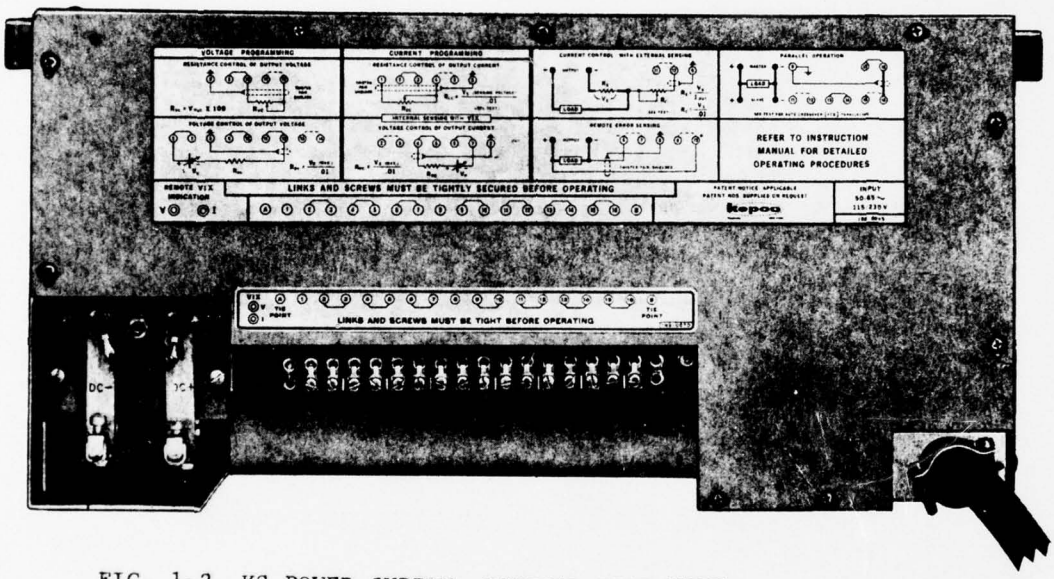


FIG. 1-2 KS POWER SUPPLY, TYPICAL REAR VIEW

SECTION I - INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This instruction manual contains information for the installation, operation, and maintenance of the KEPCO Series KS regulated power supplies.

1-3 GENERAL DESCRIPTION (Refer to FIG.'s 1-1 and 1-2)

1-4 The KEPCO KS Design Group consists of a series of precision regulated, highly efficient power supplies whose specifications and electrical characteristics are identical, except as noted in table 1-1. Phase controlled silicon controlled rectifiers in conjunction with a feedback regulating system provide the output power. High resolution controls in the voltage and current regulating modes are provided. Automatic crossover between the two operating modes is indicated by front panel lights. The rear barrier strip provides for the convenient access to the circuitry for the purpose of remote programming or system integration. Heavy duty rear output terminals for load connection are provided. Built-in forced air cooling with lateral circulation provides adequate ventilation for continuous operation at any output within the specified range.

1-5 The Power Supply chassis and case are constructed of plated cold rolled steel throughout. The front panel is heavy gauge aluminum finished in Light gray Federal Std. 595, Color #26440, unless otherwise specified, and equipped with chrome plated carrying handles.

1-6 The major part of the circuitry is on plug-in type printed circuit boards, and can be conveniently disassembled for maintenance purposes. All power transistors are installed into plug-in type assemblies, especially important for periodic maintenance checks.

1-7 SPECIFICATIONS, GENERAL

a) Input Requirements: 105 VAC to 125 VAC or 210 VAC to 250 VAC, 50 cps to 65 cps, single phase
For maximum input current see table 1-1.

b) Ambient Operating Temperature: -20°C to +50°C.

c) Storage Temperature: -40°C to +85°C.

d) Isolation Voltage: Maximum output voltage plus 500V DC between chassis and either output terminal.

1-8 SPECIFICATIONS, GENERAL PERFORMANCE

a) Controls: Continuously adjustable 10-turn voltage and current controls permit output settings from zero to the maximum voltage and cur ent. Resolution: 0.05% of maximum output.

b) Programming: Special terminals provide for remote resistive programming of voltage or current at 100 ohms per volt. Programming terminals are also provided for programming by means of remotely located voltage or current signals.

c) Automatic Crossover: The automatic crossover circuit switches the operating mode of the power supply automatically from constant voltage to constant current or vice versa depending on the load relationship to the panel voltage and current adjustments. In the voltage regulation mode, the current control serves as a current limit adjustment while in current regulating mode, the voltage control serves as a voltage limiting adjustment.

d) VIX Indicators: The power supply's operating mode is indicated by a pair of front-panel signal lamps. One lamp is lighted during voltage regulated operation, the other during current regulated operation (internal current sensing only). Crossover from one mode to the other is signalled by the extinction of one lamp and the lighting of the other.

e) VIX Remote Signal: A pair of rear-panel pin jacks, labelled "V" and "I" provide external access to the VIX signal. Pin V is 8 volts positive with respect to pin I during voltage regulated operation. Pin I is 8 volts positive with respect to pin V during current regulated operation. Maximum loading: 10 K ohms; isolated from ground and the output terminals of the power supply. Crossover from one mode to the other is signalled by an abrupt polarity reversal.

f) Remote Error Sensing: Error sensing terminals enable specified voltage regulation to be maintained directly at the load by compensating for voltage drops up to 0.5 volts across each load supply lead.

g) Series/Parallel Operation: Automatic crossover capability permits series or parallel operation in either voltage or current regulating modes. Units operate automatically to share a load by means of their automatic crossover feature. Connections are also provided for operation in master/slave configuration.

h) Cooling: Lateral circulation by blowers insures efficient heat transfer; permits stacking of multiple units without overheating.

i) No Voltage Overshoot: No output voltage overshoot from turn-on, turn-off or power failure for output settings above 25% of maximum rated voltage. Below 25%, output overshoot is a function of load and is negligible for loads in excess of 10%.

1-9 SPECIFICATIONS, VOLTAGE REGULATION MODE

a) Regulation:

1) Line: Less than .005% output voltage change for 105-125V AC or 210-250V AC line variation, at any output voltage within the specified range.

2) Load: Less than 0.01% or 0.5 mv output voltage change, whichever is greater, for no load to full load change at any output voltage within the specified range.

b) Stability: Output voltage varies less than 0.01% or 3 mv, whichever is greater, over a period of 8 hours after warmup. Measured at constant line voltage, load and ambient temperature.

c) Temperature Coefficient: Output voltage changes less than 0.01% per °C.

d) Ripple: Less than 1 mv rms.

e) Recovery Time: 50 microseconds.

f) Output Impedance: Specified for each model within the load frequency range shown in Table 1-1. Above 10 kc include the reactive impedance of the effective series inductance as indicated.

1-10 SPECIFICATIONS, CURRENT REGULATION MODE

a) Output Range:

1) Internal Sensing: Current regulation from less than 0.5% to 100% of the maximum specified current. Automatic crossover to voltage limiting provided.

2) External Sensing: Current regulation from 10 ma to 100% of the maximum rated current.

b) Compliance:

1) Internal Sensing: Voltage compliance range is zero to the voltage control setting. The setting is adjustable, zero to 100% of the rated voltage range.

2) External Sensing: Voltage compliance is zero to 100% of the maximum output voltage.

For any selected current value, the output voltage is automatically varied throughout the compliance range as required to regulate the output current through a variable load.

c) Regulation, Internal Sensing:

1) Line: Less than 0.01% or 1 ma, whichever is greater, output current change for 105-125V AC or 210-250V AC line variation at any output current within the specified range. For models rated at 10 amperes or less output current, the 1 ma regulation specification governs.

2) Load: Less than 0.01% or 1 ma, whichever is greater, output current change for the maximum change in load resistance within the rated compliance range. For models rated at 10 amperes or less output current, the 1 ma regulation specifications governs.

d) Regulation, External Sensing:

1) Line: For 105-125V AC or 210-250V AC line variations, output current changes less than 0.01% when the specified voltage sample is maintained across the external sensing resistor.

2) Load: For the maximum change in load resistance, within the rated compliance range, output current changes less than 0.01% when the specified voltage sample is maintained across the external sensing resistor.

The sensing resistor is chosen to produce a one volt drop at the maximum operating current. A separate control is used externally to provide high resolution current adjustability.

e) Stability: Output current varies less than 0.05% or 5 ma, whichever is greater, over a period of 8 hours after warmup. Measured at constant line voltage, load and ambient temperature.

f) Temperature Coefficient: Output current changes less than 0.05% per °C.

g) Ripple: Less than 0.1% of output current setting or 0.05% of maximum current rating, whichever is greater, rms.

1-11 SPECIFICATIONS, PHYSICAL

a) Meters: Model numbers in table 1-1 include 2 1/2", rectangular voltmeter and ammeter; 2% full scale accuracy. Unmetered units have the suffix "M" deleted from the model number.

b) Terminals and Controls:

1) On Front Panel: AC on-off switch, circuit breaker/fuse and two VIX mode lamps. 10-turn voltage control, 10-turn current control, reference circuit fuse, DC output and ground terminals (8 3/4" models have output terminals on the rear only).

2) On Rear of Chassis: Two VIX remote signal 0.08" pin jacks. Barrier strip connections for: remote error sensing, voltage and current programming by remote resistance and/or voltage, master-slave, parallel operation, external current sensing. DC output and ground terminals. Output terminals are isolated from the chassis, either positive or negative terminal may be grounded.

c) Dimensions: Standard EIA rack dimensions. Refer to FIG. 1-3.

d) Finish: Light gray Federal Std. 595, Color #26440. (Special finishes to order).

1-12 ACCESSORIES

1-13 Accessory equipment for this power supply is available (but not supplied) to increase its range of applications.

a) VIX-1 Relay, translates the VIX remote signal, available at two connectors in the rear of the unit, into a heavy duty relay closure for external signal applications.

b) KP-10 PROGRAMMING PANEL, precision decade programming resistors for 6 digit voltage programming and 3 digit current programming.

c) FG-100, FUNCTION GENERATOR. Precision, slow speed, triangular wave generator for voltage programming of the power supply.

d) MP 1-3000, MOTORIZED PROGRAMMER. Provides a mechanical 10-Turn potentiometer sweep.

e) VIP-1, OVERVOLTAGE/OVERCURRENT PROTECTOR, A 1% or 0.1V overvoltage will crow-bar the supply within 50 μ sec.

f) VIP-3, OVER AND UNDER VOLTAGE
OVER AND UNDER CURRENT PROTECTOR
A 1% or 0.1V over or under voltage will crow-bar the supply within 50 μ sec.

g) VIP-4, 200 Ampere Overvoltage Crow-bar. Range 5-50 volts. A 1% or 0.1V overvoltage will crow-bar supply with 50 μ sec.

h) VP-K-Series Overvoltage Protector, a 5% or 0.25V overvoltage will trigger the power supply within 5-10 μ sec. (Adjustable)

VP-KCA - for all KS Models except as listed below.

VP-KS1 - for KS 36-30(M), KS 60-20(M), KS 120-10(M).

VP-KS2 - for KS 8-100(M), KS 18-50(M).

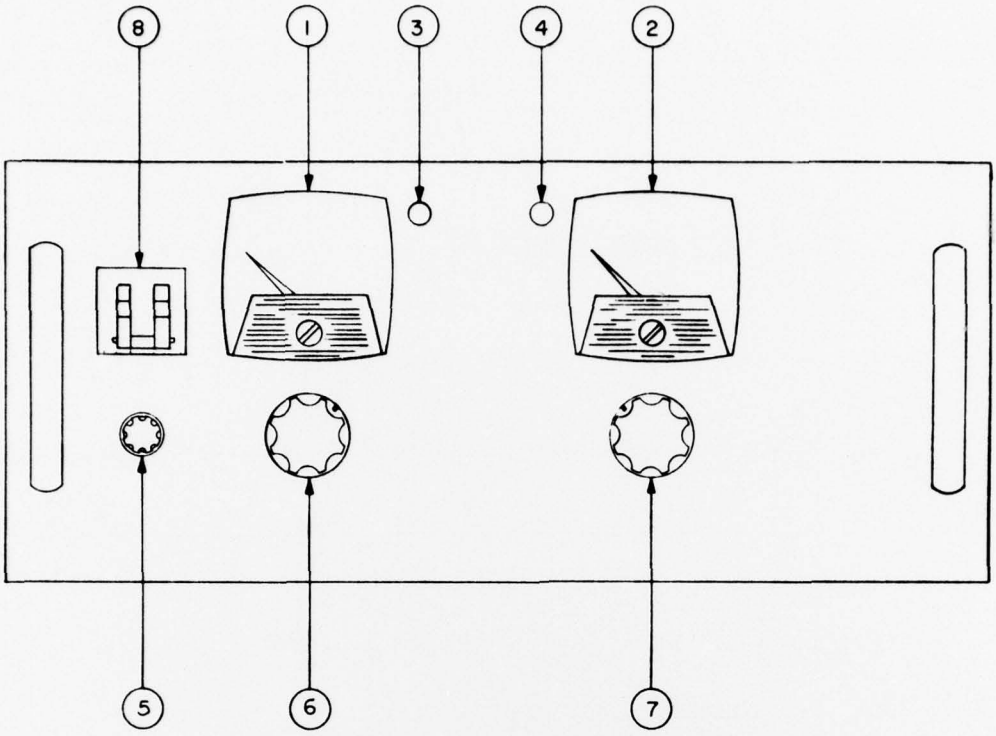


FIG. 2-2 TERMINATIONS, FRONT

TABLE 2-1, TERMINATIONS, FRONT

NO.	TERMINATION OR CONTROL	FUNCTION
1.	VOLTMETER	INDICATES OUTPUT VOLTAGE
2.	AMPERE METER	INDICATES OUTPUT CURRENT
3.	VIX INDICATER	DISPLAYS VOLTAGE OPERATING MODE
4	VIX INDICATER	DISPLAYS CURRENT OPERATING MODE
5	FUSE	PROTECTS REFERENCE TRANSFORMER
6.	VOLTAGE CONTROL	TEN TURN POTENTIOMETER, SETS OUTPUT VOLTAGE
7	CURRENT CONTROL	TEN TURN POTENTIOMETER, SETS OUTPUT CURRENT
8	LINE SWITCH AND	CONNECT UNIT TO AND FROM POWER LINE,
	CIRCUIT BREAKER	PROTECTS AGAINST OVERVOLTAGE OR OVERCURRENT

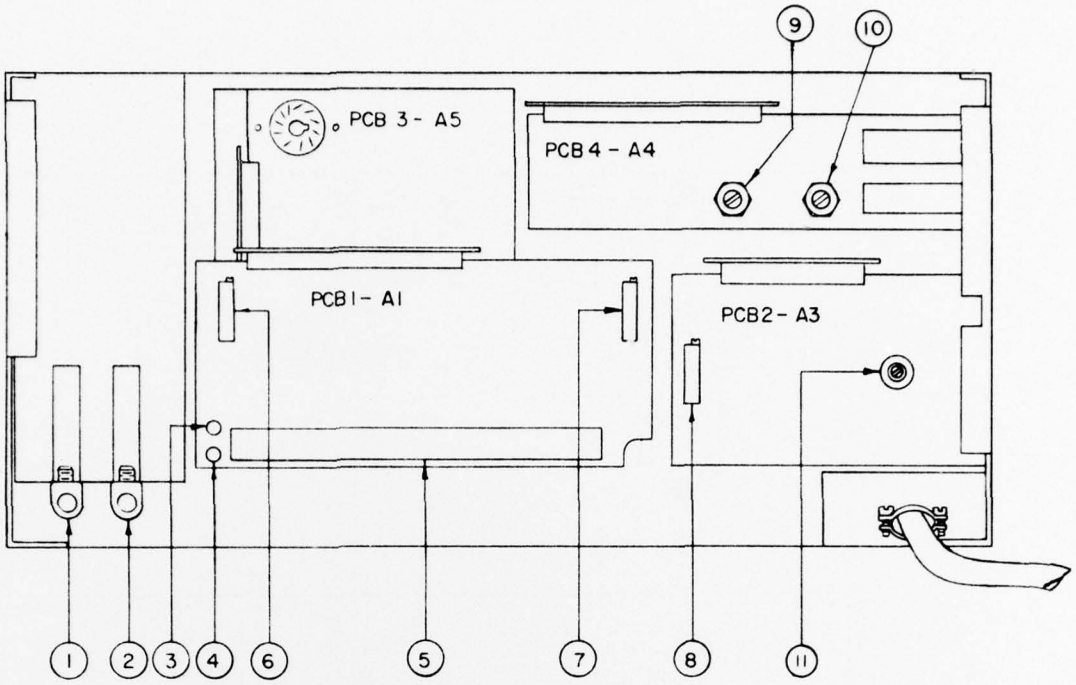


FIG. 2-3 TERMINATIONS, REAR

TABLE 2-2 TERMINATIONS, REAR

NO.	TERMINATION OR CONTROL	FUNCTION
1	OUTPUT TERMINAL(−)	MINUS TERMINAL, DC OUTPUT
2	OUTPUT TERMINAL(+)	PLUS TERMINAL, DC OUTPUT
3	VIX CONNECTOR	VIX SIGNAL OUTPUT (+ IN V MODE, − IN I MODE)
4	VIX CONNECTOR	VIX SIGNAL OUTPUT (− IN V MODE, + IN I MODE)
5	REAR BARRIER STRIP	16 CONNECTIONS TO INTERNAL CIRCUITRY (SEE SECT. 3)
6	R40, POTENTIOMETER	MAXIMUM CURRENT ADJUST (SEE SECT. 5)
7	R42, POTENTIOMETER	MAXIMUM VOLTAGE ADJUST (SEE SECT. 5)
8	R311, POTENTIOMETER	MAXIMUM PASS VOLTAGE ADJUST (SEE SECT. 5)
9	R402, POTENTIOMETER	CURRENT COMPANSATOR ADJUST (SEE SECT. 5)
10	R404, POTENTIOMETER	AMMETER CALIBRATION (SEE SECT. 5)
11	R322, POTENTIOMETER	LINE VOLTAGE FEEDBACK ADJUST (SEE SECT. 5)

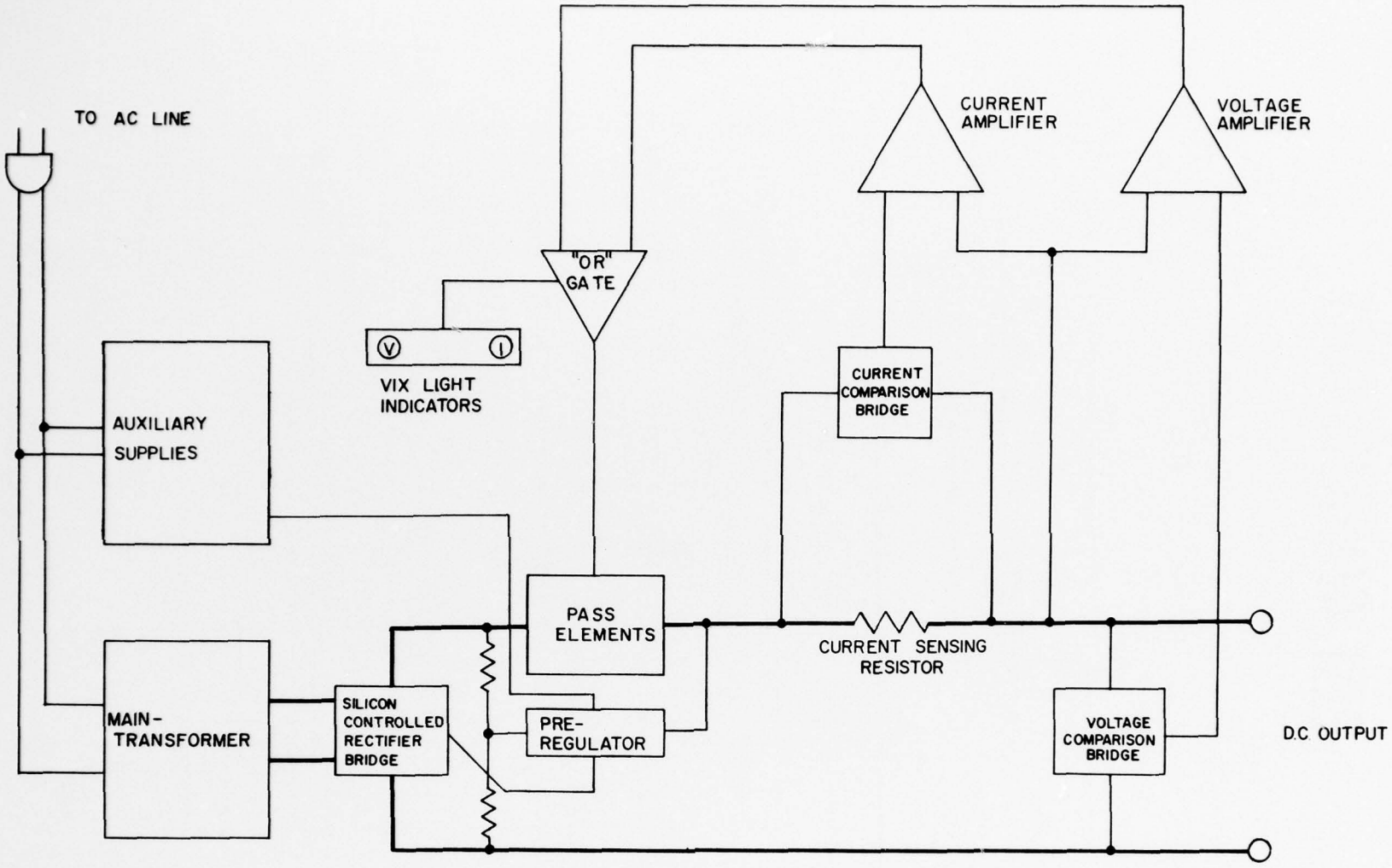


FIG. 4-2 KEPCO KS SERIES POWER SUPPLY, BLOCK DIAGRAM

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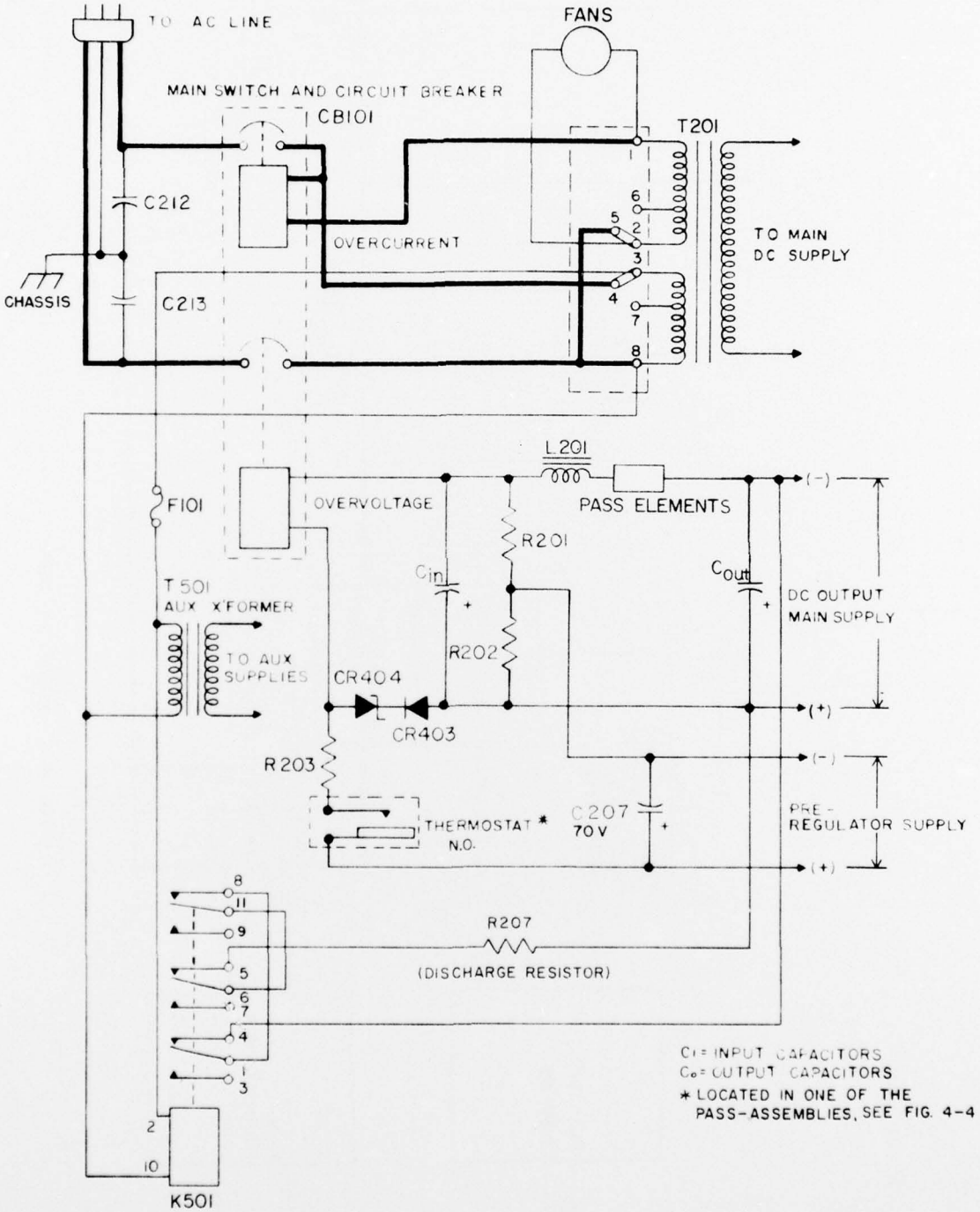


FIG. 4-3, AC INPUT CIRCUIT
SIMPLIFIED

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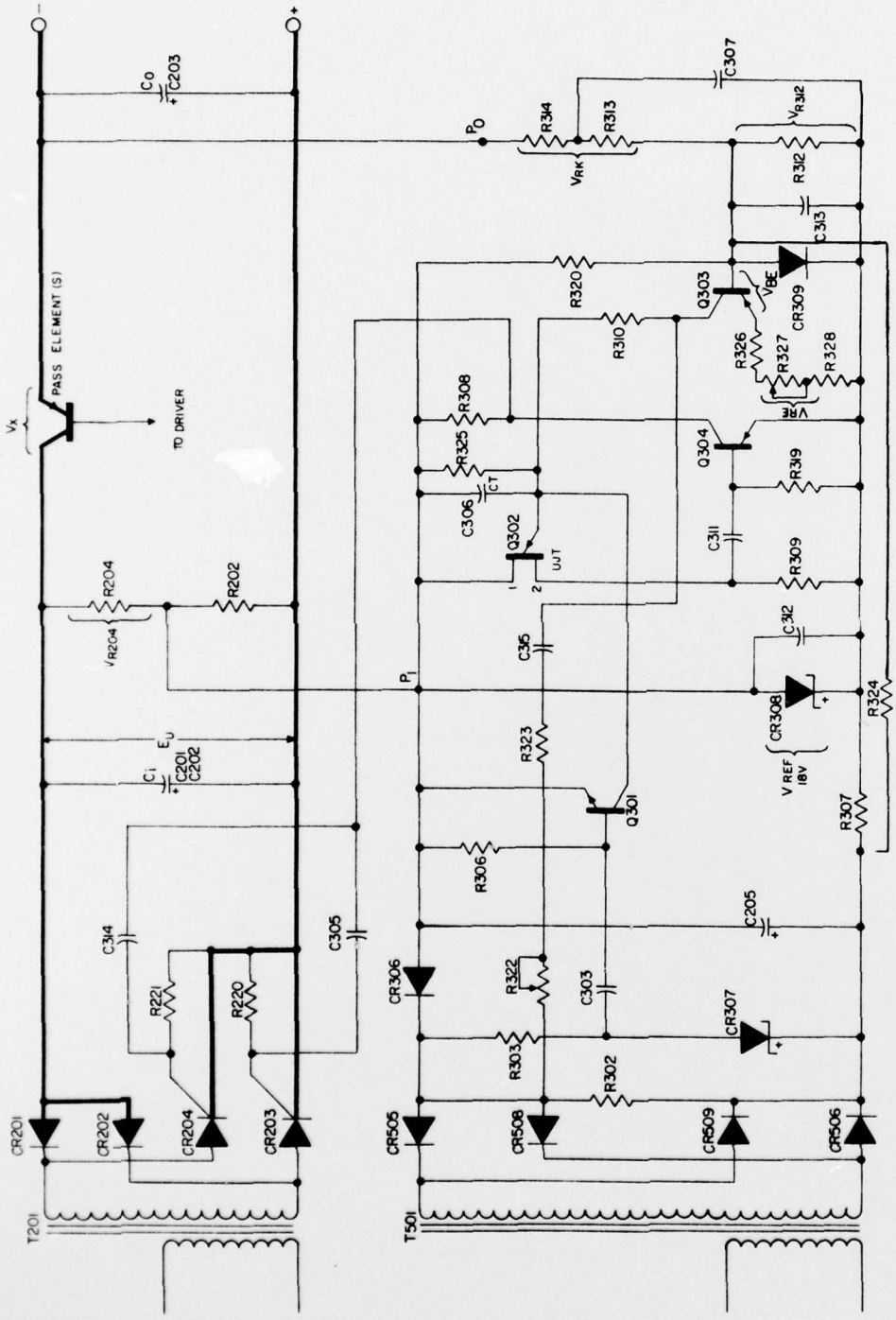
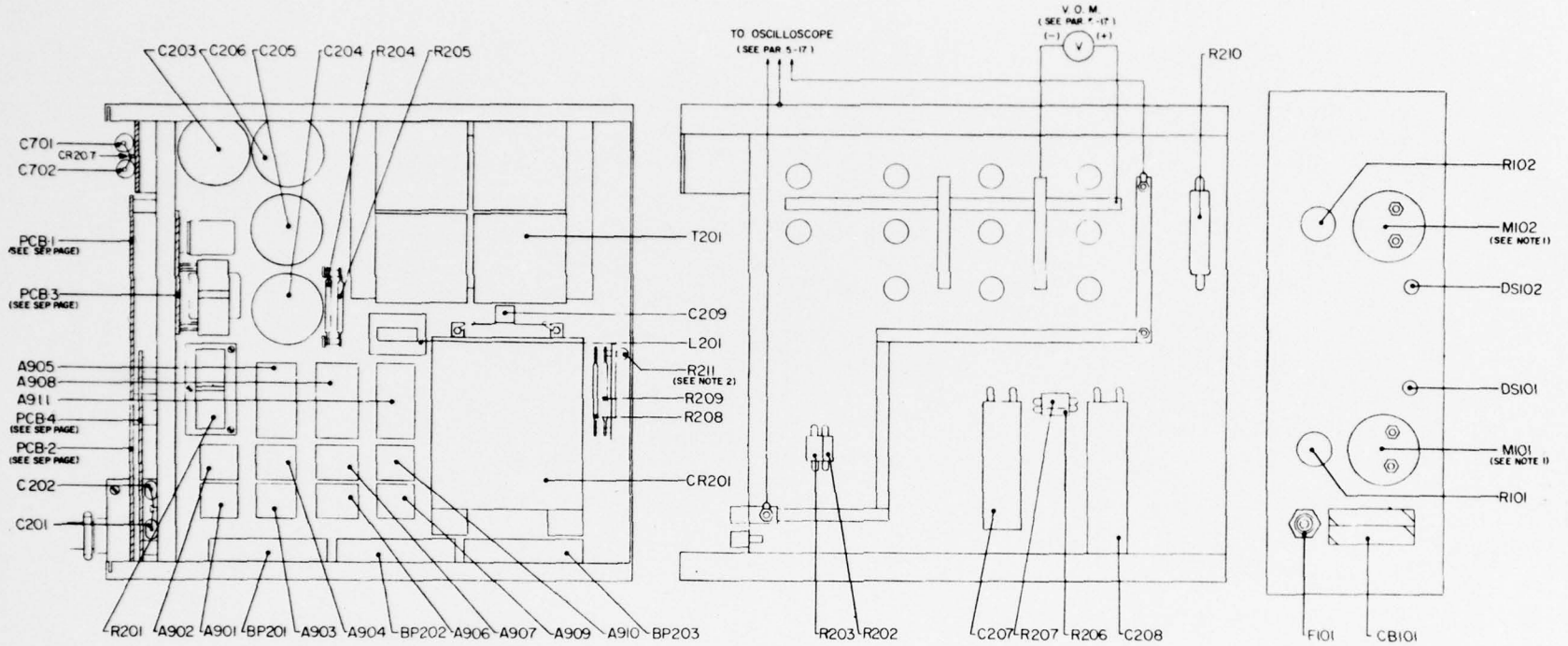


FIG. 4-5 PRE-REGULATOR CIRCUIT SIMPLIFIED

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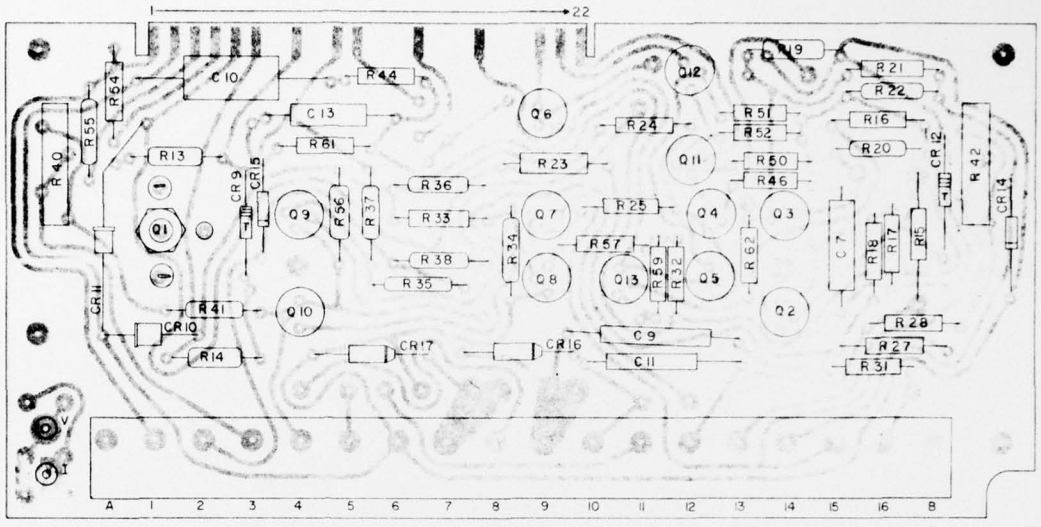
FIG 4-7 CONTROL SECTION, KS POWER SUPPLIES, SIMPLIFIED.

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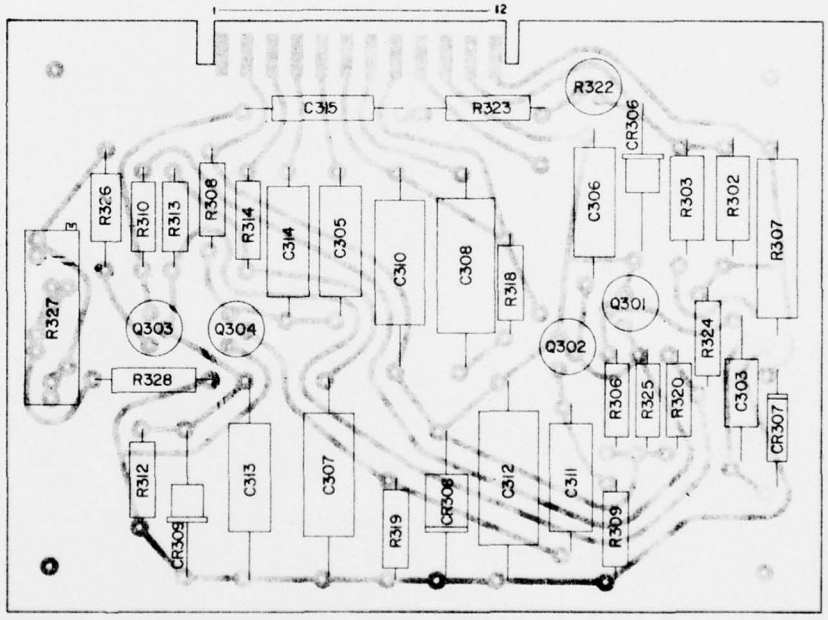


NOTES:
1. MI01 & MI02 ON METERED UNITS ONLY.
2. R211 ON UNMETERED UNITS ONLY.

FIG. 5-2 COMPONENT LOCATION, MAIN CHASSIS ASSEMBLY (A-2)



A) ASSEMBLY A1, PCB 1

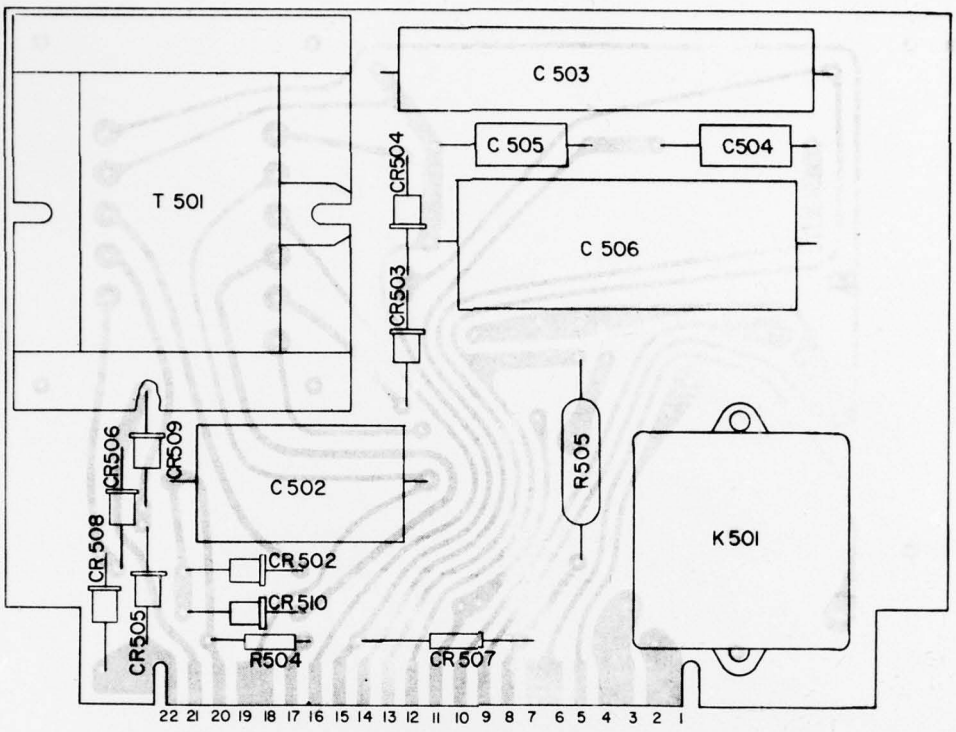


B) ASSEMBLY A3, PCB 2

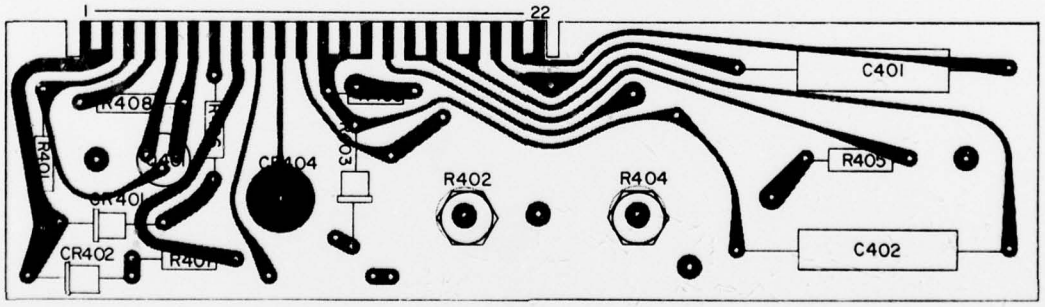
NOTE : ON MODEL KS 120-10M C308 IS OMITTED.

FIG. 5-7 COMPONENT LOCATION, PRINTED CIRCUIT BOARDS

A) ASSEMBLY A1
B) ASSEMBLY A3
C) ASSEMBLY A5
D) ASSEMBLY A4



C) ASSEMBLY A5, PCB 3

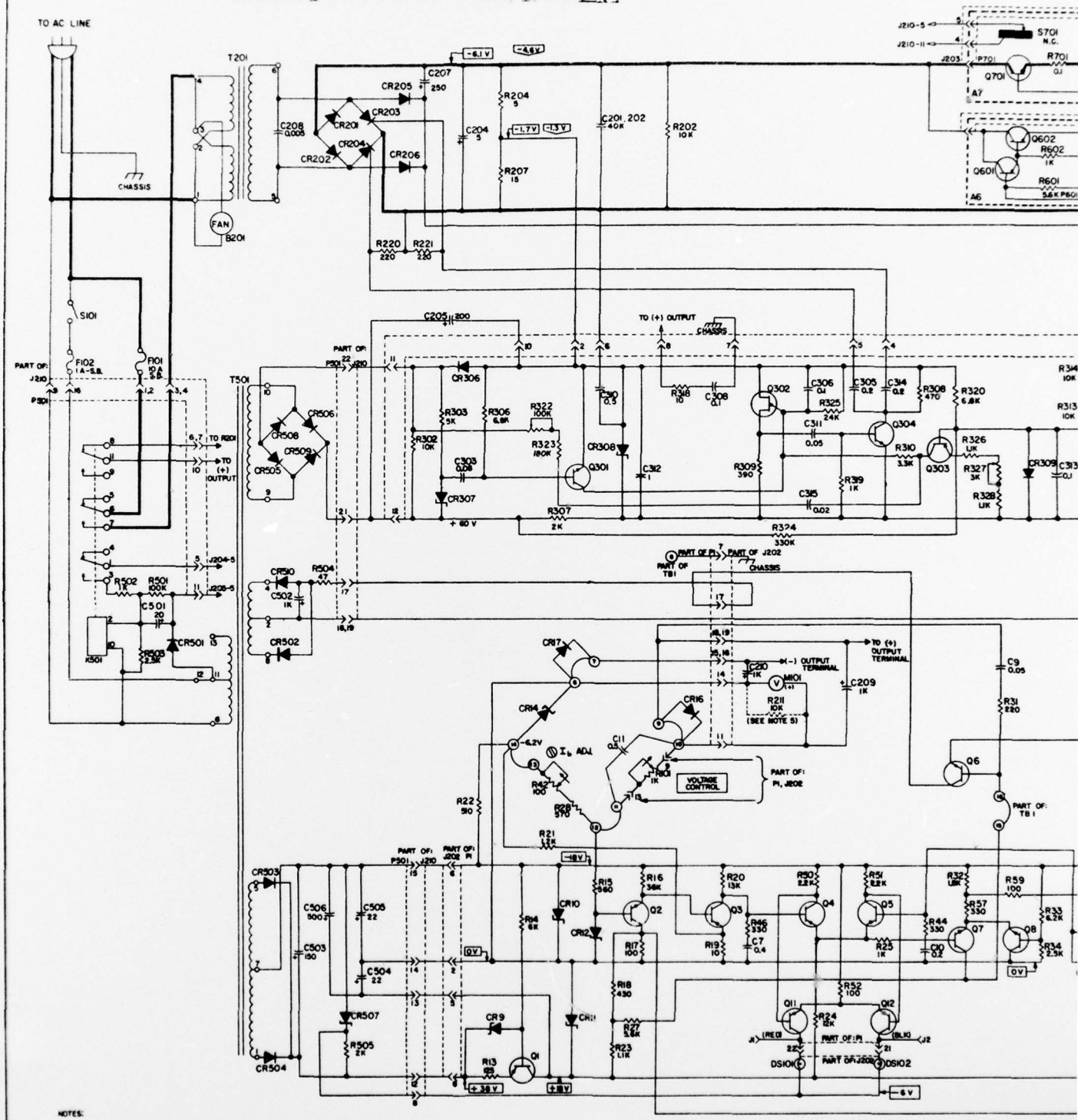


NOTES:
1. THIS DRAWING USED FOR MODELS KS8-100M, KS36-30M AND KS18-50M.
2. R408 USED IN KS8-100 ONLY.

D) ASSEMBLY A4, PCB 4

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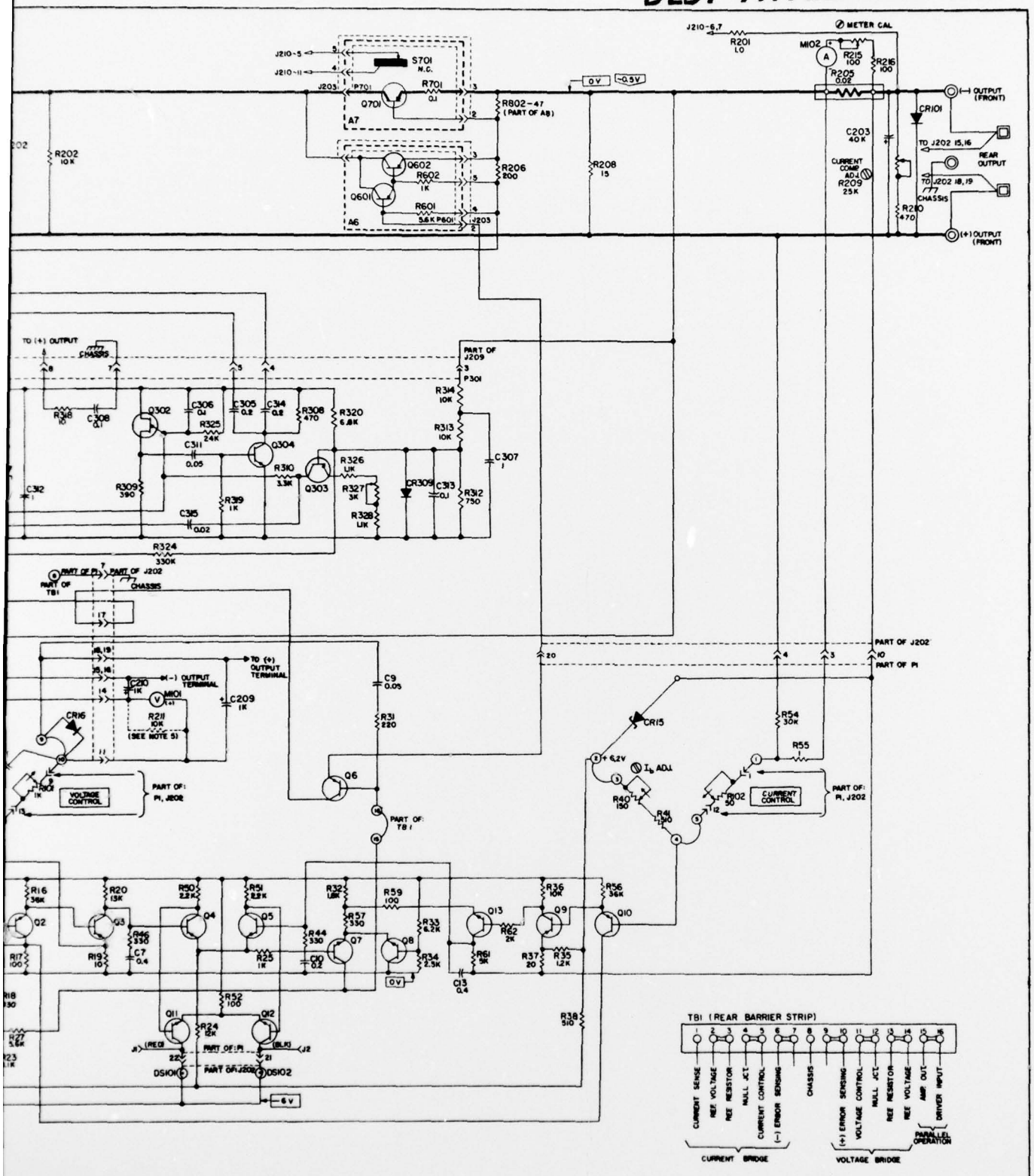
NOTES:

1. K501 IS A PLUG-IN TYPE RELAY, WITH AN 11 PIN PLUG. THE NUMBERS REPRESENT PIN NUMBERS.
2. ALL RESISTOR VALUES ARE IN OHMS, K=1,000.
   ALL CAPACITOR VALUES ARE IN MICROFARADS, K=1,000.
3. VOLTAGE READINGS IN RECTANGLES (▭) ARE TYPICAL VALUES FOR VOLTAGE MODE OPERATION WITH AC LINE AT 115 VAC, 60 CPS, DC OUTPUT VOLTAGE SET TO MAXIMUM, AND AT NO LOAD MEASUREMENTS REFERRED TO (-) OUTPUT TERMINAL.
4. VOLTAGE READINGS IN (S) SIDED SYMBOLS (⬭) ARE TYPICAL VALUES FOR CURRENT MODE OPERATION AT MAXIMUM OUTPUT VOLTAGE AND CURRENT. MEASUREMENT REFERRED TO (-) OUTPUT TERMINALS.
5. M101, M102, R215, R216 IN METERED UNITS ONLY. R211 IS USED IN UNMETERED UNITS ONLY.
6. ORDER REPLACEMENT PARTS BY KEPCO PART NUMBER SEE PARTS LIST
7. VOLTAGE READING WHICH APPLY TO NOTES 3 & 4 ARE TYPICAL AND SUBJECT TO COMPONENT TOLERANCES.

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Data subject to change without notice
PATENT NOTICE: Applicable Patent Nos. ● will be supplied on request.

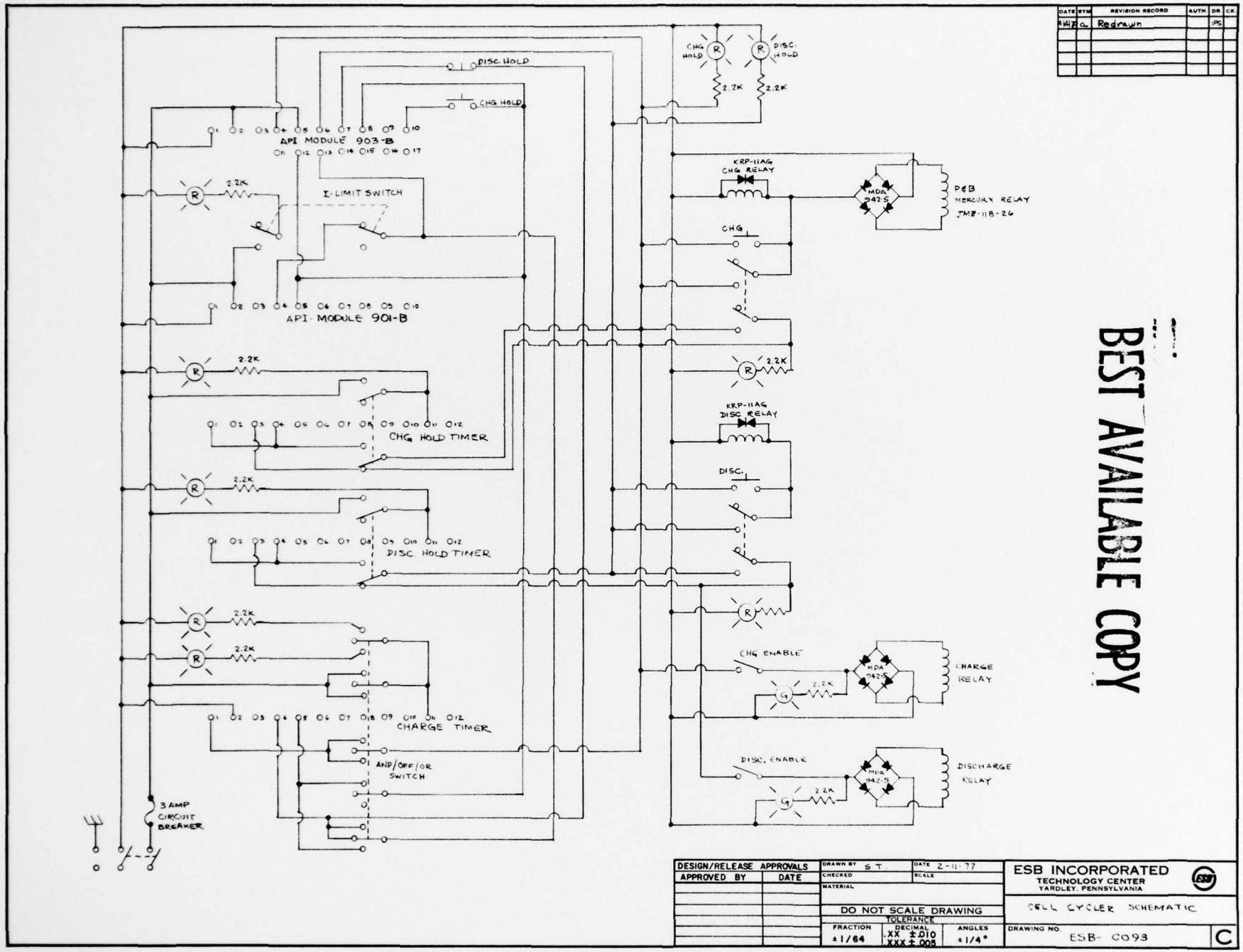
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PATENT NOTICE: Applicable Patent Nos. ● will be supplied on request.

FIG. 5-8 MAIN SCHEMATIC, MODEL KS8-25



DATE	SYM	REVISION RECORD	AUTH	DR	CK
4/4/77	A	Redrawn		JPS	

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DESIGN/RELEASE APPROVALS	
APPROVED BY	DATE

DRAWN BY S.T.	DATE 2-11-77	ESB INCORPORATED	
CHECKED	SCALE	TECHNOLOGY CENTER	
MATERIAL		YARDLEY, PENNSYLVANIA	
DO NOT SCALE DRAWING		CELL CYCLER SCHEMATIC	
TOLERANCE		DRAWING NO. ESB- C093	C
FRACTION ±1/64	DECIMAL .XX ±.010 .XXX ±.005	ANGLES ±1/4°	