PRELIMINARY PROPOSAL
NUMBER 276

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DCX-2 MACHINE
BUILDING 9201-2

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

PRELIMINARY PROPOSAL

INDEX NO. 276

DCX–2 MACHINE
BUILDING 9201-2

Prepared For
OAK RIDGE NATIONAL LABORATORY
By
ENGINEERING DIVISION
Y-12 PLANT

OAK RIDGE NATIONAL LABORATORY
Operated By
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

Preliminary Proposal
Index No. Number 276

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FIGURES

DCX-2 MACHINE, BUILDING 9201-2

A. REFERENCE DATA

1. Letter from Y-12 Plant Superintendent and Deputy Director ORNL to Director Research & Development, subject "Request for Directive, Preliminary Proposal Number 276, DCX-2 Machine, Building 9201-2."

2. Letter from Manager ORO to Vice-President UCNC, subject "DCX-2 Fabrication," dated August 25, 1960.

3. Report, subject "Proposal for a Thermonuclear Experiment Involving Injection of Molecular Ions at 600 kev, Dissociation by Multiple Passes Through an Arc, & Exponentiation Upon the Resulting Trapped Atomic Ion Population," by Bettis, et al., dated March 4, 1960. (ORNL Central Files Number 60-1-73).

B. GENERAL DESCRIPTION OF PROJECT

An experimental project termed the DCX-2 experiment will be established in Building 9201-2. This thermonuclear experiment will be centered around the DCX-2 apparatus (formerly termed ORION), and will represent a second stage in the experimentation on plasma buildup by high energy injection. The apparatus will be in the form of a magnetic mirror device somewhat like DCX-1, but arranged to permit multiple passes of the injected molecular ion beam through the arc.

The major equipment will be located in the crane bay area on the second floor of Building 9201-2. The DCX-2 machine itself will be placed adjacent to the existing 600 kv D.C. power supply, from which power will be supplied for the ion injection. The project will also include such auxiliaries as vacuum pumping equipment and an instrument control room. Power and other utilities services are available in the building.

C. JUSTIFICATION OF BASIC NEED

DCX-2 will be a device by means of which a thermonuclear experiment can be performed involving the injection of molecular ions at 600 kev, dissociation of the injected beam by multiple passes through an arc, and exponentiation upon the resulting trapped atomic ion population. This new device will provide a much larger and more versatile apparatus to expand the experimental results obtained from DCX-1, and to perform experiments which

TABLE I

DESIGN PARAMETERS OF DCX-1 (LATEST CONFIGURATION) VS DCX-2

H^+ TRAPPING ASSUMED FOR BOTH

	DCX-1	DCX-2
Central Field	10,000 gauss	12,000 gauss
Mirror Ratio	2.1	3.5
Homogeneity of Field	very poor	good
Adiabaticity of Trapped Orbits	(none) $\frac{2\pi\rho}{L} \approx 1$	(good) $\frac{2\pi\rho}{L} \approx 0.15$
Number of Passes	1.0	60 nominal
Nominal Maximum Beam Current	15.0 ma	500.0 ma
Trapped Proton Energy	300.0 kev	300.0 kev
Magnet Power	3.0 megawatts	12.0 megawatts
Distance Between Mirror Coil Centers	30.6 inches	160.0 inches
Distance Between Mirror Coils	17.5 inches	124.0 inches
Inside Diameter of Liner	28.0 inches	36.0 inches
Inside Diameter of Mirror Coil	18.0 inches	16.0 inches
Overall Length of Vacuum Tank	18.5 feet	27 feet

cannot be done in DCX-1 due to limitations of physical size, coil strength, mirror ratio, etc., (see design parameters of DCX-1 vs DCX-2 in Table I).

The object of the experiment will be to determine the extent to which a 300 kev H^+ plasma can be built up in density beyond the range of 10^9 - 10^{10} H^+ particles per cubic centimeter now obtained in DCX-1. This plasma buildup is to be achieved by using multiple passes of the injected molecular ionic beam through the dissociation medium instead of using a single pass as is done in DCX-1. Multiple pass dissociation efficiencies would exceed 50 per cent compared with about five per cent for single passes.

To obtain these multiple passes, a much longer plasma chamber must be available since the path length of the H_2^+ beam through the accumulated H^+ circulating beam would be meters in length.

In DCX-2 the magnetic volume will be much larger than in DCX-1 so that the new device will not depend entirely upon absolute containment for particles within magnetic mirrors, but can also use adiabatic containment for orbits that stray from encirclement of the magnetic axis.

D. PRELIMINARY SCHEMATIC PLANS

The location of Building 9201-2 is shown in Figure 1. Other drawings showing floor plans, electrical diagrams, and the arrangement of the DCX-2 machine are presented in Appendix 2.

E. OUTLINE SPECIFICATIONS

Mechanical

The major mechanical design problems presented by DCX-2 relate to the following components:

1. An appropriate chamber for creating and maintaining a sufficient vacuum into which the ion beam can be injected and passed through the desired arc, and in which the plasma can be contained.

2. Equipment for positioning and rigidly fixing the magnet coils under the high axial forces resulting from the magnetic field.

3. A device for passage of the source tube through the vacuum tank wall with sufficient flexibility to permit adjustment through the required range of movement.

4. A track and dolly arrangement on which the tank, coils, diffusion pumps, vacuum manifolds, and associated equipment can be mounted to facilitate expeditious disassembly and accurate realignment on reassembly.

5. A support and positioning device for the high-energy ion source.

6. Miscellaneous smaller components such as support and positioning devices for instrumentation, cooling coils and connections, and electrode support and positioning devices.

The vacuum chamber is to consist principally of two concentric cylindrical regions separated by a water-cooled copper liner. The source tube and instrument probes will be connected to the tank wall by a vacuum seal and will enter the high vacuum region through a low conductance, sliding-fit connection in the liner wall. The tank and liner will be so constructed that the liner will be bakable but the bake-out arc will not "see" any O-ring vacuum seals.

Each of the twelve magnet coils will be independently mounted on adjustable feet to permit slight vertical, horizontal and angular motion for alignment. Adjustable spacing devices will be provided to maintain proper spacing of the magnet coils against the magnetic forces created when the coils are in operation.

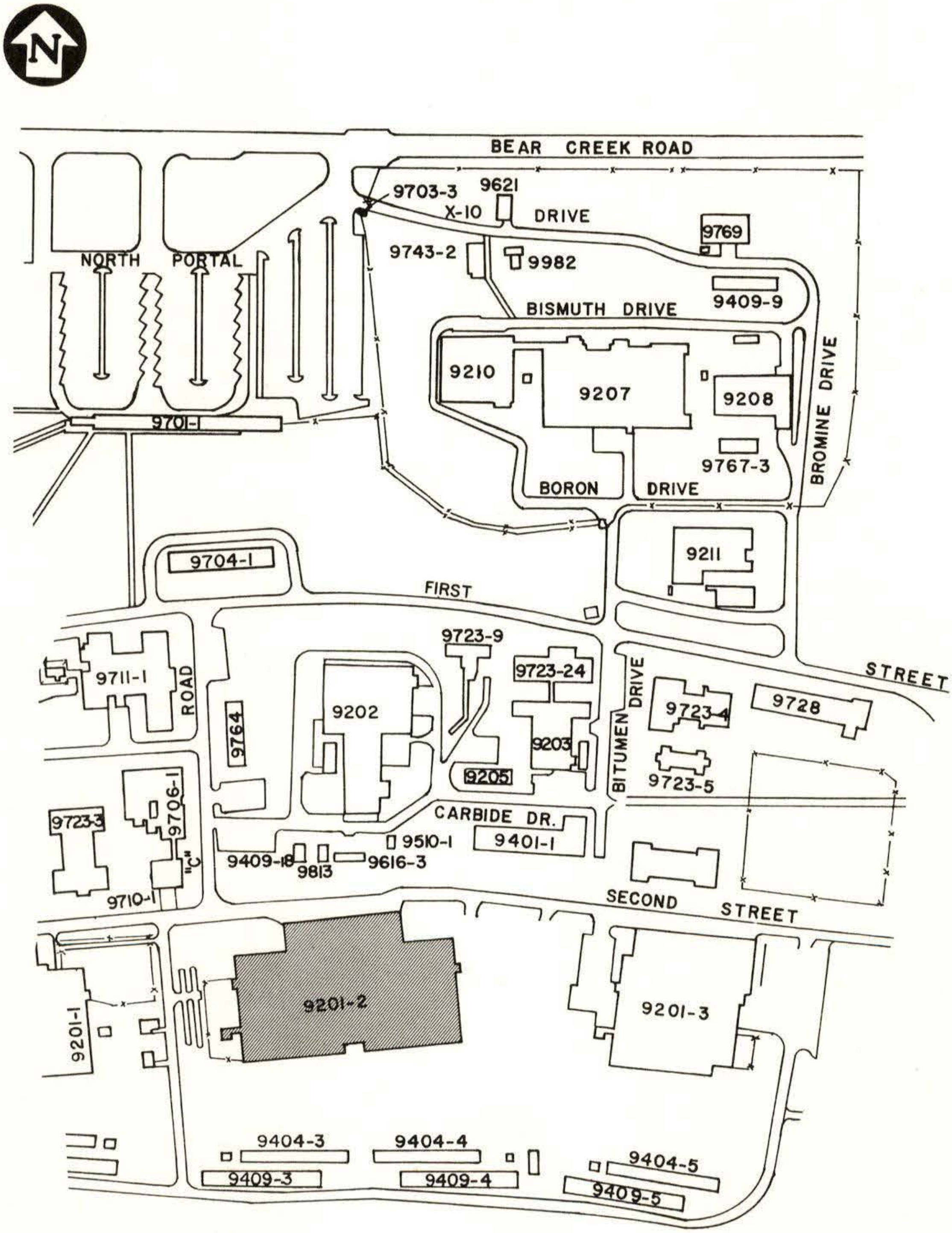


Figure 1 – PLOT PLAN SHOWING LOCATION OF BUILDING 9201-2.

The ion source tube will enter the tank through a special housing (an integral part of the tank) and will pass through the liner to the high-vacuum region. The source tube will be adjustable horizontally both parallel and transverse to the tank axis, and angularly in a plane parallel to the tank axis through the maximum anticipated injection angle.

All components of the DCX-2 machine proper will be supported on dollies mounted on a continuous track extending beyond the ends of the machine to permit rolling the various sections apart for maintenance or alterations as required, and to permit the possible addition or deletion of certain sections if required. The various sections of the tank will be connected to each other by means of quick-disconnect flange couplings. Realignment of each section will not be necessary after each disassembly unless one section has been removed.

An adjustable mounting device to support the high-energy ion source from a bridge-type crane will be used to give the ion source tube the freedom of movement discussed above.

Instrumentation

A central, air-conditioned control room will be located at a distance from the DCX-2 machine, where the intensity of the magnetic field is low enough to allow operation of standard instrumentation. The control room will have an operating console with instrument and electrical switchboard panels located around the console.

Vacuum system instrumentation will consist of vacuum indicating and recording instruments, diffusion pump protectors, and an automatic liquid-nitrogen filling system. The vacuum measurements will be made with thermocouple gages and magnetically shielded, hot-filament, ionization gages.

The diffusion pump protectors will use thermocouple-gage sensing elements and will serve to close the diffusion pump vacuum valves in case of an inadvertent pressure rise.

The cooling water system instrumentation will include flow switches and water temperature measuring devices. The flow switch will be used as a protective device in case of cooling water failure. The water temperature measurement will be used as a guide to minimum water usage for adequate cooling.

The tank instrumentation will consist of liner temperature measurements and calorimetric measurements of particle distribution. The liner temperature will be monitored with thermocouple recorders during liner bake-out. The total energy input to the liner will be determined by calorimetric measurement on the liner cooling water, except for a narrow strip where the primary neutrals strike. This primary neutral beam will be measured with a separate calorimeter. Additionally, its distribution will be determined by a series of small calorimetric probes displayed on a high-speed profile monitor. Tank vacuum and arc current and voltage will be indicated on the console and at the tank on slave indicators to facilitate striking the arc.

Radiation in the vicinity of the machine will be monitored by a neutron- and gamma-sensitive ionization chamber.

Additional instrumentation will provide for magnet current and voltage measurements, and for high speed oscillograph and oscilloscope presentation of diagnostic information.

Instruments located on the ion source and on the insulating stack providing power from the high-voltage power supply to the accelerator tube will be transduced and transmitted pneumatically to the control room.

Electrical

Electrical power for Building 9201-2 is provided by an existing 50,000 kv-a, 154/13.8 kv, three-phase building transformer. The 13.8 kv distribution system is supplied from centrally located metal-clad switchgear. The bulk of the auxiliary equipment is supplied from 1000 kv-a, 13.8 kv/460 volt unit substations located near work areas.

An additional 1000 kv-a, 13.8 kv/460 volt unit substation will be required for the DCX-2 services.

Direct current power for the magnet coils will be provided by four existing double-ended motor-generator sets having a total capacity of 20.5 megawatts. Water-cooled cable will carry D.C. power from the generator busses to air-operated isolation switches and from the switches to the magnet coils. There will be twelve such coils, as follows:

2 Outboard Booster Coils
2 Mirror Coils
6 Inboard Booster Coils
2 Magnetic Dip Coils

Structural

A mobile overhead structure will be provided to support the ion source and shielding, spanning from the south enclosure wall of the 600 kv power supply to column line G. The guide rails will extend approximately forty feet in an east-west direction on each side of the transverse center line of the DCX-2 machine.

Two reinforced concrete curbs five feet six inches high, ten inches thick, and five feet on centers will be installed in which the guide rails for the machine will be imbedded. The curbs and rails will extend to the same east-west limits as the overhead ion source support structure.

A semi-demountable, non-magnetic-metal working platform designed for a loading of two hundred pounds per square foot will be provided approximately five feet above present floor level. The platform will cover approximately the same area as the overhead support structure, and will be provided with access ramps and stairs.

A sound-insulated control room approximately thirty feet by thirty-five feet at the 959-foot elevation will house the remote control panels. The control room and working platform will be connected by a ramp.

The present second floor concrete structure will be reinforced as required to support the DCX-2 for the entire length of the guide rails, the working platform, and all separate accessory equipment.

Piping

Utility services required for the DCX-2 machine will be supplied from the existing building main headers. New branch headers and piping connections to equipment will be provided. The DCX-2 experiment will require demineralized cooling water, process water, vacuum, instrument air, plant air, drains, and liquid nitrogen piping systems, as follows:

Demineralized Water - The existing closed cooling water system of demineralized water has adequate capacity to maintain the DCX-2 machine components at the required operating temperatures. The major part of the cooling water will be required for the electromagnetic coils where the water will flow through the hollow electric conductors and remove the heat generated by high current rates. This water will also be used to cool the beam injection "snout", the inner thin-wall tank liners, and all water-cooled electrical cables. Flow orifices will be installed to prevent damage to the unit from loss of cooling water flow. A pressure reducing station will be provided to assure constant water supply pressure as required for uniform flow rates. The piping system will be arranged for quick disconnection and drainage so that minor adjustments or repairs can be accomplished without unnecessary delay or cost.

Process Water - Process water will be piped to those pieces of equipment that need a very dependable water supply or that require only small quantities of cooling water (such as diffusion pumps, Kinney pumps, instruments, etc.). The process water outlets from such equipment will discharge to waste. The use of process water for small cooling requirements instead of the demineralized cooling water has proven necessary on the existing experimental rigs to minimize possible contamination of the closed demineralized cooling water system.

Vacuum - A "roughing" vacuum system will be provided to evacuate the DCX-2 machine from atmospheric pressure down to about 50 microns pressure in about 20 minutes (only about 10 minutes will be needed if the large diffusion pumps and cold traps are valved off). This roughing system will connect to a 15 hp combination Kinney pump.

The diffusion pumps will discharge into a "backing" system. This backing system will connect to a 15 hp combination Kinney pump.

A third 15 hp combination Kinney pump will be installed and cross-connected with the other pumps to serve as spare capacity. The Kinney pumps will discharge into vent piping so that all evacuated gases will be discharged above the roof. All three Kinney pumps are available at the site.

Instrument Air - Instrument air piping will provide instruments, controls, and other accessories with a dependable supply of oil-free, dust-free, dry, compressed air.

Plant Air - Plant air will be piped to service outlets for use in air-powered tools and the like.

Drains - Additional floor drains and open-sight drains will be provided at all points where quick water drainage is needed. Many water-cooled cable and equipment connections must be drained. rapidly so that the sections of the machine can be separated in minimum time.

Liquid Nitrogen - A liquid nitrogen supply system will be provided to supply the vacuum cold-traps. Two portable, vacuum-sealed, stainless steel dollies will be set on weighing scales to determine the amount of liquid nitrogen in the dollies. Only one dolly will be used at a time to allow the other to be sent out for refilling.

The liquid nitrogen (about -320°F) will flow under pressure to the cold traps through vacuum-jacketed nominal one-half inch, schedule 40, type 304L stainless steel pipe of welded construction. The liquid nitrogen level in the cold traps will be kept constant by suitable controllers. The cold nitrogen gas vaporized in the cold traps will be piped to vent above the building roof. Final connections to the cold traps will be made using flexible stainless steel hoses. Pressure relief valves will be provided between valves to prevent bursting pressures that could result from vaporizing liquid nitrogen in closed sections.

F. STATEMENT OF PRINCIPAL HAZARDS

The DCX-2 machine will be operated initially with an H_2^+ ion beam. In this operation no neutrons will be generated. The gamma radiation level in the operating area is expected to be less than 4 mr/hr, while the X-ray intensity will not exceed 1 mr/hr. A lead shield will be installed around the ion source to hold the X-ray radiation to this value. Above the source the X-radiation level will be somewhat higher, but since the source is some twenty feet above the crane bay floor, it is felt that no additional shielding will be required above the ion source. Instruments will be installed to monitor these radiation levels continuously.

At a later date the machine will be operated with a deuterium ion beam. During this operation high-energy neutrons will be generated, as will gamma and X-ray radiation, necessitating the construction of a water-wall shield. This future shielding is not a part of the present project.

G. SUMMARY COST ESTIMATE

The estimated costs of the proposed installation are summarized in the following table. Further details of this cost estimate are presented in Appendix 1.

The cost of this experimental project will accrue as an operating expense under AEC Activity 05 04 04.

	UCNC Participation	CPFF Contractor Participation	Total
Engineering Design & Inspection	$ 98,000	$ 0	$ 98,000
Direct Costs	629,000	517,000	1,146,000
Indirect Costs	202,000	77,500	279,500
Allowance for Contingencies	91,000	59,500	150,500
TOTAL	$1,020,000	$654,000	$1,674,000

H. PROPOSED STARTING AND COMPLETION DATES

This work is tentatively scheduled as shown below. These dates are based on receipt of directive authorization by October 1, 1960.

	Start	Complete
Engineering Design	In Progress	February 1, 1961
Procurement (UCNC)	October 1, 1960	May 30, 1961
Shop Fabrication (UCNC)	October 15, 1960	May 30, 1961
Installation	December 1, 1960	July 31, 1961

It is anticipated that startup operations can begin by about June 15, 1961. Because of the unavoidably long procurement lead time on much of the material, and because of the limited area of the installation site, it is not believed probable that this date can be significantly improved.

I. METHOD OF ACCOMPLISHMENT

It is proposed that UCNC furnish all architect-engineering services including design and inspection, make final tie-ins, and furnish miscellaneous services to the contractor. UCNC will also procure certain of the special experimental equipment, and will fabricate the remainder in the Y-12 shops. All other work, including other procurement, should be done by a cost-type contractor under prime contract. Since this project involves experimental apparatus of great complexity, and because of the limited time available, the employment of a fixed-price contractor is not considered feasible.

APPENDIX 1

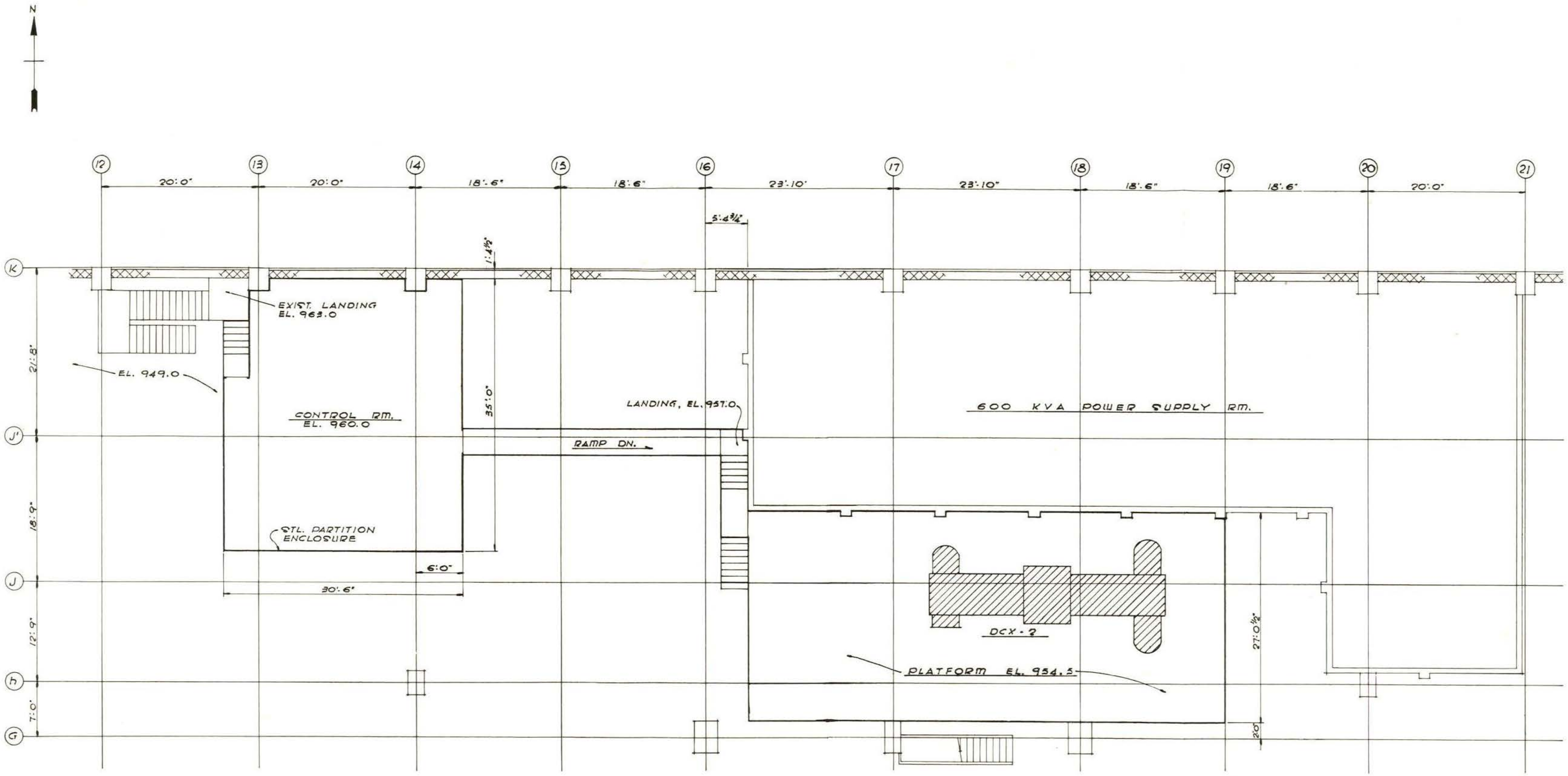
COST INFORMATION

DETAIL OF COST ESTIMATE

	Material	Labor	Total
I. UCNC PARTICIPATION			
Engineering	$ 0	$ 98,000	$ 98,000
Direct Costs:			
Equipment Procurement	$221,000	$ 0	
Equipment Fabrication	184,000	199,000	
Miscellaneous Services and Tie-Ins	10,000	15,000	
Subtotal	$415,000	$214,000	629,000
Indirect Costs (65% of labor)			202,000
Contingencies			91,000
Total UCNC			$1,020,000
II. CPFF CONTRACTOR PARTICIPATION			
Direct Costs:			
Structural	$ 66,200	$ 34,440	
Electrical	125,600	65,600	
Piping	42,100	37,280	
Mechanical	34,500	80,800	
Instrumentation	2,000	28,480	
Subtotal	$270,400	$246,600	$ 517,000
Indirect Costs			77,500
Contingencies			59,500
Total CPFF			$ 654,000
III. GRAND TOTAL PROJECT			$1,674,000

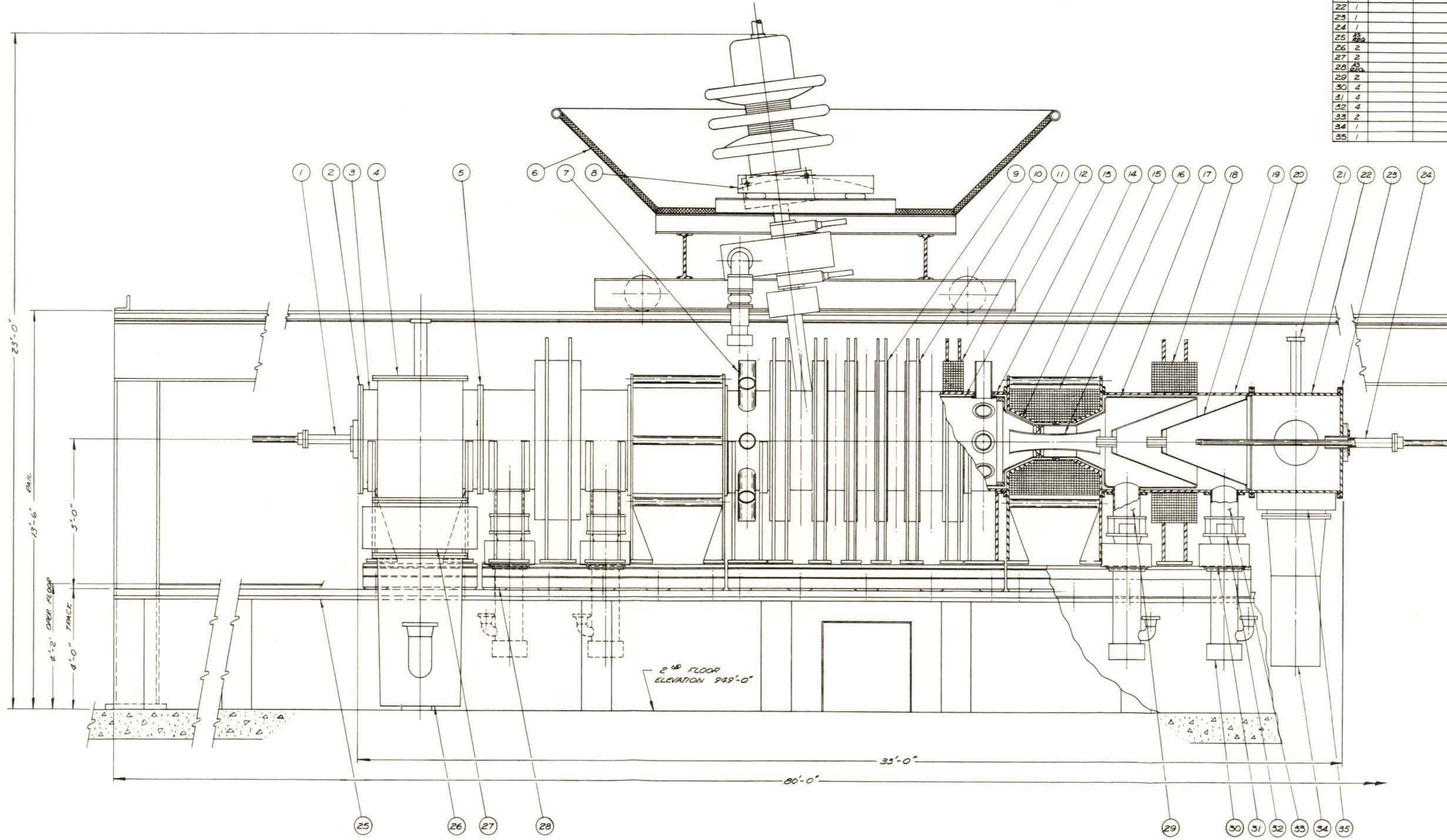
APPENDIX 2

DRAWINGS

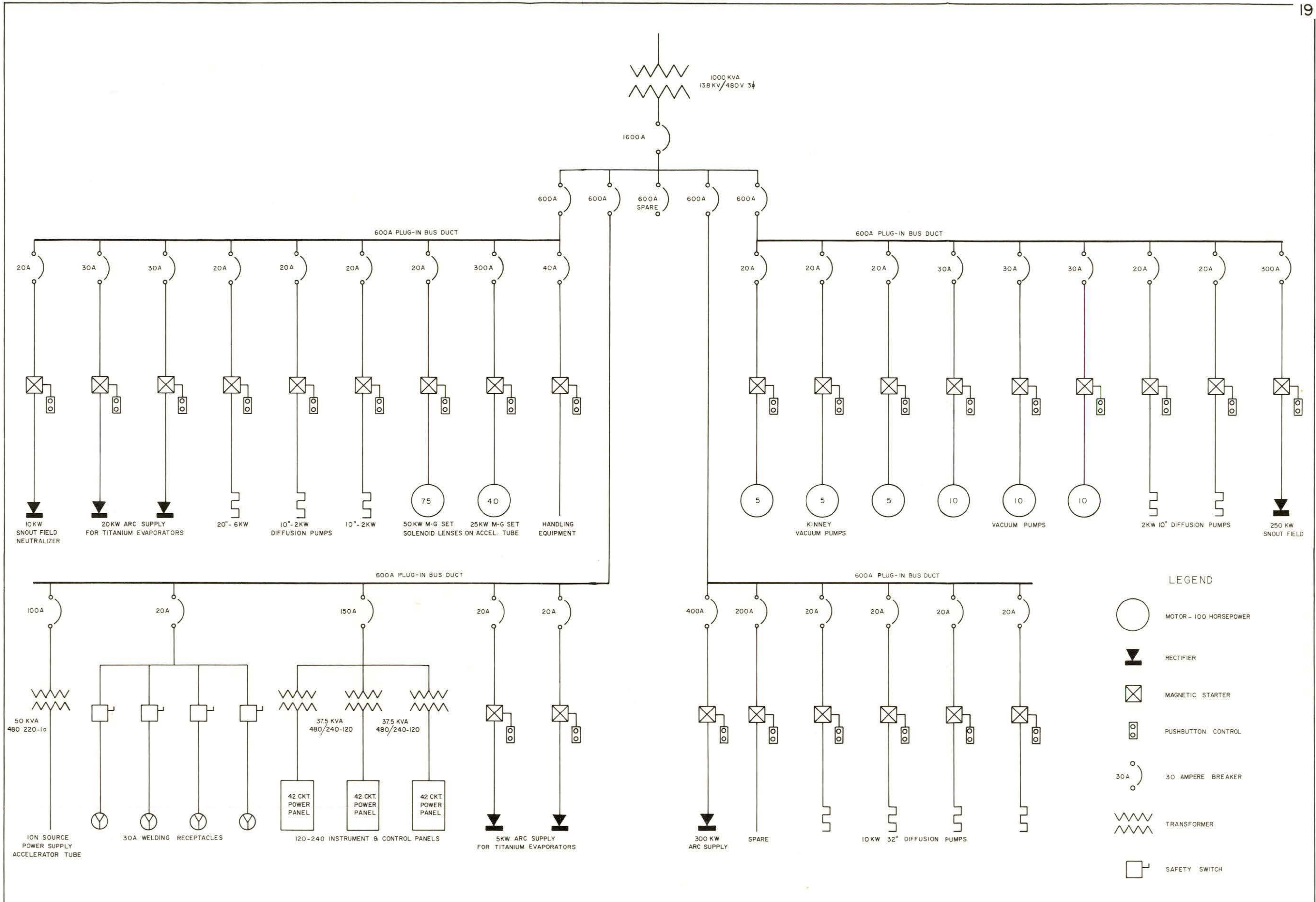


FLOOR PLAN
FIGURE 2

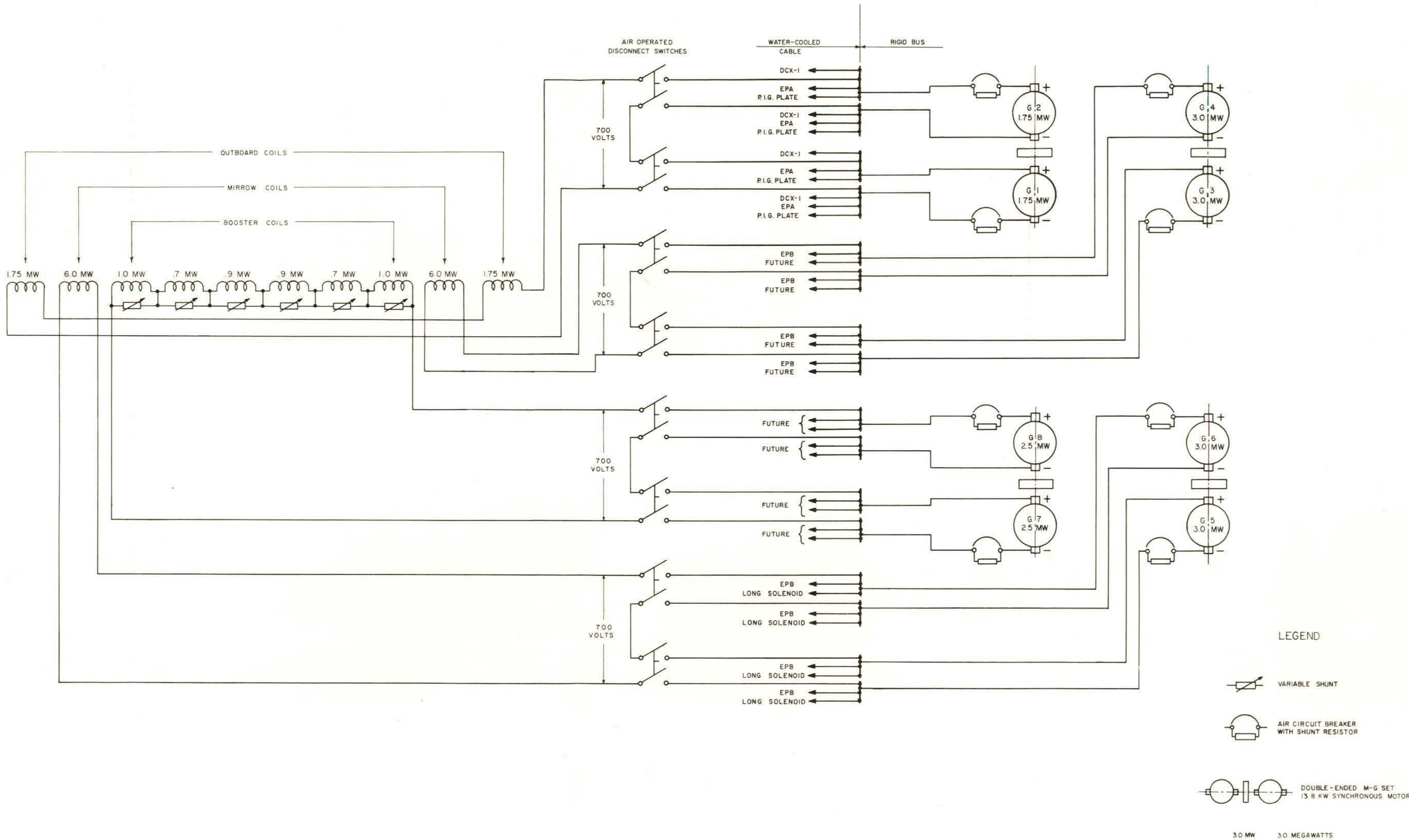
ITM	QTY.	DWG. NO.	MATERIAL	DESCRIPTION
1	1			CATHODE ASSEMBLY
2	1			CATHODE FACE PLATE
3	1			CATHODE MANIFOLD
4	2			PNEUMATIC RIGHT ANGLE VALVE 32"
5	AS REQ.			MARMAN BAND CONNECTORS
6	1			SOURCE SHIELDING PLATFORM
7	53			SIGHT PORT TUBES
8	1			SOURCE ADJUSTMENT ASSY.
9	2			5" TANK COIL
10	2			6" TANK COIL
11	2			8" TANK COIL
12	1			TANK LINER SECTION
13	1			TANK
14	2			TANK END LINER SECTION
15	2			MIRROR COIL ASSEMBLY
16	2			MIRROR COIL VENTURI BAF. SECT.
17	2			MIRROR COIL BAFFLE SECTION
18	2			OUTBOARD COIL ASSEMBLY
19	2			INTERMEDIATE BAFFLE SECTION
20	2			INTERMEDIATE BAFFLE MANIFOLD
21	1			PNEUMATIC RIGHT ANGLE VALVE 20"
22	1			ANODE MANIFOLD
23	1			ANODE FACE PLATE
24	1			ANODE ASSEMBLY
25	AS REQ.			TRACK
26	2			DIFFUSION PUMP 32"
27	2			BAFFLE 32"
28	AS REQ.			DOLLY
29	2			VALVE TRANSITION
30	4			DIFFUSION PUMP 7"
31	4			BAFFLE 7"
32	4			PNEUMATIC SLIDE VALVE 7"
33	2			VALVE TRANSITION
34	1			DIFFUSION PUMP 20"
35	1			BAFFLE 20"



MACHINE ELEVATION
FIGURE 3



480 VOLT POWER SUPPLY
FIGURE 4



D.C. POWER SUPPLY
FIGURE 5