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Engineering Design, Construction, Operation, and Maintenance of the 7-Ohm Line and Relativistic Klystron Facilities

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SFA--93/004

Engineering Design, Construction, Operation, and Maintenance for the 7-Ohm Line and Relativistic Klystron Facilities

SFA, Inc.
1401 McCormick Drive
Landover, Maryland 20785

Contract Number: N00014-89-C-2042

Prepared for: Naval Research Laboratory
4555 Overlook Avenue, SW
Washington, DC 20375-5000

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13. ABSTRACT (Maximum 200 words) SFA designed, built, installed, operated, and maintained special-purpose equipment and fixtures in support of experimental research in high-power RF radiation and particle acceleration. Specifically, SFA personnel designed and fabricated hardware for experimental application of the 7-Ohm line generator; modulated intense relativistic electron beams (IREBs); constructed magnetic field coils and low-voltage, high-energy capacitor banks; upgraded the relativistic klystron facility; and designed and fabricated a relativistic klystron amplifier.				
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Under contract N00014-89-C-2042, SFA designed, built, installed, operated, and maintained special-purpose equipment and fixtures in support of experimental research in high-power RF radiation and particle acceleration. Specifically, SFA personnel worked on the following tasks:

- Design and Fabrication of Hardware for Experimental Application of the 7-Ohm Line Generator
- Modulation of Intense Relativistic Electron Beams (IREBs)
- Construction of Magnetic Field Coils and Low-Voltage, High-Energy Capacitor Banks
- Upgrade of the Relativistic Klystron Facility
- Design and Fabrication of Relativistic Klystron Amplifier

Design and Fabrication of Hardware for Experimental Application of the 7-Ohm Line Generator

SFA designed and built new hardware to apply the 7-ohm line generator to different experiments. This generator is a high-voltage machine constructed out of a 700 kV Marx generator, a pulse-forming line, and a high-voltage diode. The generator is constantly changed to match different experimental requirements. SFA personnel performed mechanical tasks related to the preparation, maintenance, and operation of this high-voltage machine. SFA planned, installed, and removed the scientific devices used as support equipment in the experimental area, and assisted in the assembly, rigging, and repair of devices used in the various experiments. SFA personnel maintained the vacuum pumps and oil and water systems. SFA also performed general maintenance on the 700 kV Marx generator, which included periodically cleaning the Marx column and triggering system. Other duties included routinely cleaning the high-voltage diode and pulse line, maintaining the vacuum system, and fabricating carbon cathodes and stainless steel cathode stocks.

Modulation of Intense Relativistic Electron Beams

To modulate the intense relativistic electron beams (IREBs), SFA designed and built structures consisting of coaxial cavities, which were pumped to a pressure of 10^{-5} Torr and maintained in close tolerance. The structures were machined out of stainless steel, and the surfaces of the cavities were lined with a 1-millimeter layer of either copper or silver. The mechanical design of these structures required familiarity with microwave circuit design. SFA fabricated, assembled, and installed the coaxial cavities; solved problems within the system; and applied leak detection techniques. SFA personnel also performed calibration checks and adjustments on vacuum systems, and aligned the cavities.

Construction of Magnetic Field Coils and Low-Voltage, High-Energy Capacitor Banks

SFA personnel constructed magnetic field coils and low-voltage, high-energy capacitor banks. This work included making forms, made of a non-conducting material, on which magnetic wires were wound as a long or short solenoid. The magnetic field coil withstood a minimum magnetic force of 10 kg/cm^2 during a minimum operation of 100 ms. The coil was energized by a 20 kV capacitor bank operated by ignitrons. SFA's responsibilities included layout, materials flow and handling, assembly, cost reduction, problem solving, fabrication, and quality control. SFA also ensured that proper grounding techniques and safety methods for high-voltage equipment were followed.

Upgrade of the Relativistic Klystron Facility

SFA personnel upgraded the relativistic klystron facility. SFA's responsibilities for this project included planning, construction, alteration, maintenance, setup, operation, and repair services for the facility's reconstruction. SFA managed the rigging subcontractor in the relocation of experimental components. In addition, SFA designed and installed acoustical partitions to buffer this high-noise facility from administrative support personnel. SFA installed capacitor banks, a Marx column, and a triggering system in the new Marx tank. SFA personnel constructed the pulse line and high-voltage diodes; installed the capacitor bank for low-voltage, high-energy magnetic-field coils; and installed a circulating water system and control panel for the pulse line and magnetic field coil. SFA also rewired the screen room for electronic equipment and installed a vacuum system for the high-voltage diode.

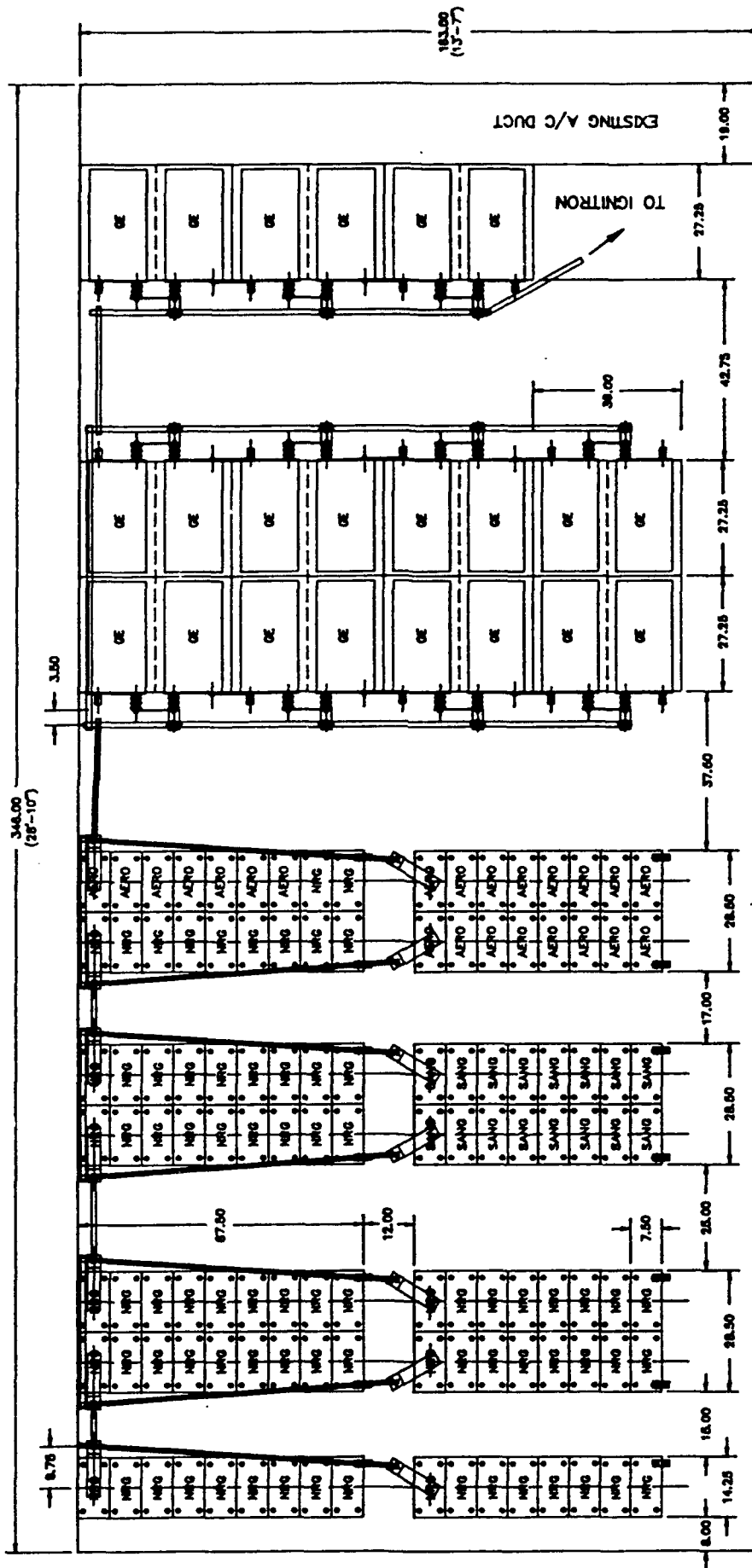
Design and Fabrication of Relativistic Klystron Amplifier

SFA designed and built a high-power relativistic klystron amplifier with a complete vacuum system (see Appendix). SFA personnel provided the engineering design and fabrication drawings for the coaxial high-voltage generator facility. SFA provided the layout of the floor plan for the new facility. SFA personnel laid out and installed 250 energy storage capacitors connected together with resistors, contact switches, and grounding systems. SFA personnel designed and prepared fabrication drawings of an oil tank and a high-voltage parallel transmission line to be connected to the existing 7-ohm Blumlein and Marx generator. SFA also designed and prepared fabrication drawings of the diode sub-assembly with a double insulator. Fabrication drawings were designed and prepared for a pumping ports housing with two ports connected to a diffusion pump, cold trap, and a mechanical gate valve through a pump adapter, with a third port connected to a large mechanical booster pump to increase vacuum pumping speed. SFA provided fabrication drawings for a viewing port housing with six rectangular ports, used for diagnostic testings and for access to the double insulator to clean carbon residue. SFA prepared fabrication drawings of the cathode sub-assembly and designed an end cover plate with test probes. Outer and inner magnetic field coils were designed. SFA personnel designed and prepared fabrication drawings for the cart to support the outer magnetic field coil. This cart can adjust the coil to its required height and position, and may move toward or away from the diode using dual roundway bearings that sit on tracks in the floor. SFA personnel performed the layout of the L-band waveguide transmission line to connect an existing magnetron located in an adjacent laboratory to the new facility. An L-band splitter was designed; the splitter, a waveguide switch, three isolators, and two bi-directional couplers were installed in the L-band waveguide transmission line. Radio frequency and microwave leak tests were performed on all joints after the system was installed.

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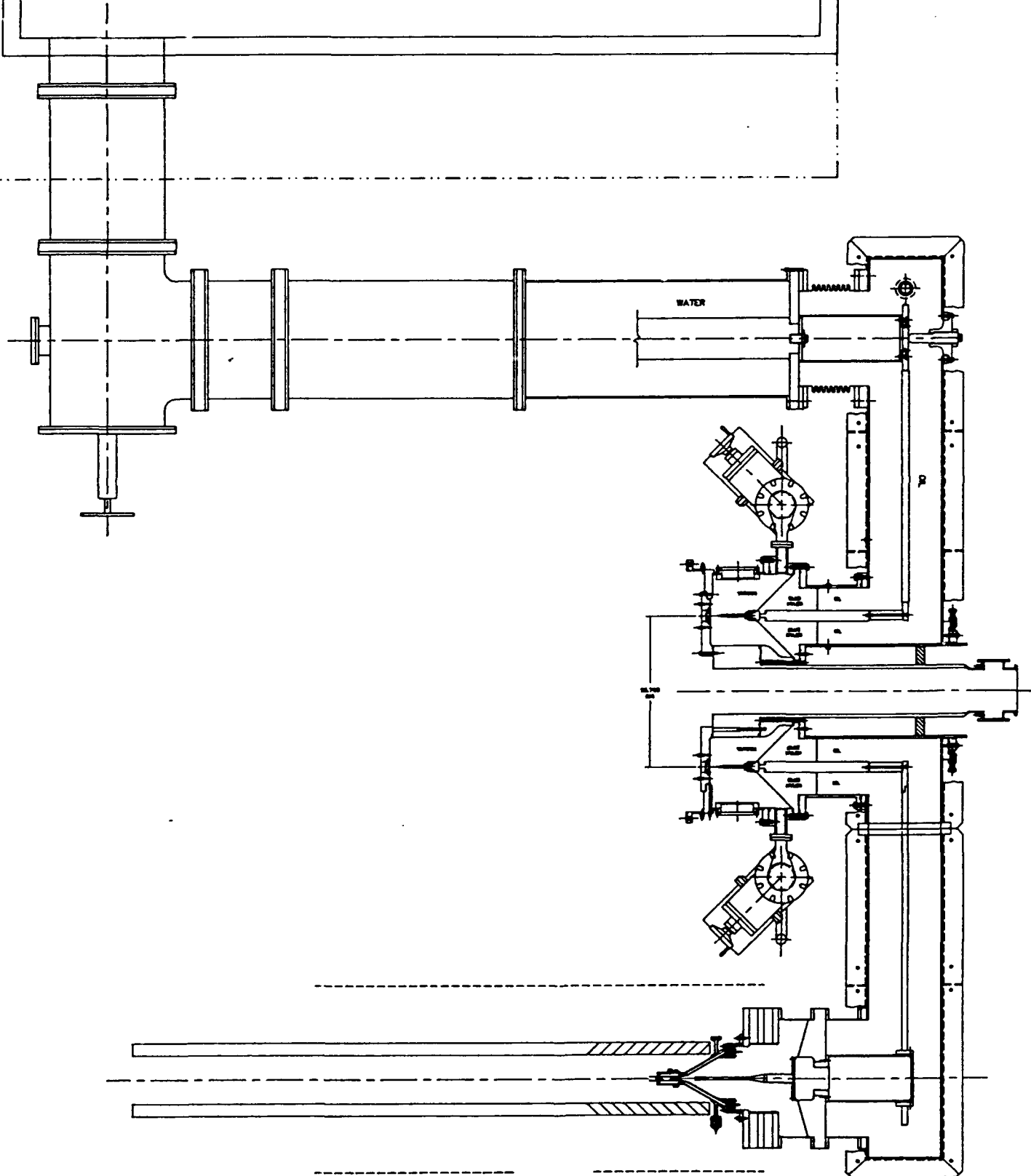


Capacitor layout, building 101, room 140

CAPACITOR LAYOUT
BLDG 101, RM 140

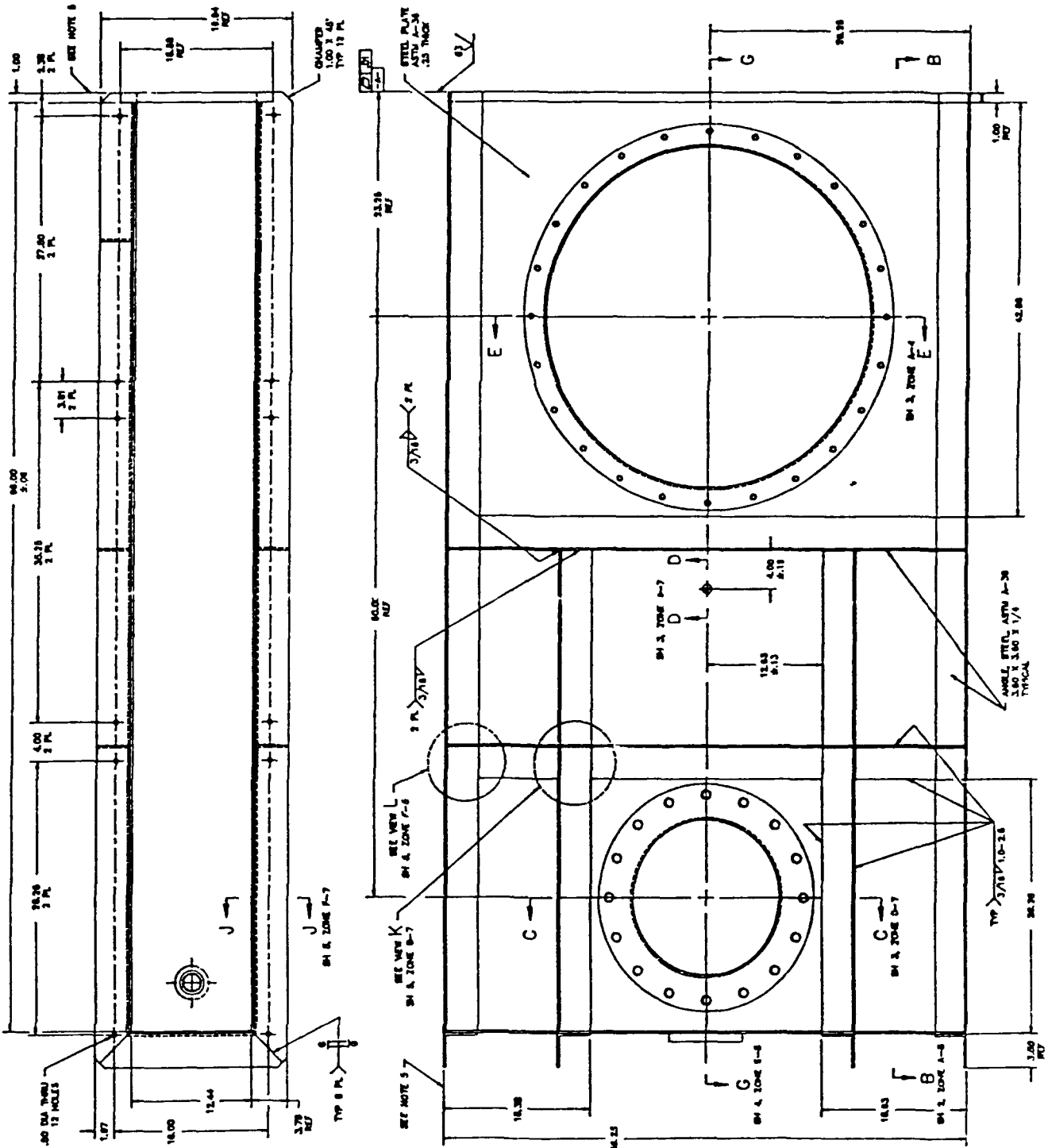
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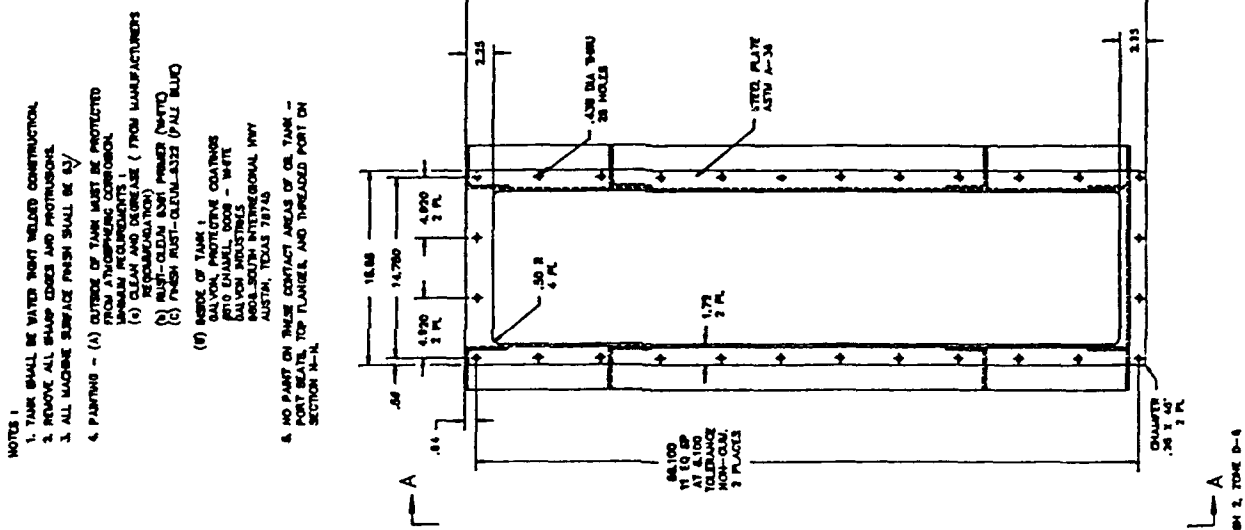
MARX TANK



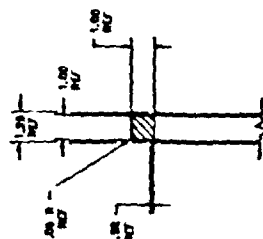
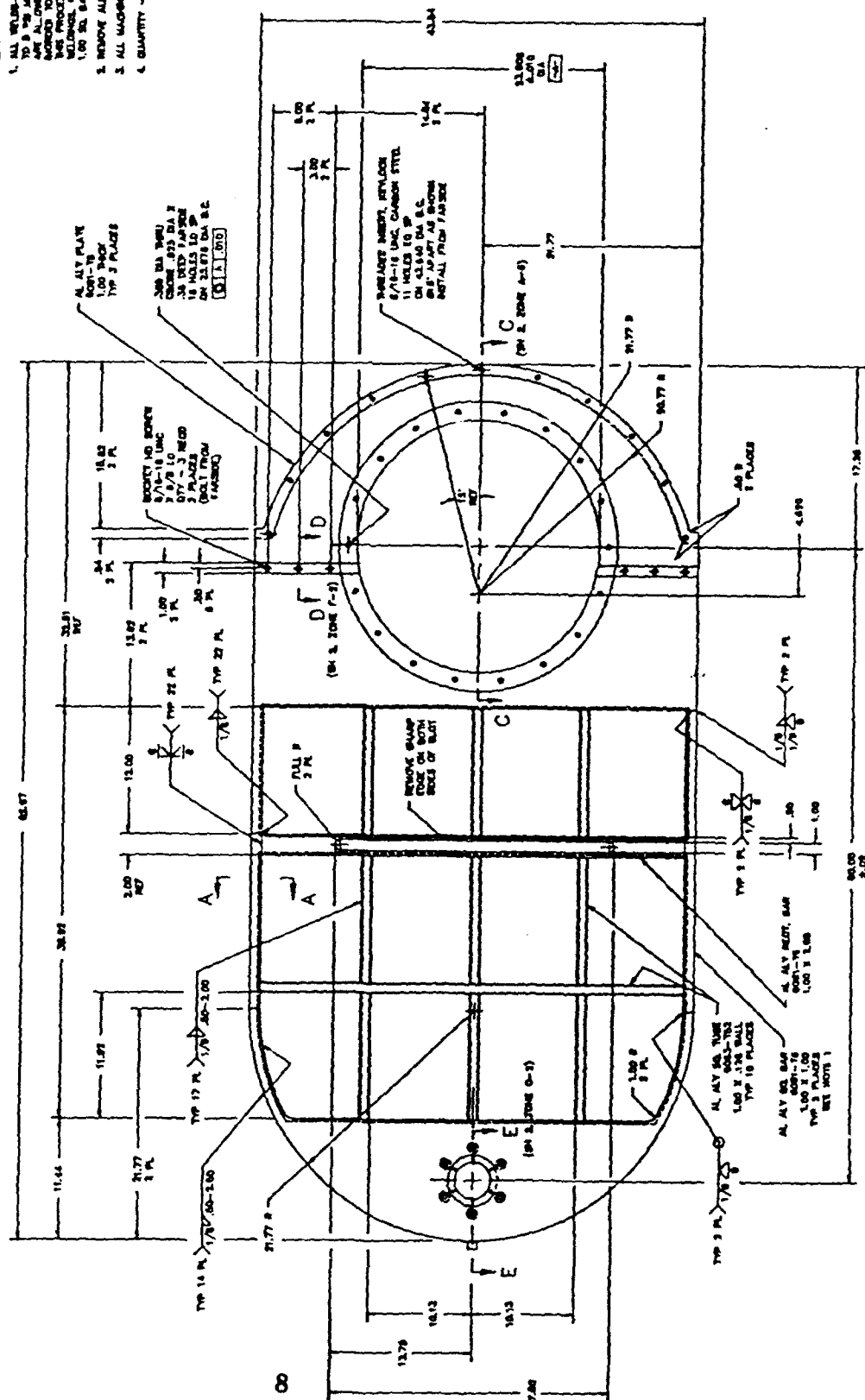
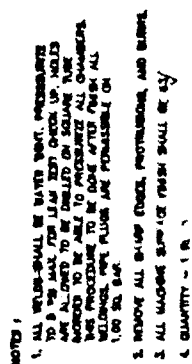
Coaxial high-voltage generator

Oil tank





OIL TANK, EXTENSION



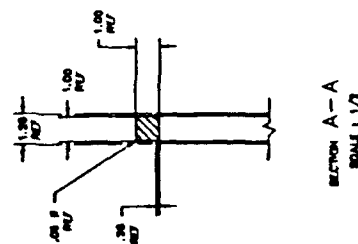
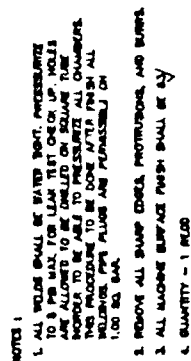
SECTION A-A
SCALE: 1/2"

THOMAS PLATES NOT SHOWN

High-voltage parallel transmission line

H.V. PARALLEL
TRANSMISSION LINE

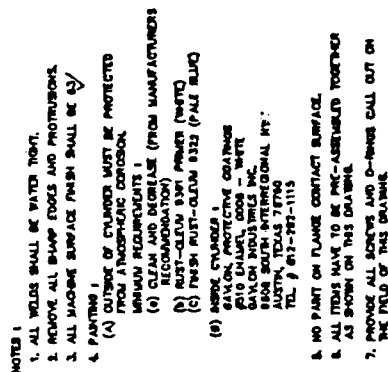
01-0010



H.V. PARALLEL
TRANSMISSION LINE EXT.

High-voltage parallel transmission line, extension

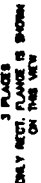
01-0019



Coaxial high-voltage generator diode sub-assembly

TOLERANCES	
DEFINIALS	ANGLES
XX 4.02	40'0"
XX 4.008	

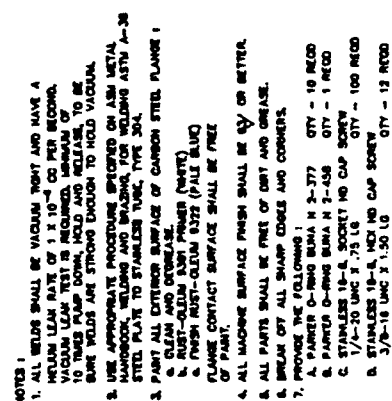
COAXIAL H.V. GENERATOR DIODE SUB-ASSY	91-0021
--	---------



Pumping ports housing

[illegible]

4. ALL MACHINE SURFACE FINISH SHALL BE 63 OR BETTER.
5. QUANTITY - 1 PCED

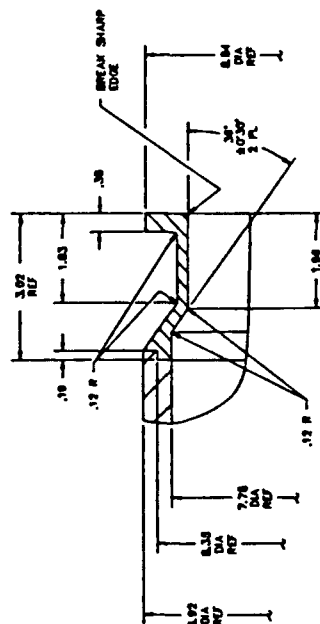


VIEW B
SCALE: 1/4"



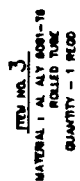
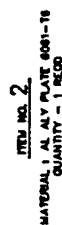
NOTES:

1. ALL BOLDS SHALL BE VACUUM TEST AND HAVE A VACUUM LEAK RATE OF 10⁻⁶ CC PER SECOND. THESE PARTS SHOULD BE WASHED AND DRYED TO BE SURE BOLDS ARE STRONG ENOUGH TO HOLD AND HOLD TOGETHER.
2. ALL MACHINE SURFACE FINISH SHALL BE $\frac{1}{2}$ OR BETTER.
3. BREAK OUT ALL SHARP EDGES AND CORNERS.
4. ALL PARTS SHALL BE FREE OF DIRT AND GRIT.
5. ALL PLUNGED AND CONTACT SURFACES HAVE TO BE FLUSHED AFTER PLUNGING.



ITEM NO. 1
QUANTITY - 1 RECD

91-0029

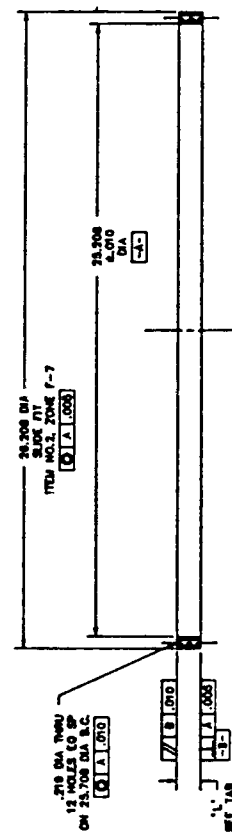


DASH NO.	QTY	MATERIAL
-1	400	LUOTE BAR 1.00 DIA
-2	90	* GRAPHITE BAR, GRADE DFP-1, 1.00 DIA X 1 FT LG

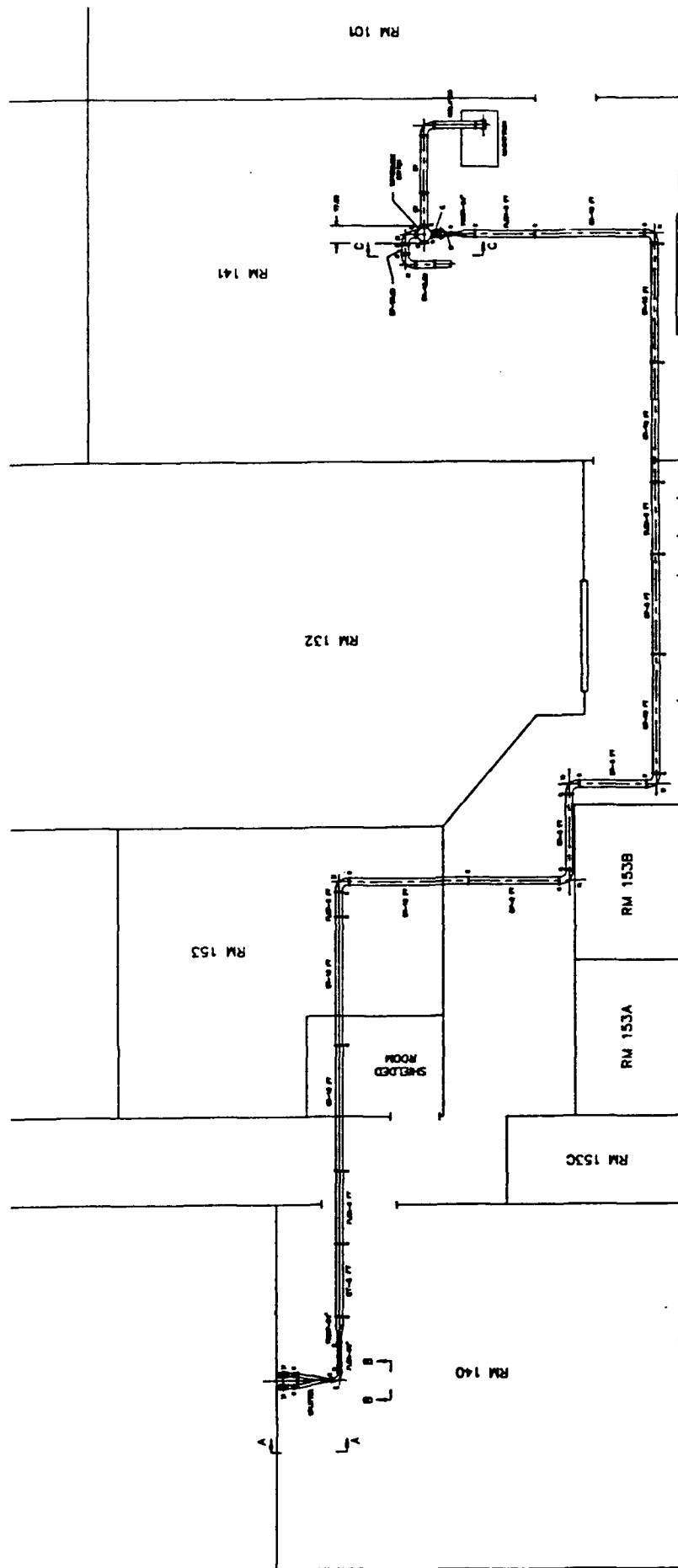
POOD GRAPHITE INC.
DECATUR, TX 76234
TEL 817-627-2121

DASH NO	QTY	%
-1	1	.30
-2	1	.78
-3	1	1.00

ITEM NO. 4
MATERIAL: AL ALY 6061-T6



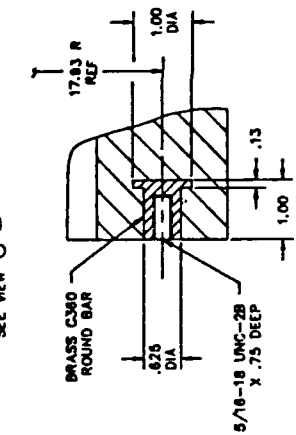
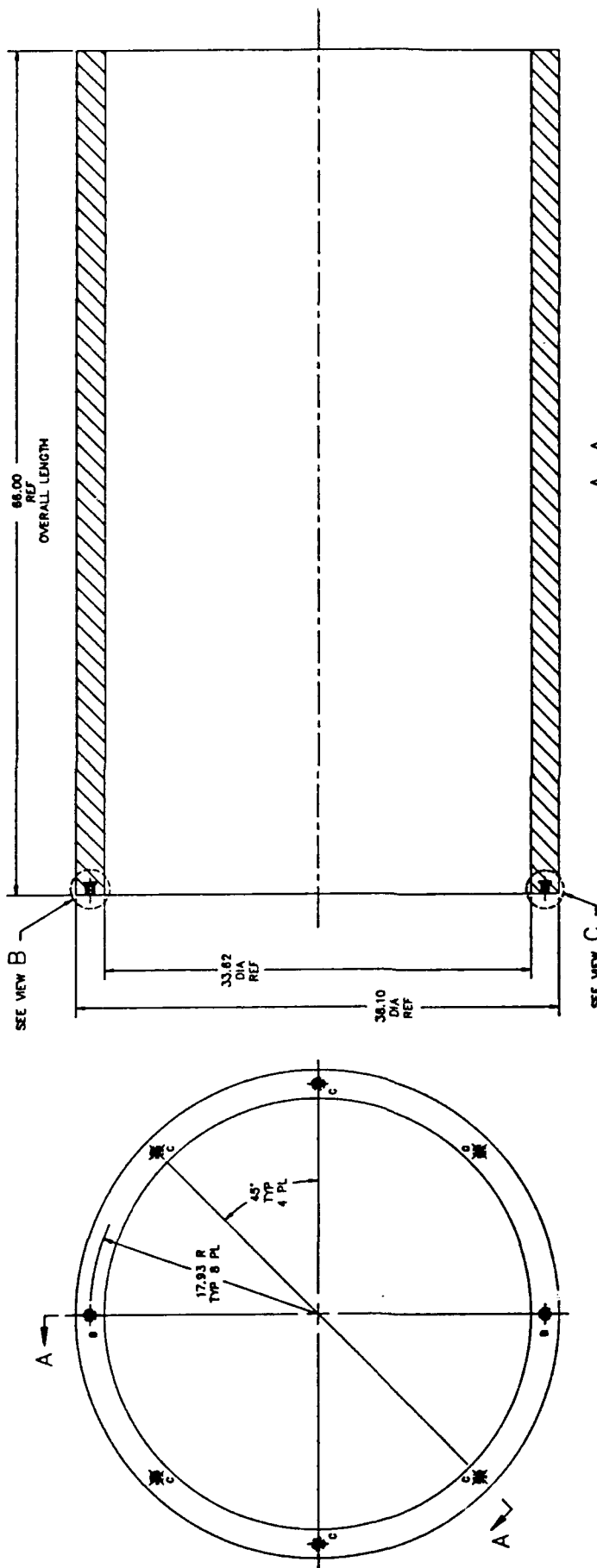
11



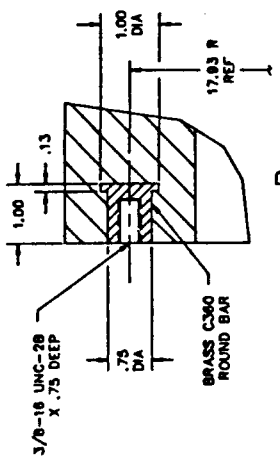
L-BAND WAVEGUIDE
TRANSMISSION LINE

L-band waveguide transmission line

DATE: 1/14/78



5/16-18 UNC HOLES MARK "C"
6 PLACES AT 45° AS SHOWN
WILL BE USED FOR MECHANICAL PURPOSE
FOR THE DESIGN CONSTRUCTION OF THE BRASS BLOCK
ANYTHING SIMILAR OR EQUIVALENT IS PERMISSIBLE
SCALE : 1/1

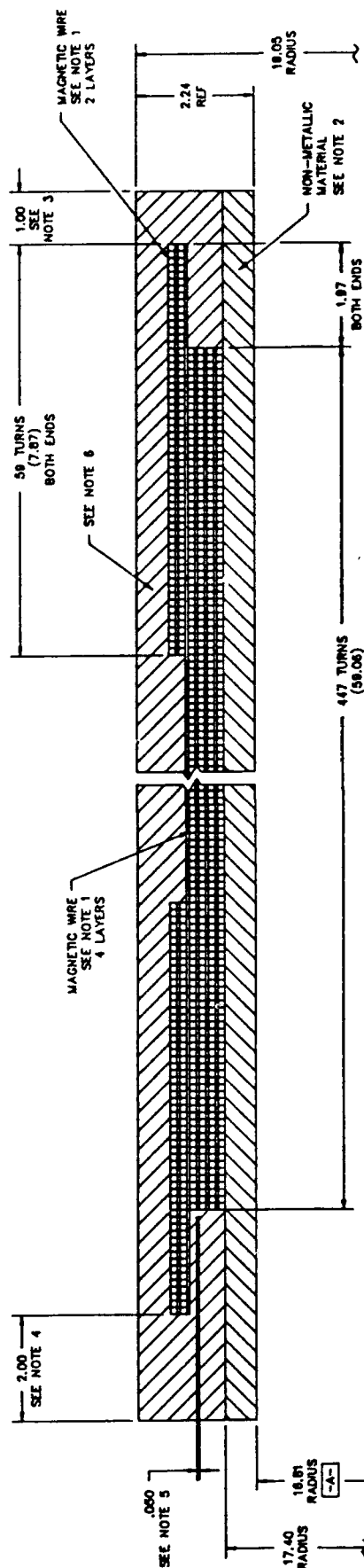


2 PLACES AT 180° APART
FOR ELECTRICAL TERMINAL "IN" & "OUT"
FOR THE DESIGN CONSTRUCTION OF THE BRASS BLOCK
ANYTHING SIMILAR OR EQUIVALENT IS PERMISSIBLE
CONNECTIONS TO WIRE DESIGN CONSTRUCTION
TO BE DETERMINED BY MANUFACTURER
DIMENSIONS SHOWN ARE REFERENCE ONLY
SCALE : 1/1

OUTER INDUCTIVE COIL
(LARGE)

91-0051
W-12

Outer inductive coil (large)



NOTES:

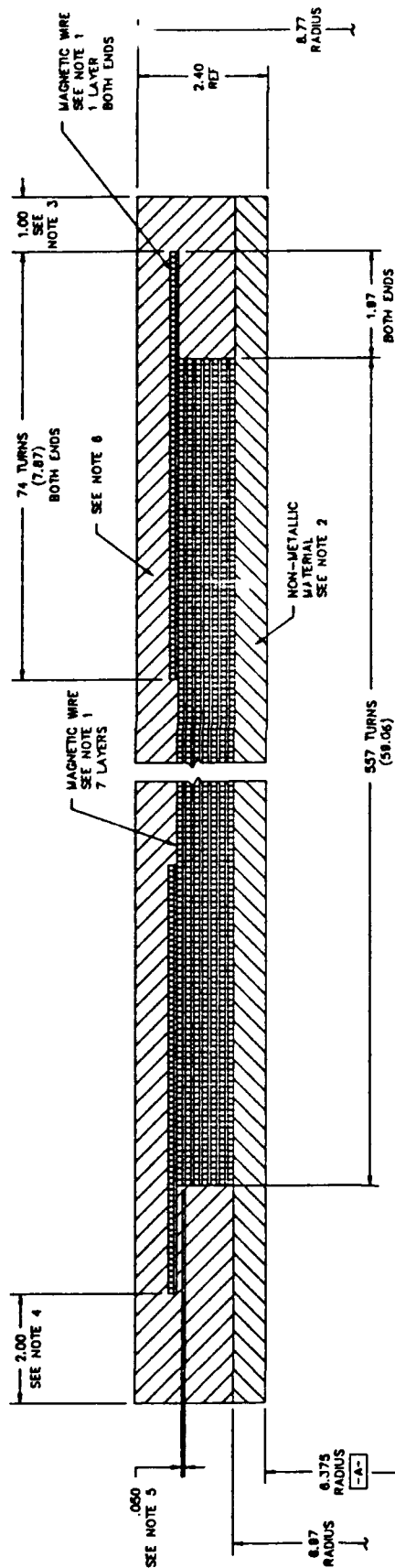
1. SQUARE INSULATED MAGNET WIRE, GAGE #8, 0.1285" X 0.1285" BARE WIRE, INSULATION CAPABLE TO WITHSTAND TEMPERATURES IN EXCESS OF 100 DEG CENTIGRADES AND HOLD OFF VOLTAGES OF 20 VOLTS BETWEEN ADJACENT TURNS.
2. MAGNET WIRE SHALL BE WOUND ON A NON-METALLIC TUBE, CAPABLE TO WITHSTAND THE WEIGHT OF THE WIRE. THE INSIDE AND OUTSIDE DIAMETERS OF THE TUBE SHALL BE CONCENTRIC TO WITHIN ± 0.010 ".
3. LENGTH OF 1.00" OF INSULATING AND NON-METALLIC MATERIAL.
4. LENGTH OF 2.00" OF INSULATING AND NON-METALLIC MATERIAL.
5. EACH LAYER OF WIRE SHALL BE CONCENTRIC WITH DATUM A TO WITHIN ± 0.005 " ALONG THE ENTIRE LENGTH OF THE COIL. AFTER BEING WOUND, EACH LAYER OF MAGNET WIRE WILL BE WETTED WITH EPOXY AND COVERED WITH INSULATING PAPER. THE PAPER WILL EXTEND AXIALLY 0.5" BEYOND THE MAGNET WIRE LAYER (TO PREVENT SURFACE FLASHOVER), AND IT WILL OVERLAP ON ITSELF BY AT LEAST 1.0". SUBSEQUENTLY, THE WIRE LAYER WILL BE COVERED BY STRANDED FIBERGLASS WET-LAD PAPER. AFTER BEING CURED AND HARDENED THE FIBERGLASS INSULATION SHALL BE MACHINED SO THAT THE TOTAL INSULATION THICKNESS BETWEEN LAYERS IS 0.050" AND THE MACHINED SURFACE IS CONCENTRIC WITH DATUM A TO WITHIN ± 0.005 " ALONG THE ENTIRE LENGTH OF THE COIL.
6. INSULATING AND NON-METALLIC MATERIAL.

7. ALL LAYERS OF THE MAGNET WIRE SHALL BE WOUND IN THE SAME DIRECTION. FOR EXAMPLE, IF STARTED CLOCKWISE, ALL LAYERS WILL BE CLOCKWISE. THE HELIX OF THE WINDINGS SHALL BE OPPOSITE FROM LAYER TO LAYER. ALL WIRE CONNECTIONS SHALL BE IN SERIES, CONNECTING AN END OF ONE LAYER TO THE BEGINNING OF THE NEXT ONE.
 8. MAGNET WIRE USED IN EACH LAYER SHALL BE CONTINUOUS. NO JOINT IS PERMISSIBLE. CONNECTIONS BETWEEN LAYERS WILL BE DONE BY BRAZING.
 9. INSIDE DIAMETER TOLERANCE ± 0.0007 , OUTSIDE DIAMETER TOLERANCE ± 0.0007 .
 10. THE ENDS OF THE COIL SHALL BE VACUUM IMPREGNATED WITH EPOXY IN SUCH A WAY THAT THE EPOXY COMPLETELY FILLS THE Voids CREATED BY THE INSULATING PAPER EXTENDING BETWEEN THE WIRE LAYERS.
- SPECIFICATIONS AND REQUIREMENTS:
1. OPERATING VOLTAGE OF 15 KV ON TERMINALS.
 2. PULSE DURATION - 200 MILLISEC ONDS OR LARGER.
 3. MECHANICALLY ABLE TO WITHSTAND MAGNETIC FIELDS OF UP TO 15 MOUSSES.
 4. MINIMUM LIFETIME OF 10,000 SHOTS, AS PER CONDITIONS STATED IN 1, 2, & 3. ONE SHOT EVERY 6 MINUTES, AND NOT MORE THAN 50 SHOTS PER DAY.

Outer inductive coil (large)

OUTER INDUCTIVE COIL
(LARGE)

91-0051
REV 1-68



NOTES:

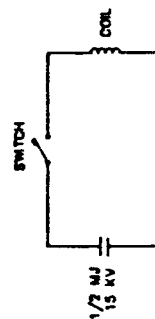
1. SQUARE INSULATED MAGNET WIRE, GAGE #10, 0.102" X 0.102" BARE WIRE INSULATION CAPABLE TO WITHSTAND TEMPERATURES IN EXCESS OF 100 DEG. CENTIGRADE AND HOLD OFF VOLTAGES OF 20 VOLTS BETWEEN ADJACENT TURNS.
2. MAGNET WIRE SHALL BE WOUND ON A NON-METALLIC TUBE, CAPABLE TO WITHSTAND THE WEIGHT OF THE WIRE. THE INSIDE AND OUTSIDE DIAMETERS OF THE TUBE SHALL BE CONCENTRIC TO WITHIN ± 0.010 ".
3. LENGTH OF 1.00" OF INSULATING AND NON-METALLIC MATERIAL.
4. LENGTH OF 2.00" OF INSULATING AND NON-METALLIC MATERIAL.
5. EACH LAYER OF WIRE SHALL BE CONCENTRIC WITH DATUM A TO WITHIN ± 0.005 " ALONG THE ENTIRE LENGTH OF THE COIL AFTER BEING WOUND. EACH LAYER OF MAGNET WIRE WILL BE WETTED WITH EPOXY AND COVERED WITH INSULATING PAPER. THE PAPER WILL EXTEND radially 0.5" BEYOND THE MAGNET WIRE LAYER (TO PREVENT SURFACE FLASHOVER), AND IT WILL OVERLAP ON ITSELF BY AT LEAST 1/8". SUBSEQUENTLY, THE OVERLAP WILL BE COVERED BY STRANDED FIBREGLASS WET-LAD WITH EPOXY. AFTER BEING CURED AND HANDLED THE FIBREGLASS INSULATION SHALL BE MACHINED SO THAT THE TOTAL INSULATION THICKNESS BETWEEN LAYERS IS 0.050" AND THE MACHINED SURFACES CONCENTRIC WITH DATUM A TO WITHIN ± 0.005 " ALONG THE ENTIRE LENGTH OF THE COIL.
6. INSULATING AND NON-METALLIC MATERIAL.

7. ALL LAYERS OF THE MAGNET WIRE SHALL BE WOUND IN THE SAME DIRECTION. FOR EXAMPLE, IF STARTED CLOCKWISE, ALL LAYERS WILL BE CLOCKWISE. THE MELX OF THE WINDINGS SHALL BE OPPOSITE FROM LAYER TO LAYER. ALL WIRE CONNECTIONS SHALL BE IN SERIES, CONNECTING AN END OF ONE LAYER TO THE BEGINNING OF THE NEXT ONE.
8. MAGNET WIRE USED IN EACH LAYER SHALL BE CONTINUOUS. NO JOINT IS PERMISSIBLE. CONNECTIONS BETWEEN LAYERS WILL BE DONE BY BRAZING.
9. INSIDE DIAMETER TOLERANCE ± 0.0080 ", OUTSIDE DIAMETER TOLERANCE ± 0.0080 ".
10. THE ENDS OF THE COIL SHALL BE VACUUM IMPREGNATED WITH EPOXY IN SUCH A WAY THAT THE EPOXY COMPLETELY FILLS THE VOIDS CREATED BY THE INSULATING PAPER EXTENDING BETWEEN THE WIRE LAYERS.

SPECIFICATIONS AND REQUIREMENTS:

1. OPERATING VOLTAGE OF 15 KV ON TERMINALS.
2. PULSE DURATION - 200 MILLISEC. OR LARGER.
3. MECHANICALLY ABLE TO WITHSTAND MAGNETIC FIELDS OF UP TO 15 KG/AUSS.
4. MINIMUM LIFE TIME OF 10,000 SHOTS, AS PER CONDITIONS STATED IN 1, 2, 3, 4, 5, ONE SHOT EVERY 6 MINUTES, AND NOT MORE THAN 50 SHOTS PER DAY.

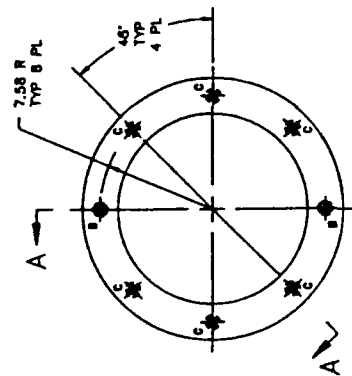
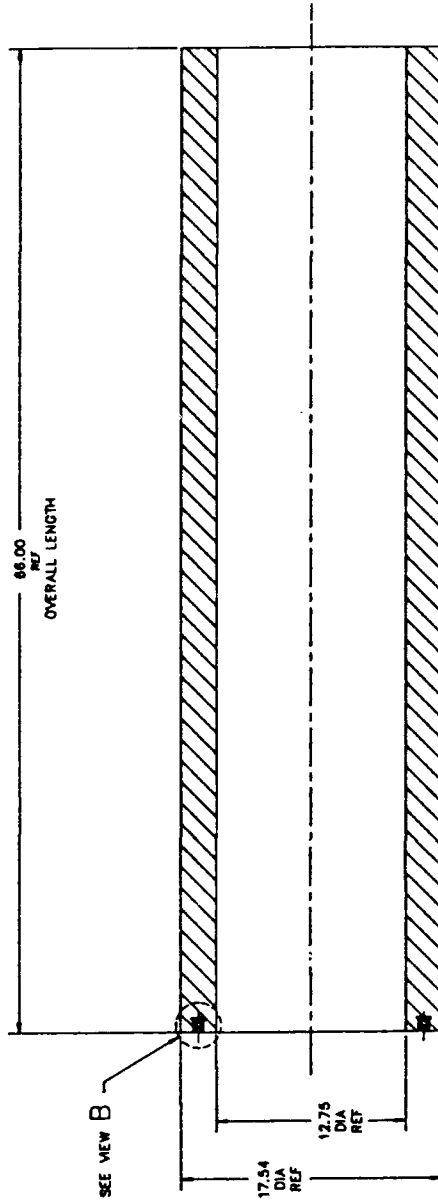
SCHEMATIC DIAGRAM



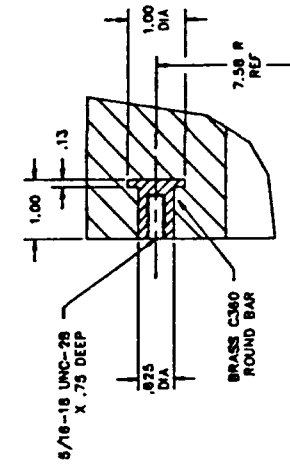
Inner inductive coil (small)

INNER INDUCTIVE COIL
(SMALL)

91-0050
10-60

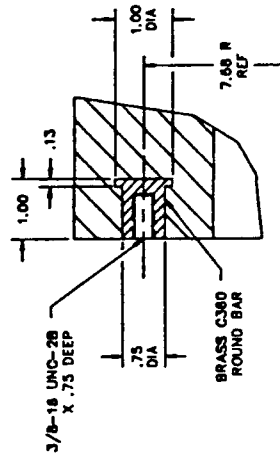


SECTION A-A
LAYERS OF MAGNETIC WIRES
NOT SHOWN ON THIS SECTION
SEE SHEET 2



VIEW C

6/16-18 UNC HOLES MARK 'C'
8 PLACES AT 45° AS SHOWN
WILL BE USED FOR MECHANICAL PURPOSE
FOR THE DESIGN CONSTRUCTION OF THE BRASS BLOCK
ANYTHING SIMILAR OR EQUIVALENT IS PERMISSIBLE
SCALE : 1/1



VIEW B

2 PLACES AT 180° PART "OUT"
FOR ELECTRICAL TERMINAL "IN" & "OUT"
FOR THE DESIGN CONSTRUCTION OF THE BRASS BLOCK
ANYTHING SIMILAR OR EQUIVALENT IS PERMISSIBLE
CONNECTIONS TO WIRE DESIGN CONSTRUCTION
TO BE DETERMINED BY MANUFACTURER
DIMENSIONS SHOWN ARE REFERENCE ONLY
SCALE : 1/1

INNER INDUCTIVE COIL
(SMALL)

91-0050
10-20

Inner inductive coil (small)

