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THE STANFORD TWO-MILE LINEAR ELECTRON ACCELERATOR*

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FIGURES

FIGURES (Cont.)

I. GENERAL DESCRIPTION

A. INTRODUCTION

In June, 1962, work began at Stanford University under contract with the U.S. Atomic Energy Commission on a two-mile-long linear electron accelerator. When this machine is completed in July 1966, it will serve as a powerful source of energetic electrons for use in physics research.

The graph of Fig. 1 shows how this machine compares with other large accelerators (existing, under construction, or under consideration). In this graph, the particle energy in BeV and the average beam current in microamperes of various machines are plotted on logarithmic scales. Symbols on the graph indicate whether each machine accelerates protons or electrons and give the present status. Not noted on the graph but of interest is the fact that all of the proton machines shown accelerate their particles along approximately circular orbits. This is also true of the majority of the electron machines, but three of these (Orsay, Kharkov, and Stanford) accelerate the electrons along a straight path. The existing Stanford machine referred to here is the 1.1-BeV Mark III Accelerator which began operation in 1951. The roster of machines which are now in operation or which are scheduled to be in operation in 1964 are located to the left of the dashed line in the figure. The largest and most energetic machines now in operation are the alternating gradient synchrotrons at Brookhaven and CERN, each of which accelerates protons to about 30 BeV. They will probably be surpassed when the Russian 70 BeV machine at Serpukhov starts operations, probably in 1966.

The two-mile Stanford Linear Electron Accelerator is distinguished not only by its length and high energy (Stage I, 20 BeV) but also by its high current, which exceeds that of any other machine now operating or under consideration by more than a factor of 10. Moreover, provisions have been made in the design of this machine which permit its later expansion (Stage II) to twice the energy (40 BeV) and twice the current (60 μamp). Only Stage I has been authorized at this time. Two "super-energy" proton accelerators are now undergoing study at Brookhaven and Berkeley. These machines would have energies of 200 BeV and 800 BeV.

B. DESCRIPTION OF SITE AND BUILDINGS

An air view of the site of the Stanford Linear Accelerator Center (SLAC) is shown in Fig. 2. This site is located about 2 miles west of the main University campus. A strip of land 1000 feet wide is reserved along the accelerator length. At the target end, the width is greater to provide space for the laboratories, shops, and research facilities. Altogether the project area amounts to 480 acres.

A close-up air view of the main laboratories and shops is shown in Fig. 3. In the foreground of the picture, the accelerator housing is shown with the covering earth back-fill partially in place.

A cross section of the underground 10-foot × 11-foot accelerator housing and the above-ground 13-foot × 29-foot klystron gallery is shown in Fig. 4. The two housings are separated by 25 feet of earth fill which serves as radiation shielding. The upper housing contains the klystrons and other equipment associated with the accelerator. Service shafts 27 inches in diameter and spaced at 20-foot intervals are provided for wave-guide and other electrical and mechanical connections between the housings. A personnel access way is located every 333 ft. A view of the two housings from the west (injector) end of the machine is shown in Fig. 5. Interior views of the klystron gallery and accelerator housing before installation of equipment are shown in Figs. 6 and 7, respectively.

A plan view of the beam switchyard at the east (target end) of the accelerator is shown in Fig. 8. In this large underground housing, about 1000 feet long, the beam transport and measurement equipment is located. These components measure the characteristics of the beam and direct it along prescribed paths into the various experimental areas.

C. ACCELERATOR COMPONENTS AND SYSTEMS

A schematic diagram of the accelerator components and systems is shown in Fig. 9. Most of these units are repeated many times in the complete accelerator. For example, there are 960 10-foot accelerator sections, 240 klystrons, 240 modulators, 30 power sub-stations, 30 sub-booster klystrons, 30 vacuum systems, etc. The instrumentation and control system is spread throughout the two-mile length; however, the entire machine can be operated from one central control room.

The principal accelerator specifications for Stages I and II are summarized in Fig. 10.

The 240 klystrons of the type shown in Fig. 11 are spaced at 40-foot intervals along the accelerator length. The 24 megawatts (maximum) of rf power output from each klystron is split four ways as shown in Fig. 12 and feeds four successive 10-foot accelerator sections through an evacuated waveguide system.

The accelerator proper consists of an array of OFHC copper disks and copper cylinders as shown in Fig. 13. These parts are independently machined to a tolerance of $\approx$ 0.0002 inch. They are carefully stacked and clamped together on a stainless steel mandrel. The entire 10-foot assembly is then brazed together in one operation in the special flame furnace shown in Fig. 14. The entire brazing procedure requires approximately 30 minutes. A view of a completed 10-foot section is shown in Fig. 15.

Four of the 10-foot accelerator sections are mounted on a single 24-inch-diameter support girder as shown in Fig. 20. This is the modular length of the accelerator for installation and alignment purposes.

II. VACUUM SYSTEM

A. GENERAL DESIGN PHILOSOPHY

The accelerator must be evacuated for two principal reasons:

(1) To prevent electrical breakdown in the high radiofrequency fields needed to accelerate the electrons, and

(2) To minimize scattering of the electrons by gaseous molecules in their passage through the accelerator. Theoretical considerations and practical experience show that a pressure of 10^{-6} torr or less is necessary in the waveguides and two-mile accelerator structure in order to achieve reliable operation. In the beam switchyard, where there is no concern with radiofrequency power of large magnitudes and where the high energies of the output electrons make them less susceptible to scattering, a pressure in the range of 10^{-3} to 10^{-4} torr is adequate.

The two-mile accelerator is designed to operate 24 hours per day with minimum shutdowns for maintenance over long periods of time. Entry into the accelerator housing or beam switchyard is not possible during operation because of the extreme radiation hazard and, indeed, must be done with caution even with the beam off due to the presence of significant levels of residual radioactivity. For these reasons, efforts have been made during the design to place those components requiring frequent maintenance outside of the radiation areas. In the case of the vacuum system, this has led to the location of the main pumping units and the gauges well above the beam level, either in the klystron gallery or on pads on top of the beam switchyard housing. The resulting long pumping paths and low conductances have required that great attention be given to obtaining clean systems with minimum real and virtual leaks.

In the discussion of the overall vacuum system, it is convenient to divide it into two parts: the vacuum system associated with the two-mile accelerator proper, and the vacuum system associated with the beam switchyard at the end of the accelerator.

B. VACUUM SYSTEM FOR THE TWO-MILE ACCELERATOR

The accelerator vacuum system includes (1) the main vacuum sub-system which maintains the accelerator and the waveguides connecting the klystrons to the accelerator at a level of 10^{-6} torr or less, (2) the roughing sub-systems for the main accelerator and for the klystron window regions, and (3) the light pipe vacuum sub-system which evacuates the 24-inch light pipe to a level of a few microns.

1. <u>Main High Vacuum Components</u>

(a) General

A schematic diagram of the main vacuum sub-system for one 333-foot sector is shown in Fig. 16. Altogether there are 30 such sub-systems along the two-mile accelerator. These sub-systems are independent except for their connection to the continuous accelerator pipe. The total pumped volume of the main vacuum system for the two-mile accelerator is approximately 2×10^5 liters. There are 4 ion-getter pumps in each sector, each rated at 500 liters/second. These pumps are connected to an 8-inch stainless steel manifold which extends the full length of the sector. Each pump can be isolated from the manifold for servicing by means of a 6-inch right angle valve. A photograph of the ion pump manufactured by Ultek Corporation of Palo Alto, California, and a diagram of the 6" valve manufactured to SLAC specifications by Westinghouse Electric Company of Pittsburgh, Pennsylvania, are shown in Figs. 17 and 18.

Four 8-inch "fingers" spaced approximately 80 feet apart extend at right angles from the main manifold and pass through 27-inch i.d. penetrations 25 feet long into the lower accelerator housing where they connect to a 5-inch manifold running parallel to the accelerator. One 5-inch "finger" per sector connects the main 8-inch manifold to the "drift space" region in the accelerator housing at the end of the sector. This region contains the beam monitoring and guidance devices which are used to measure and correct the beam parameters as the beam passes through the accelerator. At the location of each klystron, a 4-inch pipe extends from the main manifold to evacuate the upper end of the waveguide and in particular, the critical region in the vicinity of the klystron window.

Both the upper main 8-inch manifold and the lower 5-inch manifold contain a number of bellows which serve (a) to facilitate installation, (b) to provide for differential thermal expansion, and (c) to allow alignment of the accelerator without placing undue strain on the waveguides and the various connections between members. A diagram of a 5-inch manifold assembly 40 feet long is shown in Fig. 19. A photograph of the 5-inch manifold mounted on the support girder along with four 10-foot accelerator sections is shown in Fig. 20. A photograph of the 8-inch manifold in position in the klystron gallery is shown in Fig. 21. Both of these photographs are based on scaled models.

(b) Manifold Components and Techniques

Manifold components are being fabricated and assembled to SLAC drawings and specifications by two companies. The manifolds for the first two accelerator sectors are being assembled by Litton Precision Products, Inc., Division of Litton Industries, San Carlos, California. Parts for all manifolds are being supplied, and manifolds for sectors 3 through 30 are being assembled by the Cosmodyne Corporation of Torrance, California.

All manifold components are made from type 304 L stainless steel. Individual parts are cut to length, degreased, acid cleaned, rinsed, and given a final cleaning in de-ionized water. The parts are then dried in filtered warm air. Parts for the various sub-assemblies and assemblies are held together by means of suitable jigs and fixtures and are welded together in an argon atmosphere. Automatic welding techniques are used with the welding head held fixed while the parts are rotated. Temporary bake-out plugs are welded on the ends of assemblies which are approximately 40 feet long. Following leak checking, eight of the 40-foot assemblies are mounted on a steel cart to be made ready for bake-out. One end of each piece is welded to a pumping connection leading to a liquid N_2 trapped mercury diffusion pump. Bake-out of the eight assemblies takes place in a special electric furnace. Temperature during bake-out is maintained at 400 to 425°C. After bake-out, the assemblies are checked for leaks and out-gassing properties by the rate-of-rise technique. They are then let up to dry nitrogen through a pinch-off tube on the ends opposite the pumping connections. Nitrogen continues to flow while the pumped end is cut loose from the pump and a cap is welded on. The let-up tube is then pinched off, and the assembly is crated for shipment to the site.

The design of the adapters which are used in making pipe-to-bellows connections and in joining lengths of pipes by means of field welds is shown in Fig. 22. Those adapters which receive bake-out plugs are provided with a 90° groove near the outer edge. The bake-out plug is welded to the extreme outer edge beyond the groove, as shown in Fig. 23. While making ready for the field weld, the outer edge is peeled off and the field weld between adapters is made at the newly created edges, as shown in Fig. 24.

(c) Waveguide Vacuum Components

Waveguide Vacuum Pump-out.- Vacuum pump-outs connect the 8-inch manifold in the klystron gallery and the 5-inch manifold in the accelerator housing to the rectangular waveguides supplying radiofrequency power to the accelerator. The pump-outs are designed to maximize the pumping conductance while causing minimum rf reflection and minimum loss of rf power from the waveguide into the vacuum manifold. The iris structure shown in Fig. 25 has been designed for this purpose.

Waveguide Vacuum Valve. - The klystrons which supply rf power to the accelerator are sealed-off vacuum units having an internal pressure of $\approx 10^{-8}$ torr. The rf power from the tube passes through a ceramic (alumina) window into the waveguide leading to the accelerator. If the minimum anticipated average klystron life of 2000 hours is achieved, approximately 3 of the 240 klystrons will have to be replaced each 24 hours of operation. To prevent the accelerator from being let up to atmospheric pressure each time a tube is removed, which would result in loss of a large fraction of the available operating time, some means of sealing the waveguide during the replacement of klystrons is required. The two ways considered were (a) a second ceramic window, and (b) a waveguide valve. While a second window would certainly serve the purpose of sealing the waveguide, it too was known to be subject to failure and would have to be replaced from time to time, resulting in lost operating time. Therefore, the second alternative was adopted and a special waveguide valve shown in Fig. 26 was developed at SLAC. The valve consists of two mitered corners of S band waveguide and a valve body with a 2.300" opening in the common wall. When the valve is open, rf power passes through this opening. In the open condition, the valve plunger serves to plug the hole in the top of the entrance waveguide so that a negligible rf discontinuity results. The presence of the valve results in a voltage standing wave ratio of only 1.02 at the operating frequency of 2856 Mc/sec. When the valve is closed, the plunger seals the waveguide by pressing against an indium seat. Tests have shown that the valve can be opened and closed at least 100 times before the seal begins to show evidence of leaking. When this occurs, the indium can be re-melted in place and the seat reformed to its original shape.

Waveguide Flange Vacuum Seal. - As far as possible, waveguides are brazed together to make long uninterrupted runs up to about 40 feet long. At locations where future disassembly is required for various reasons, the all-metal vacuum seal shown in Fig. 27 is used. This seal consists of a half-hard copper gasket 0.030-inch thick clamped between two 3/4-inch flanges made of type 304 stainless steel. The gasket has two cross bars 0.125-inch wide which, prior to clamping, are separated about 0.005 inch more than the vertical height of the waveguide (1.345 inch). The clamping pressure causes the material of the bars to flow sufficiently to decrease the spacing to approximately the correct dimension. The waveguide makes contact with the gasket only at the top and bottom. There is no contact at the sides where the rf electric fields are zero. The resulting gaps between flanges at the sides of the waveguide serve as pump-out paths for the region between the waveguide cross section and the circular vacuum seal. The design of the seal itself is also shown in Fig. 27. The gasket is partially sheared between two "knife edges" on the flanges. The "knife edges" are machined with the sides tapered 20° to the normal toprevent deformation of the edge. This design feature allows many separate seals to be made with the same flanges with consistently good results. Tapered slots are machined in the outer edges of the gasket and the two flanges to facilitate proper alignment.

(d) Vacuum Gauges

Cold cathode gauges are used to monitor the pressure. One gauge is used to monitor the main manifold pressure; this reading is transmitted to Central Control. These gauges also actuate fast-acting valves which isolate sectors in the event of catastrophic vacuum failures along the accelerator length. Another gauge is used to monitor the pressure at the window region of each klystron. The signal from this gauge is used to actuate a protection circuit which shuts off the trigger to the klystron in case the pressure rises above adjustable threshold level. The gauges of several commerical companies are now under test. The controller for these gauges is being fabricated to SLAC specifications by the Hughes Aircraft Company and General Electric.

2. Roughing Sub-System

(a) Sector Roughing

Each 333-foot sector can be rough-pumped from a valved connection located approximately in the center of the sector. Roughing will probably be accomplished by means of a well trapped portable 6-inch oil diffusion pump backed by a rotary mechanical pump. Alternate means which are still under consideration are (a) a turbomolecular pump, and (b) a cryogenic pump.

(b) Klystron Window-Waveguide Valve Region

Each time a klystron is removed, the waveguide valve and the 3-inch valve leading to the main 8-inch vacuum manifold must be closed and this region let up to atmospheric pressure. After the klystron is replaced, this region, which has a volume of approximately 5 liters, must be roughed down before the two valves referred to can be reopened. A roughing system which has proven quite satisfactory for this purpose is shown schematically in Fig. 28. It consists of two Linde SN-2 sorption pumps filled with Linde type 5A molecular sieve material. In stage 1 of the rough-down procedure, the stage 1 pump is cooled to liquid nitrogen temperature by immersing it in a plastic dewar. Valves 1, 2, and 3 are then opened. Although a base pressure of about 2×10^{-3} torr can be reached with stage 1 pumping, it has been found experimentally that the transition from stage 1 to stage 2 at about 1 torr results in minimum total pumpdown time. Valve 1 is then closed and the stage 2 pump is cooled to liquid nitrogen temperature, resulting in a further pressure reduction to approximately 5×10^{-4} torr. At this pressure, valves 2 and 3 are closed and the main 3-inch and waveguide valves are opened, connecting the window region to the main vacuum system. The entire pumpdown procedure requires 2 to 5 minutes if the system has been purged with dry nitrogen.

The roughing system can be used to evacuate 6 to 7 klystron window regions before being reactivated by allowing the pumps to return to room temperature (usually overnight). At this time, they partially desorb through the relief valves. After about 50 pumpdowns the action becomes somewhat sluggish and it is desirable to carry out a complete reactivation by bake-out of the pumps.

3. Light Pipe Vacuum System

The light pipe used for aligning the accelerator also serves to support it. It is a 24-inch-diameter 5083F aluminum pipe fabricated in 40-foot lengths. Contiguous lengths are joined by means of a 24-inch-diameter aluminum bellows welded to a flange on the end of each pipe. The result is an articulated aluminum pipe two miles long. An end view of a 40-foot length of light pipe is shown in Fig. 29 together with the adjustable supporting jacks and the internal target which can be rotated into or out of the line-of-sight by means of a remotely controlled pneumatic actuator.

Refraction of light in the light pipe can be kept within acceptable limits by reducing the pressure to a few microns. This will be accomplished by means of four 275 CFM Roots blowers and mechanical pumps spaced along the two-mile length. These units will be located in the klystron gallery and will be connected to the light pipe by means of 6-inch pipes.

C. VACUUM SYSTEM FOR THE BEAM SWITCHYARD

As shown in Fig. 8, the beam switchyard contains a large quantity of bending magnets, quadrupoles, and various protection and monitoring devices extending over a length of approximately 1000 feet and along several branches. All of these devices are associated with extensive, large volume vacuum chambers. The problems of operation and maintenance are very severe because of the high level radiation environment. Provisions for remote handling of beam switchyard components in case replacement is necessary because of radiation damage have been essential. These factors have imposed design considerations which make the achievement of a vacuum as low as that of the accelerator (10^{-6} to 10^{-7} torr) extremely unlikely. Fortunately, a much poorer vacuum (10^{-3} to 10^{-4} torr) is adequate in this area. At these pressures and with the large volume to be pumped, diffusion pumps are the most economical solution. However, great care must be exercised to prevent contamination of the accelerator from pump oil in case of faults occurring in the beam switchyard.

A schematic diagram of the beam switchyard vacuum system is shown in Fig. 30. The entire switchyard is pumped by means of 8 pumping stations located at ground level about 40 feet above the switchyard. A diagram of the pumping station proposed for these locations is shown in Fig. 31. Each station utilizes a 6-inch oil diffusion pump backed by a 30 liter/sec mechanical pump. Refrigerated traps and pneumatically operated valves are employed in both the fore-lines and high vacuum line. Provision is made for the later addition of a 500 liter/sec ion pump if operating experience shows that sufficiently low system pressures can be maintained to make these pumps feasible.

Connection of the pumping station to the beam switchyard is accomplished by means of a 20-inch-diameter stainless steel manifold.

The differential pumping station shown schematically in Fig. 32 is located between the beam switchyard and the accelerator. The low conductance of a 1-1/2-inch tube passing through the steering magnets separates the two oil diffusion pumps of the first differential pumping stage and results in a decrease in pressure by more than two orders of magnitude. The low conductance ($\approx$ 1 liter/sec) for the second differential pumping stage is provided by the use of a standard 10-foot accelerator section. This section will be refrigerated to -30°C to trap migrating oil molecules. It has been estimated that such a trap will limit the transmission of hydrocarbons such that a period of about 20 years would be required to cover a 10-foot section of the accelerator structure (and its associated waveguide and vacuum plumbing) adjacent to the trap with a monolayer of organic molecules.

In order to protect the accelerator in case of vacuum failure in the beam switchyard, a number of fast closing valves are provided, as shown in Fig. 30. The functioning of the fast valve system is illustrated in Fig. 33. Each valve is provided with a set of pressure rise detectors which are located about 100 feet "downstream" from the valve location. One of the detectors, a piezo-electric crystal, provides a signal whenever there is a sudden rise in pressure in the form of a "shock wave" as might be produced by a catastrophic vacuum failure. The other detector, a form of McClure switch, is useful in providing a signal in the case of slow rises in pressure. These signals, after amplification, actuate a pneumatic release device which allows heavy springs within the valve to close it within a period of about 6 milliseconds. The valve can be reset remotely be means of pneumatic controls.

ACKNOWLEDGEMENTS

A machine of the size and complexity of the Stanford two-mile accelerator is necessarily the product of many people. It is not possible in a limited report of this type to give proper credit to all of those who have made important contributions. Nevertheless, the author would like to single out a number of individuals who have contributed to the vacuum components and systems described in this report.

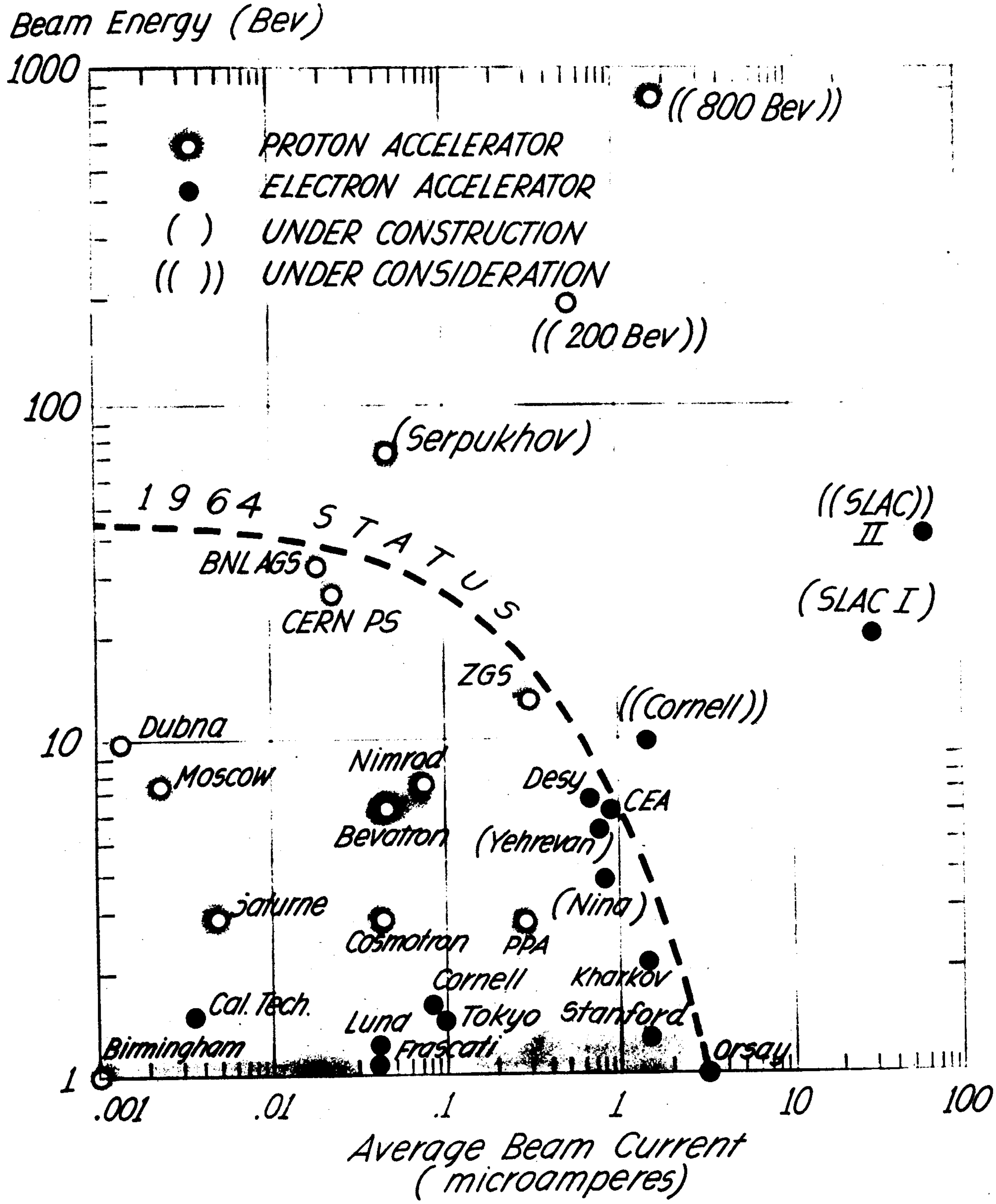
The accelerator vacuum system was designed by a group under the leadership of S.R. Conviser. Design consultation and assistance was contributed by E. Garwin, A. L. Eldredge, J. V. Lebacqz, and others at SLAC. The conceptual design of the right-angle valves manufactured by Westinghouse is due to A. Burch. G. Skoda, U. Cummings, G. Egg, and M. Baldwin have contributed to the design and testing of the various components of the main vacuum system.

The waveguide vacuum components were designed by members of the Mechanical Design and Fabrication Department at SLAC under A. L. Eldredge. The iris-type waveguide vacuum pump-out was designed by R. P. Borghi. A. Eldredge and A. Keicher designed the waveguide vacuum valve. The waveguide flange vacuum seal was designed by K. Skarpaas.

The cryogenic roughing system for the klystron window region was designed and tested by J. Jasberg and R. Fowkes, members of the Klystron Group under Dr. J. V. Lebacqz.

The light pipe and girder assembly are due to the support group of the Mechanical Design and Fabrication Department under R. Sandkuhle.

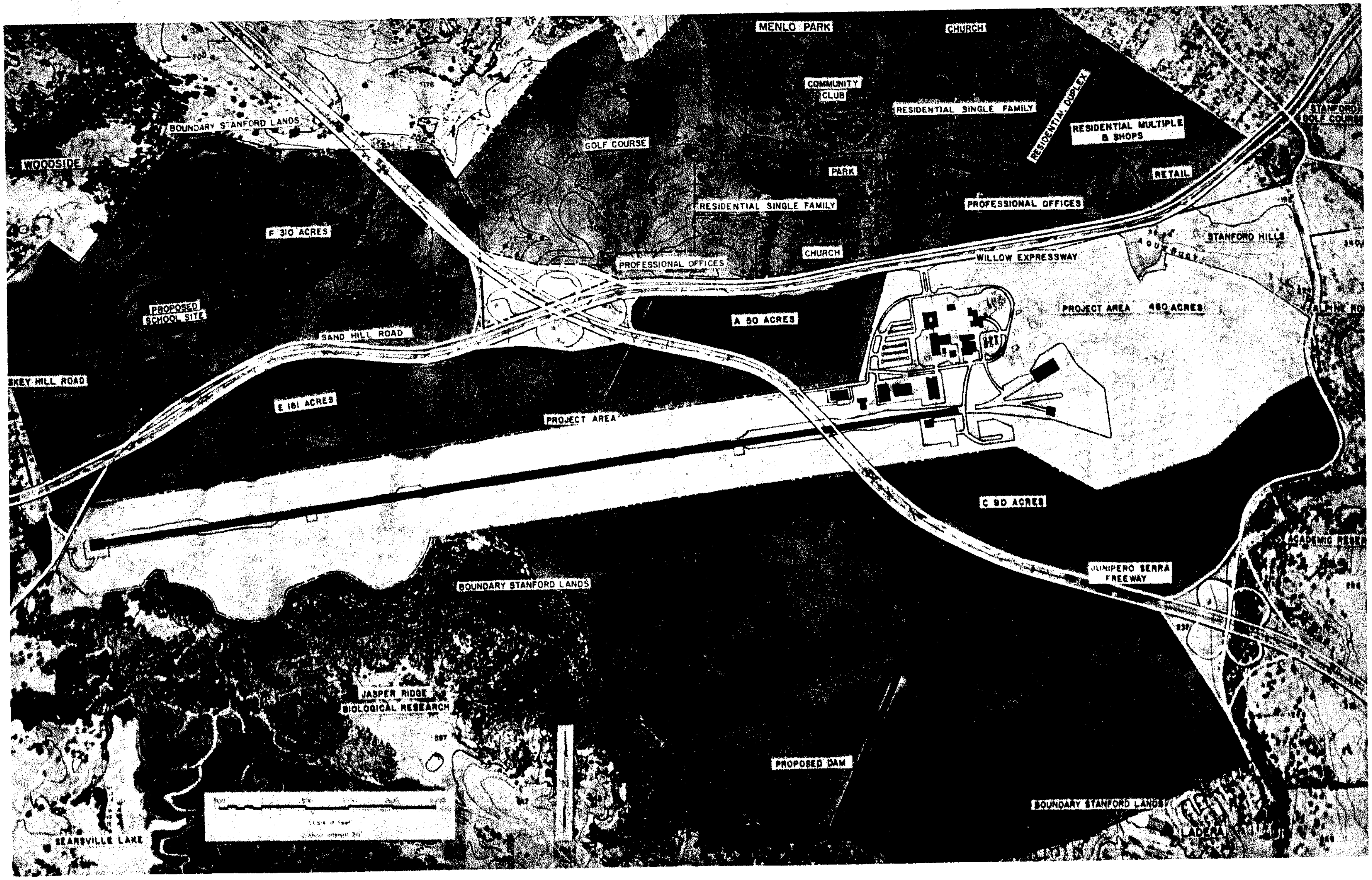
The conceptual design of the Beam Switchyard Vacuum System is due to L. Schwarcz, P. Thingstad, E. Garwin, and E. Hoyt. The protective fast valve system has been designed by J. Boyd.



Comparative graph of various accelerators.

JUNE, 1964

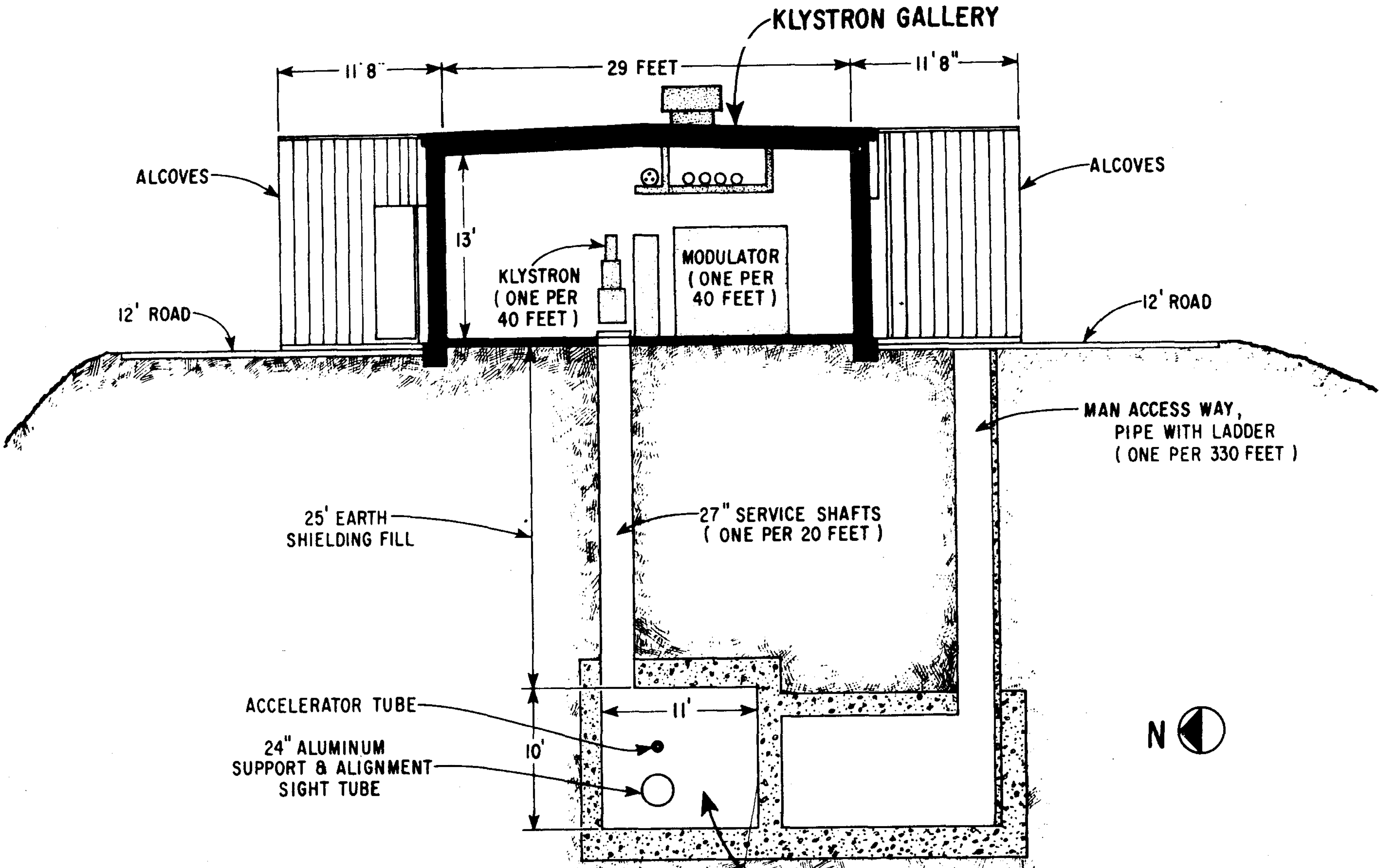
FIG. 1



MENLO PARK
CHURCH
COMMUNITY CLUB
RESIDENTIAL SINGLE FAMILY
RESIDENTIAL DUPLEX
RESIDENTIAL MULTIPLE & SHOPS
STANFORD GOLF COURSE
BOUNDARY STANFORD LANDS
WOODSIDE
GOLF COURSE
PARK
RETAIL
RESIDENTIAL SINGLE FAMILY
PROFESSIONAL OFFICES
F 310 ACRES
CHURCH
STANFORD HILLS
PROFESSIONAL OFFICES
WILLOW EXPRESSWAY
PROPOSED SCHOOL SITE
A 50 ACRES
PROJECT AREA 480 ACRES
SAND HILL ROAD
E 181 ACRES
PROJECT AREA
C 80 ACRES
JUNIPERO SERRA FREEWAY
BOUNDARY STANFORD LANDS
JASPER RIDGE BIOLOGICAL RESEARCH
PROPOSED DAM
BOUNDARY STANFORD LANDS
SEARSVILLE LAKE
LADERA

FIG. 2

FIG. 3



ACCELERATOR CROSS SECTION
LOOKING EAST IN DIRECTION OF BEAM

FIG. 4

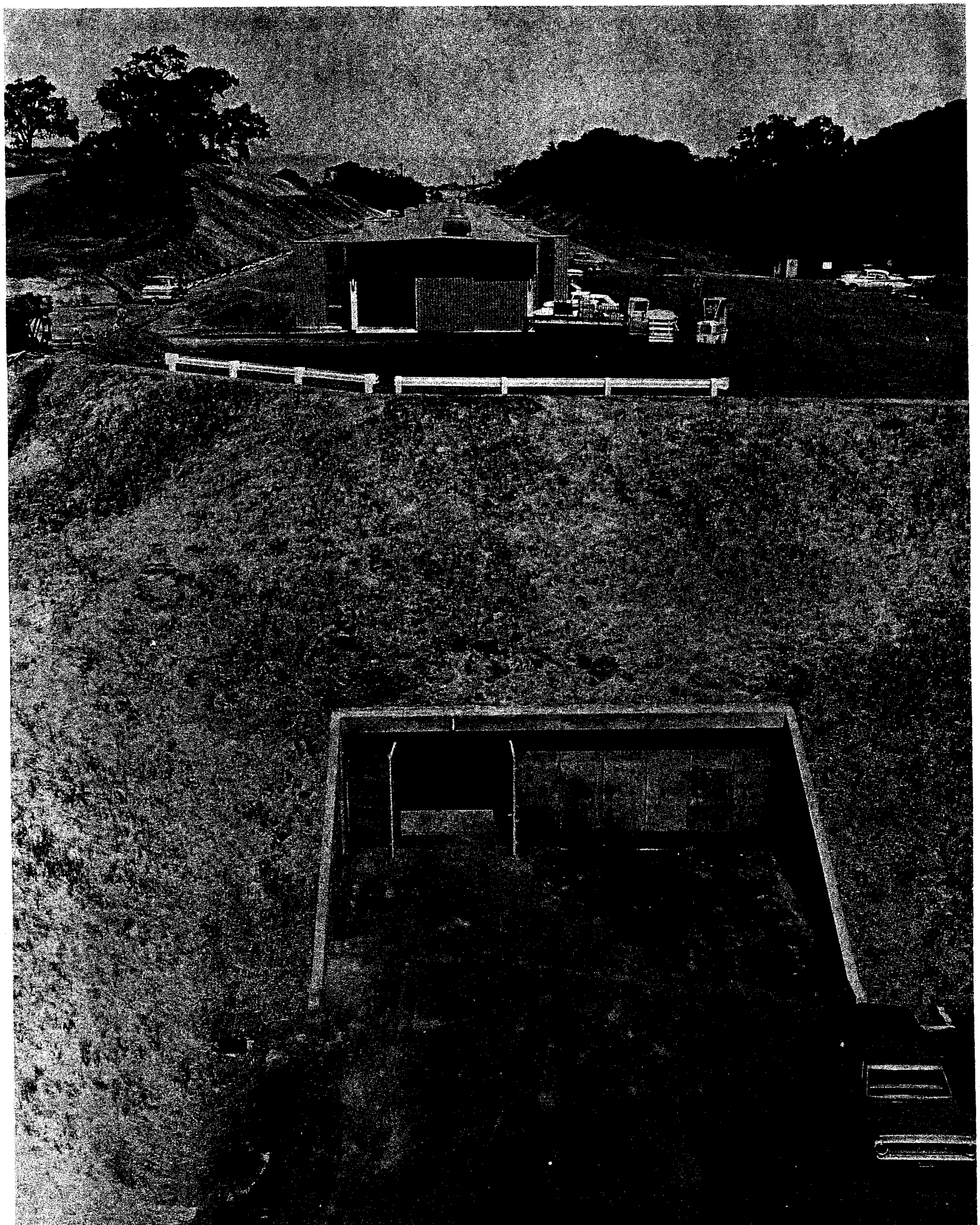


FIG. 5

FIG. 6

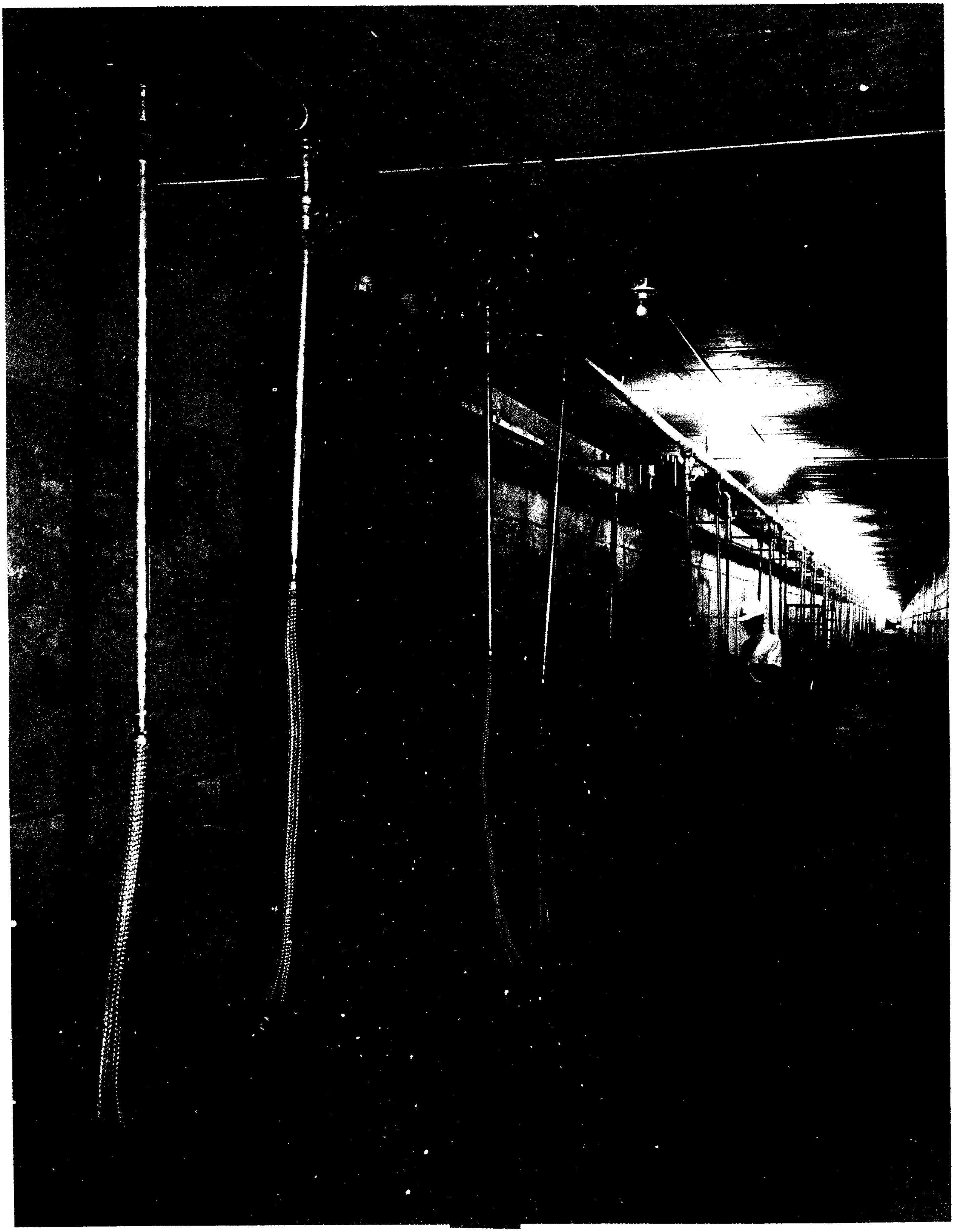
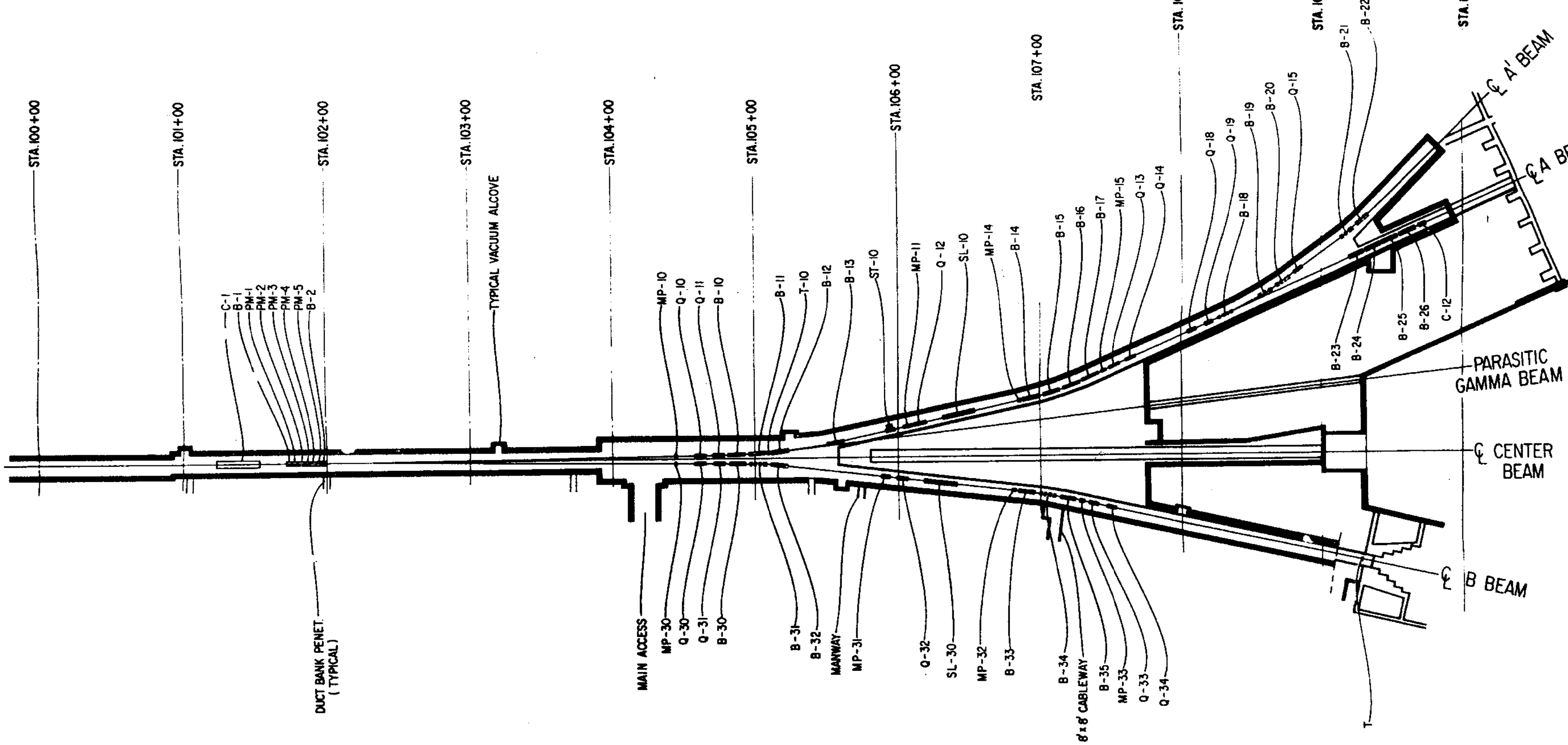


FIG. 7

PLAN AT B.S.Y. HOUSING

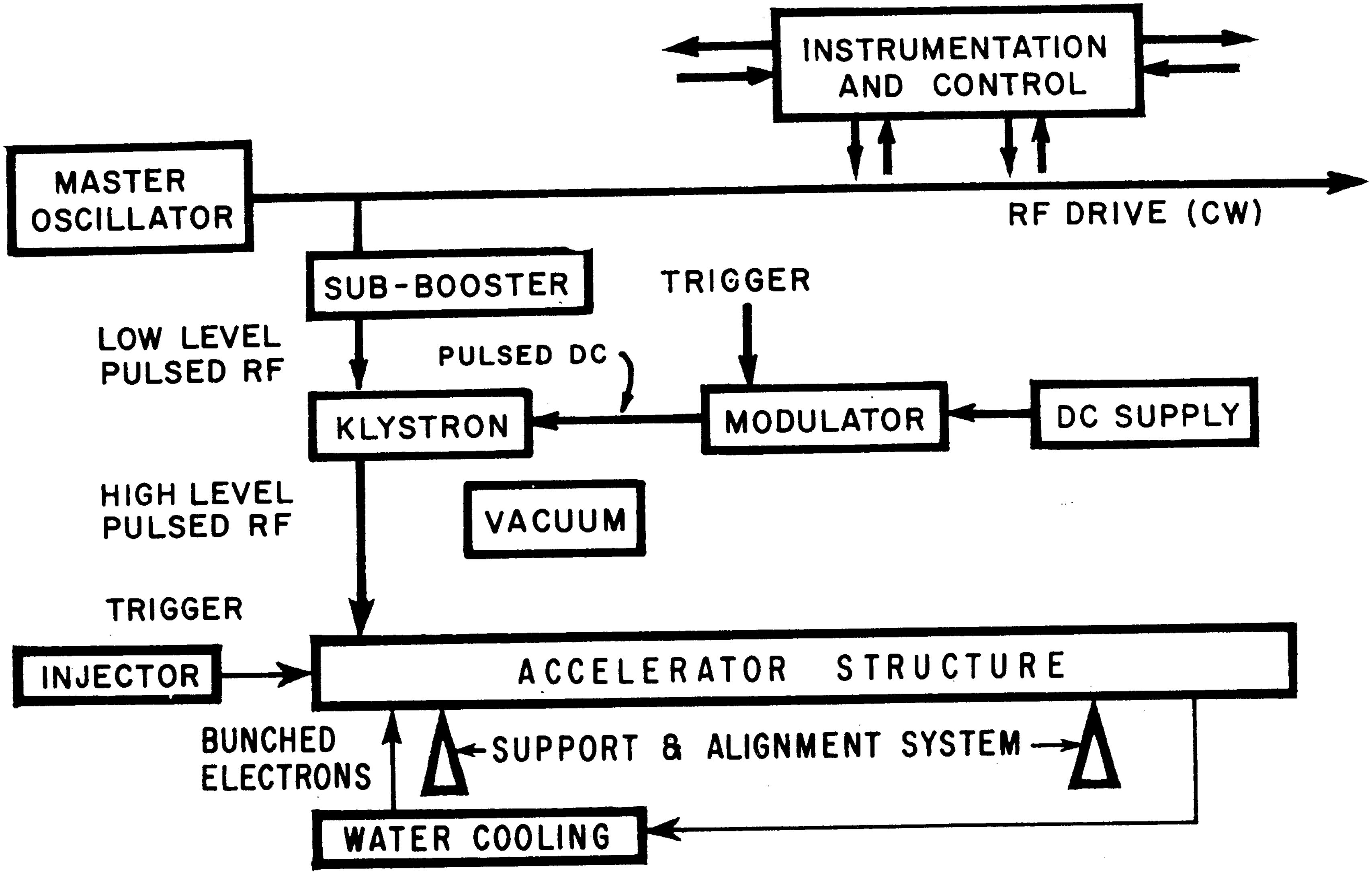


SYMBOL LIST

B	D.C. BENDING MAGNET
C	COLLIMATOR
PM	PULSE MAGNET
Q	QUADRUPOLE
SL	ENERGY DEFINING SLIT
ST	BEAM STOPPER
T	TARGET
MP	MAGNET PROTECTOR

4-1-R

FIG. 8



ACCELERATOR COMPONENTS AND SYSTEMS

FIG. 9

PRINCIPAL M ACCELERATOR SPECIFICATIONS

	STAGE I	STAGE II
ACCELERATOR LENGTH	10,000 feet	10,000 feet
LENGTH BETWEEN FEEDS	10 feet	10 feet
NUMBER OF ACCELERATOR SECTIONS	960	960
NUMBER OF KLYSTRONS	240	960
PEAK POWER PER KLYSTRON	6-24 Mw	6-24 Mw
BEAM PULSE REPETITION RATE	1-360 pps	1-360 pps
RF PULSE LENGTH	2.5 μsec.	2.5 μsec.
ELECTRON ENERGY, UNLOADED	11.1-22.2 Bev	22.2-44.4 Bev
ELECTRON ENERGY, LOADED	10-20 Bev	20-40 Bev
PEAK BEAM CURRENT	25-50 ma	50-100 ma
AVERAGE BEAM CURRENT	15-30 μa	30-60 μa
AVERAGE BEAM POWER	0.15-0.6 Mw	0.6-2.4 Mw
FILLING TIME	0.83 μsec.	0.83 μsec.
ELECTRON BEAM PULSE LENGTH	0.01-2.1 μsec.	0.01-2.1 μsec.
ELECTRON BEAM ENERGY SPREAD (MAX)	± 0.5 %	± 0.5 %
NO. OF ELECTRON ENERGY LEVELS	up to 6	up to 6
ACCELERATOR VACUUM	$<10^{-5}$ mm of Hg	10^{-5} mm of Hg
OPERATING FREQUENCY	2856 Mc/sec.	2856 Mc/sec.
OPERATING SCHEDULE	24 hrs/day	24 hrs/day

FIG. 10

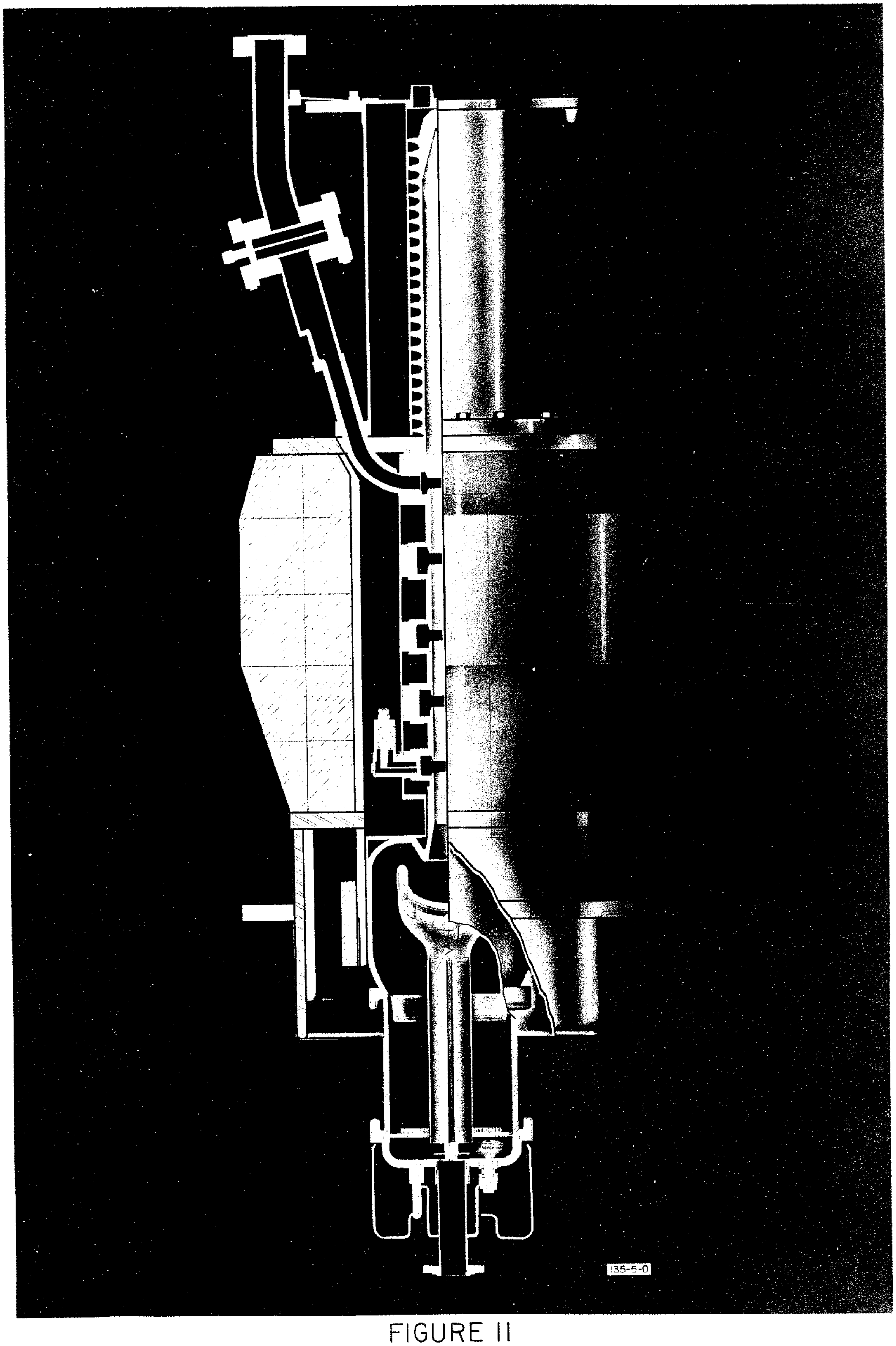
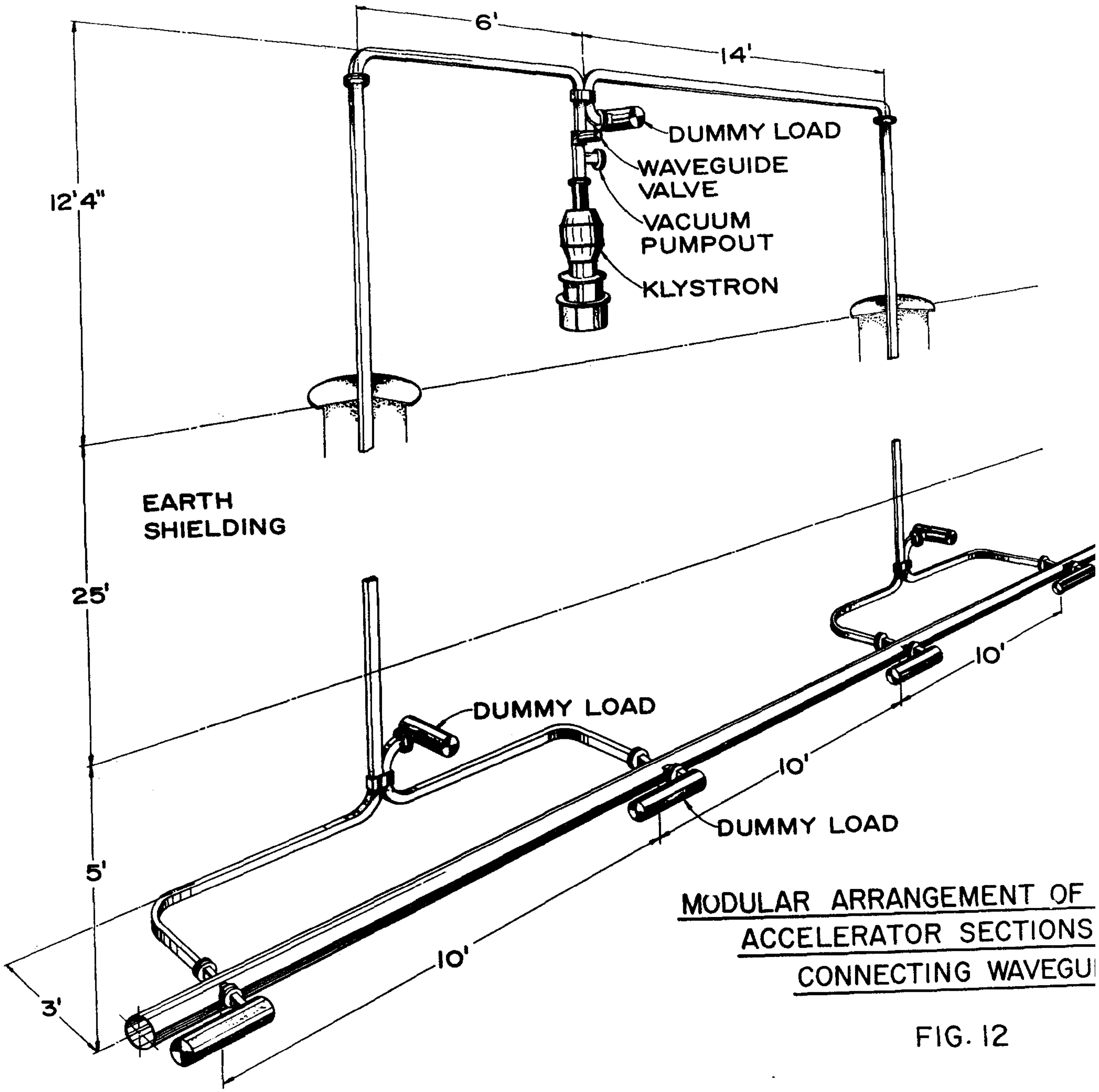


FIGURE II



MODULAR ARRANGEMENT OF
ACCELERATOR SECTIONS
CONNECTING WAVEGU

FIG. 12

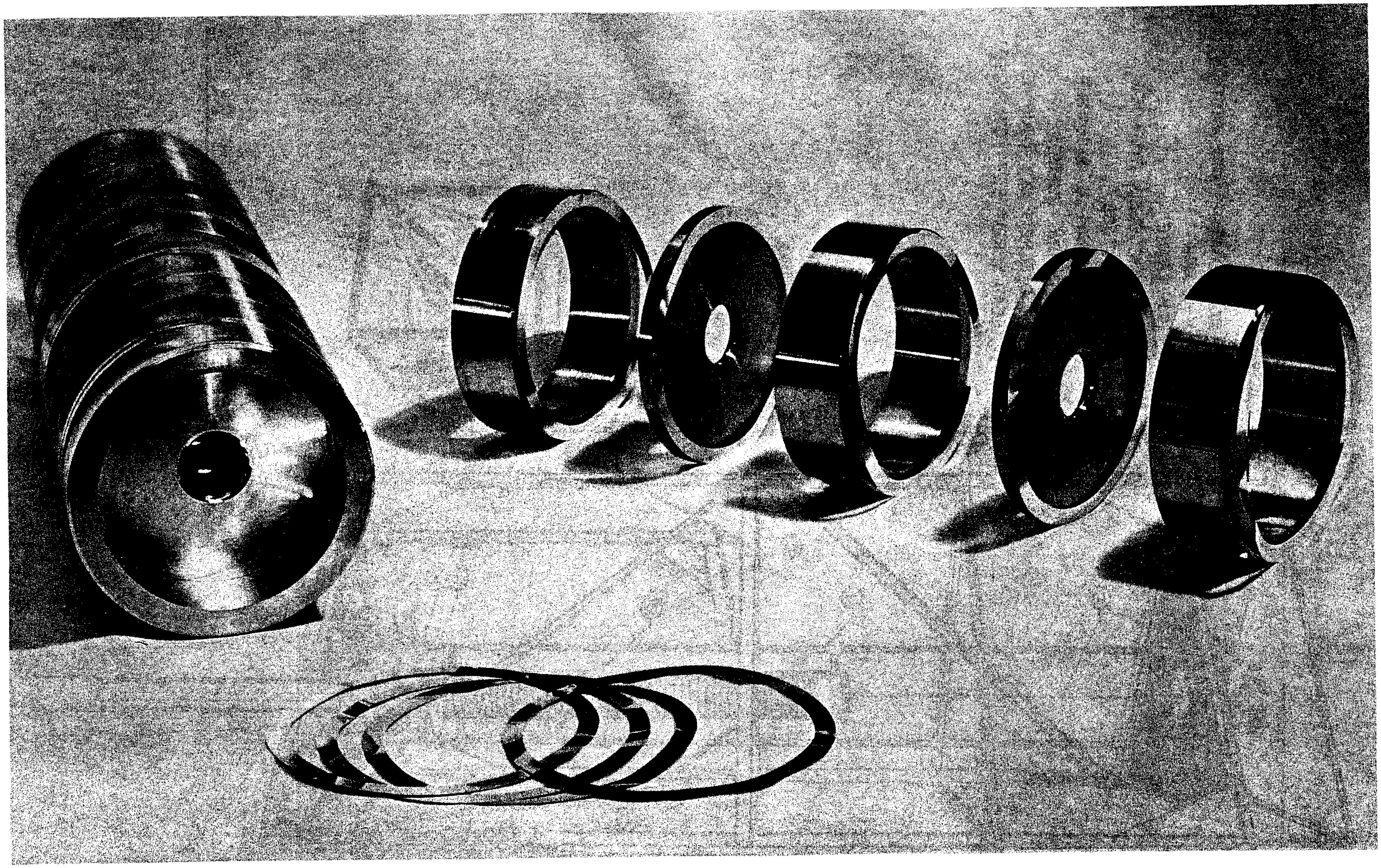
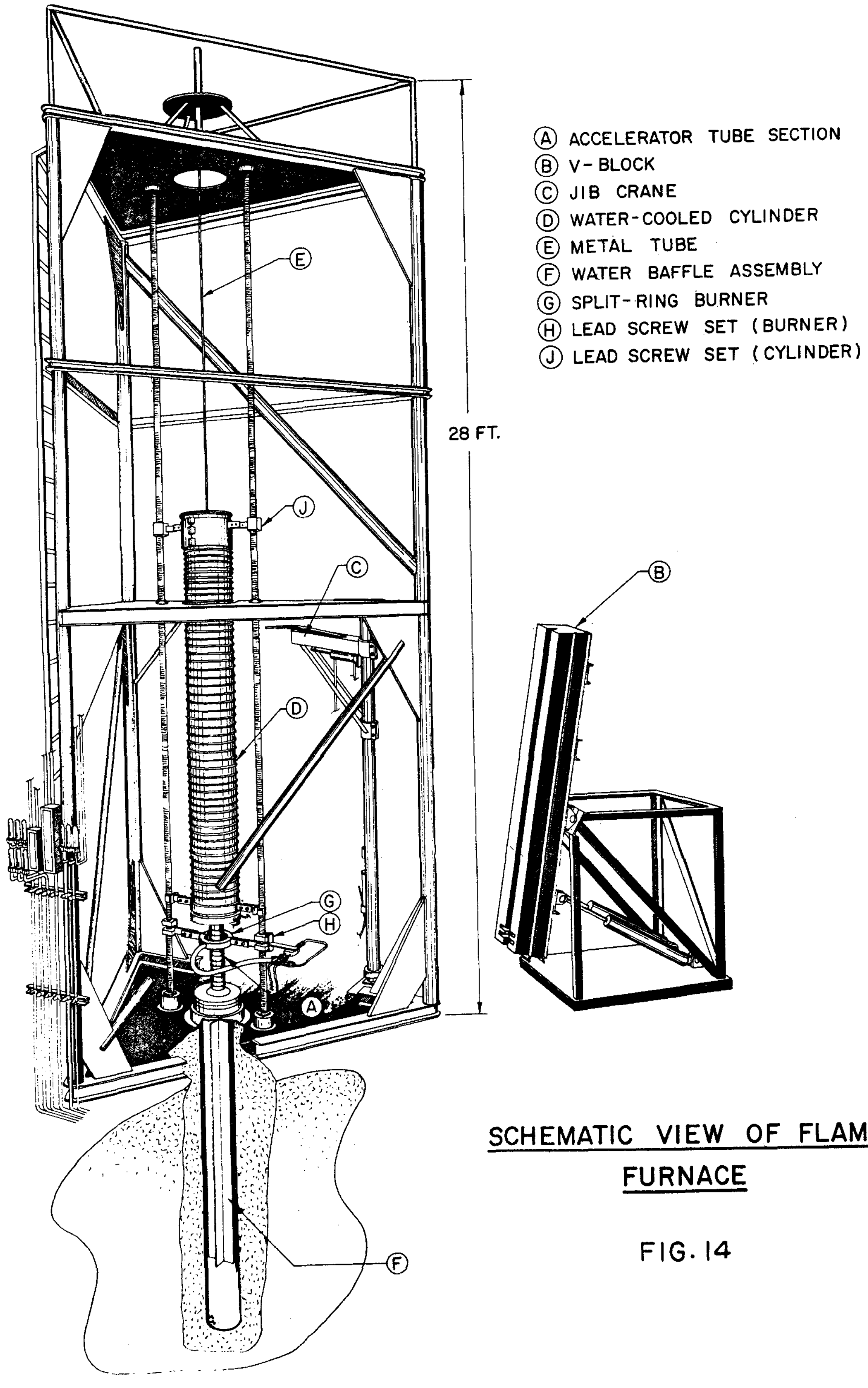


FIG. 13



SCHEMATIC VIEW OF FLAME FURNACE

FIG. 14

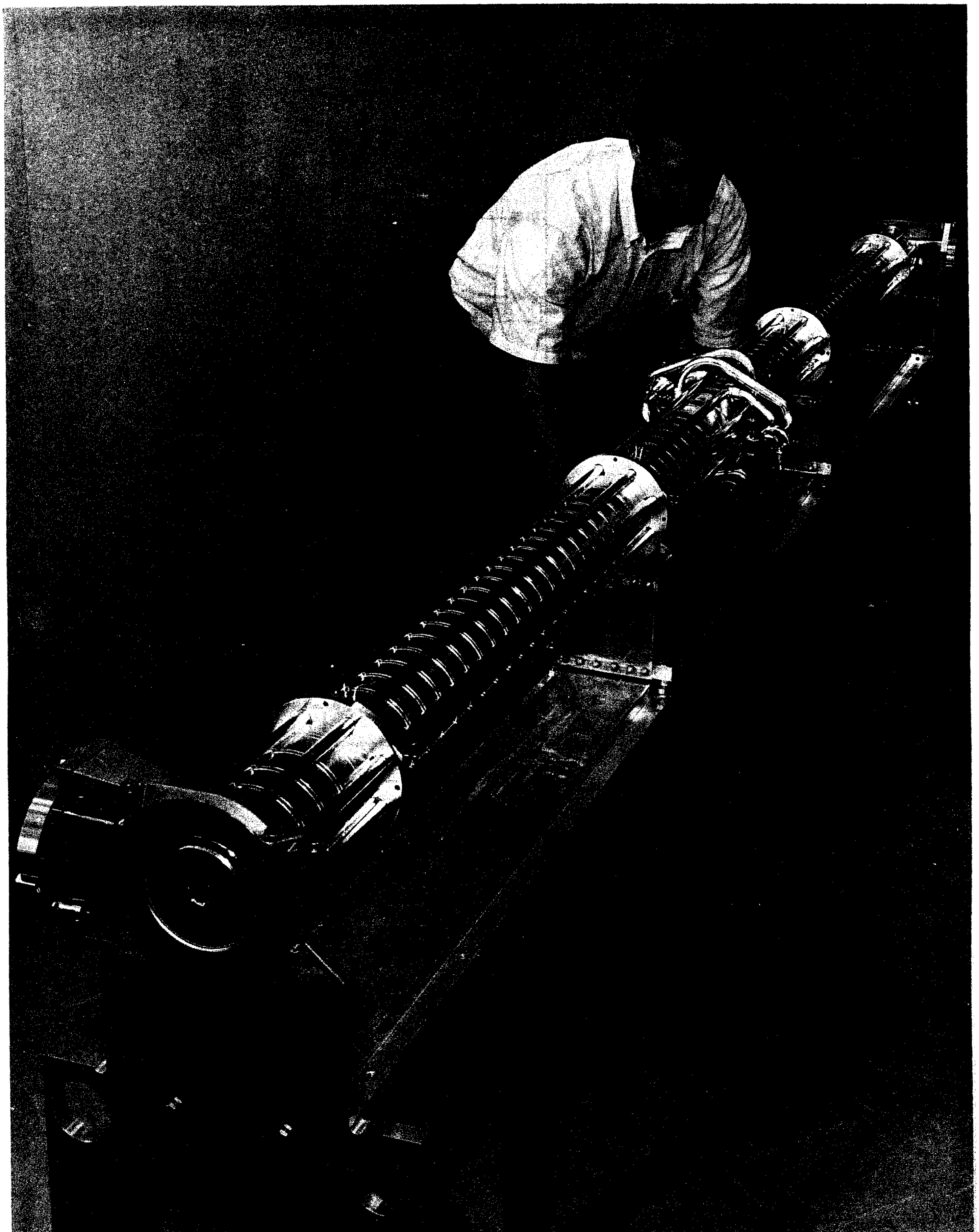
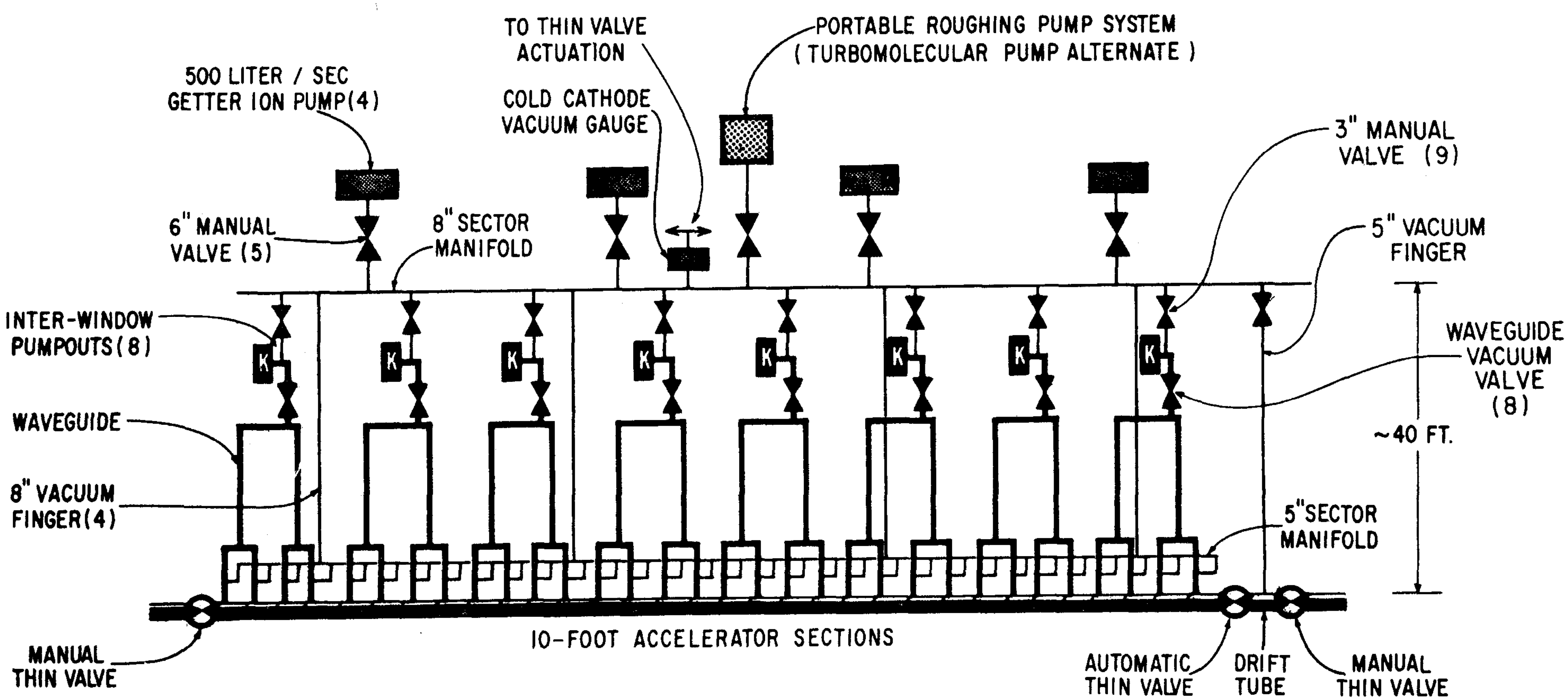


FIG. 15



VACUUM SYSTEM SCHEMATIC FOR ONE 333-FT SECTOR

145-10-B

FIG. 16

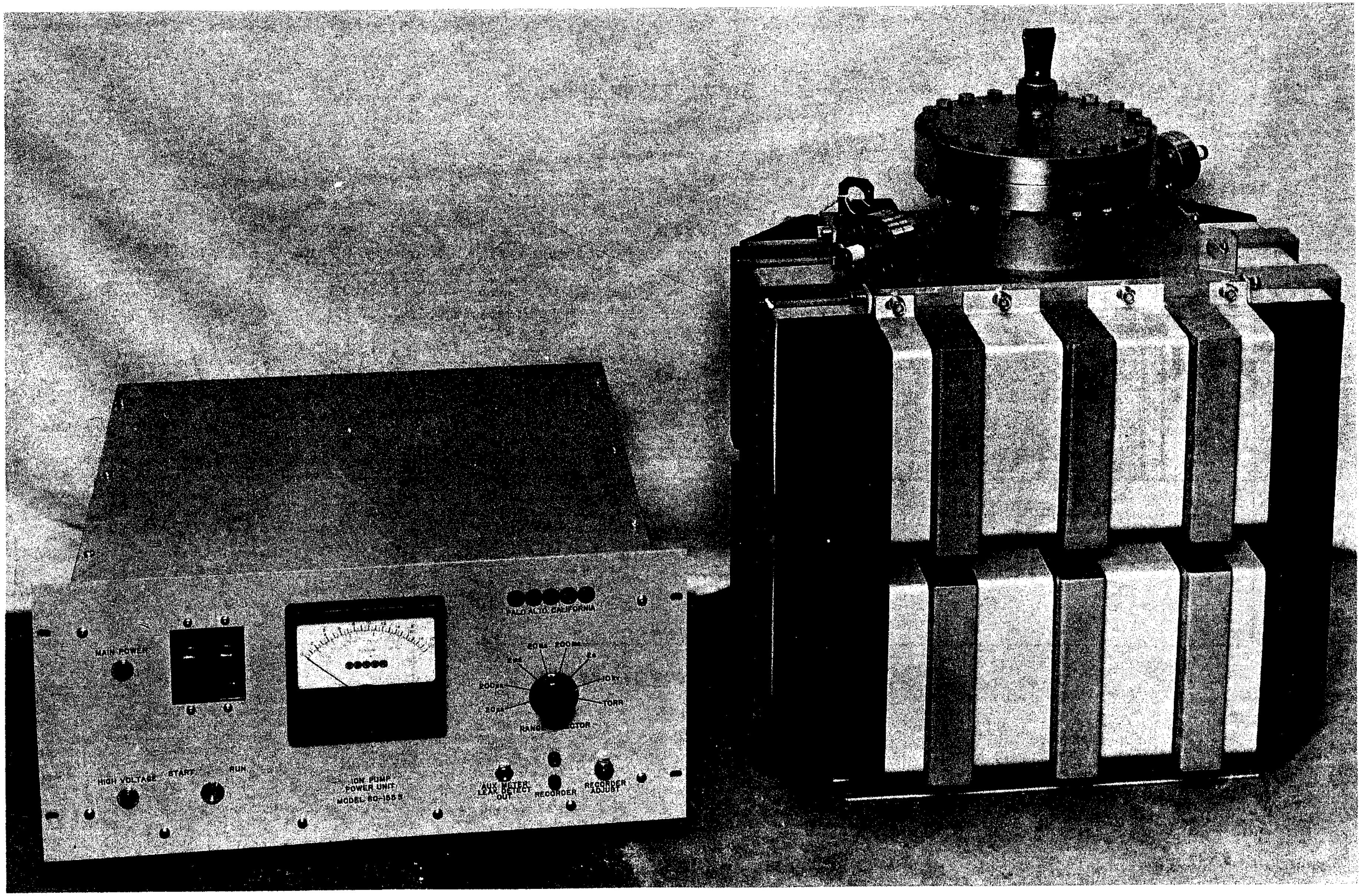
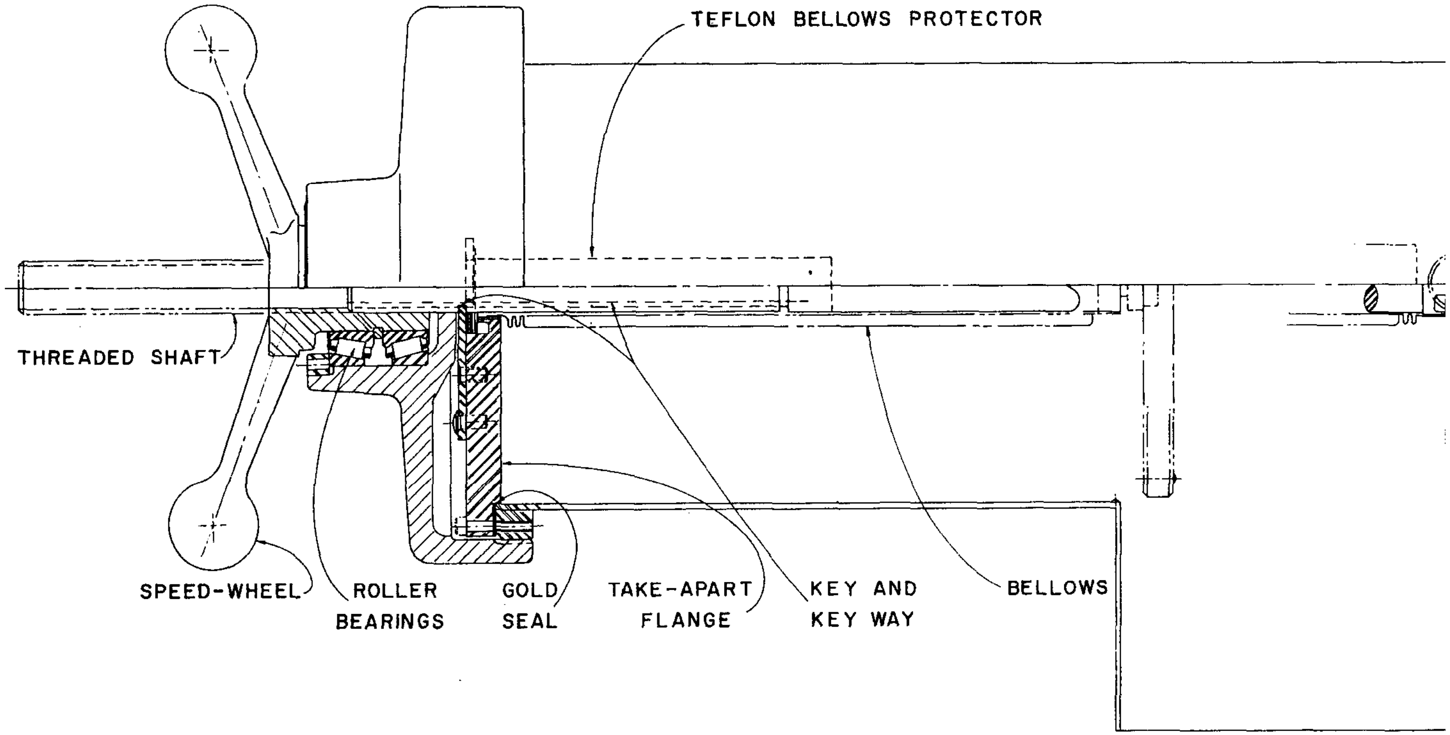
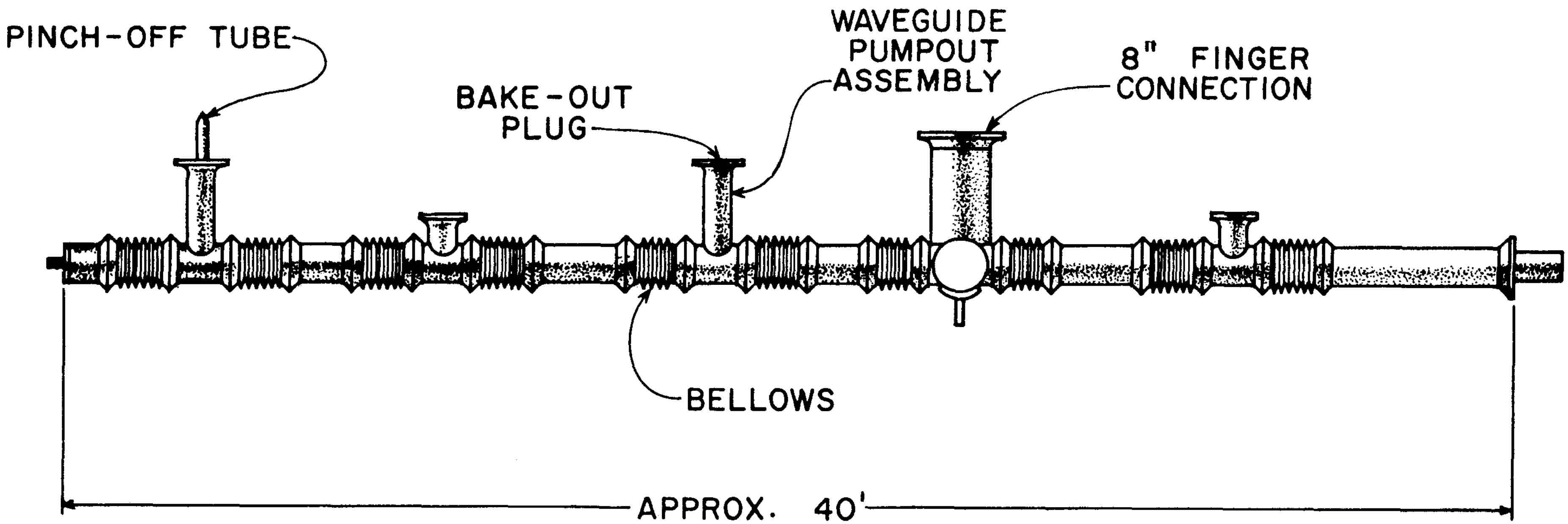

PALO ALTO, CALIFORNIA
MAIN POWER
HIGH VOLTAGE
START
RUN
ION PUMP
POWER UNIT
TORR
AUX METER
LEAK DETECT
OUT
RECORDER
RECORDER
ADJUST

FIG. 17



6" RIGHT ANGLE VALVE

FIG. 18



VACUUM 5" MANIFOLD ASSEMBLY

145-7-B

FIG. 19

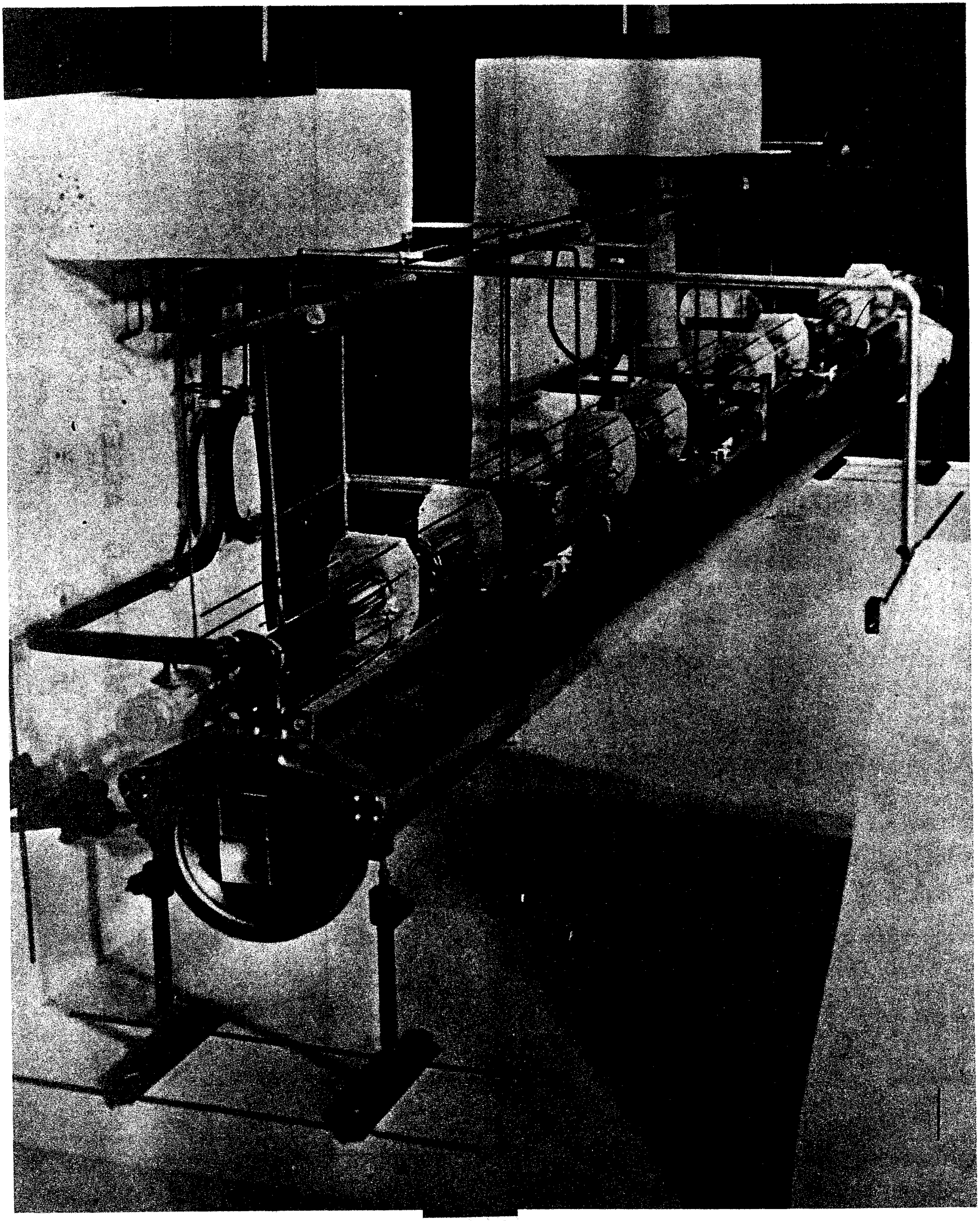


FIG. 20

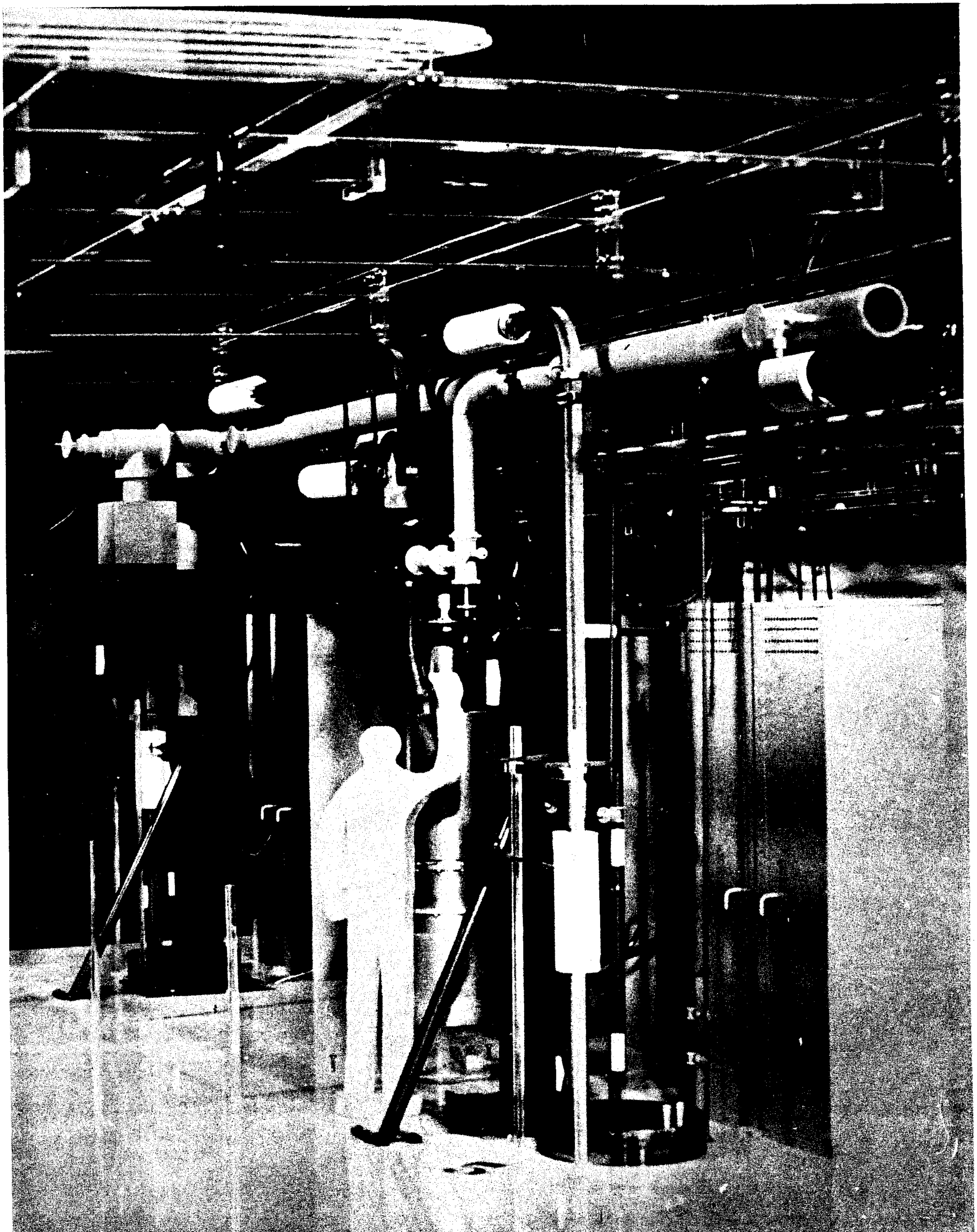
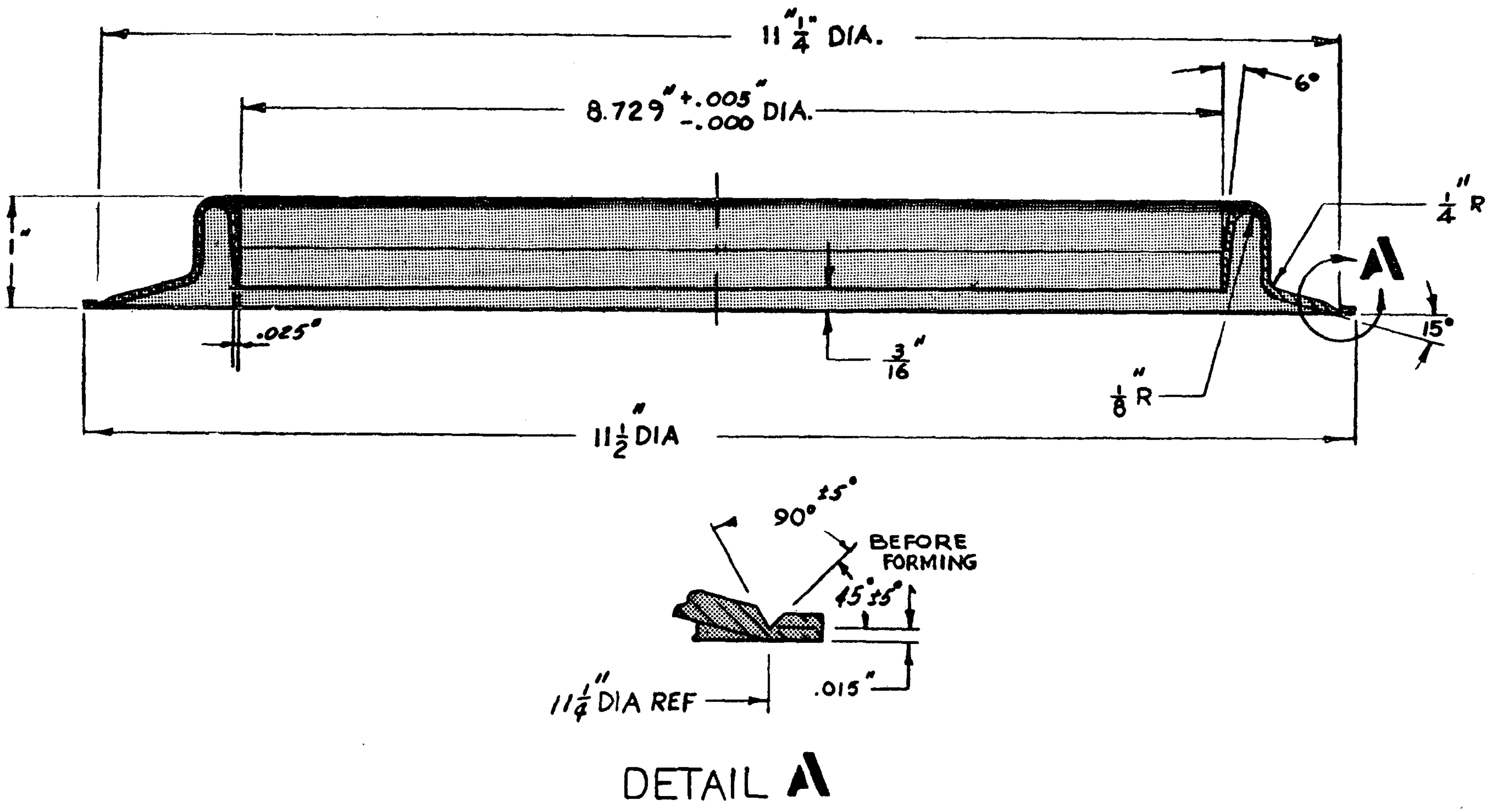


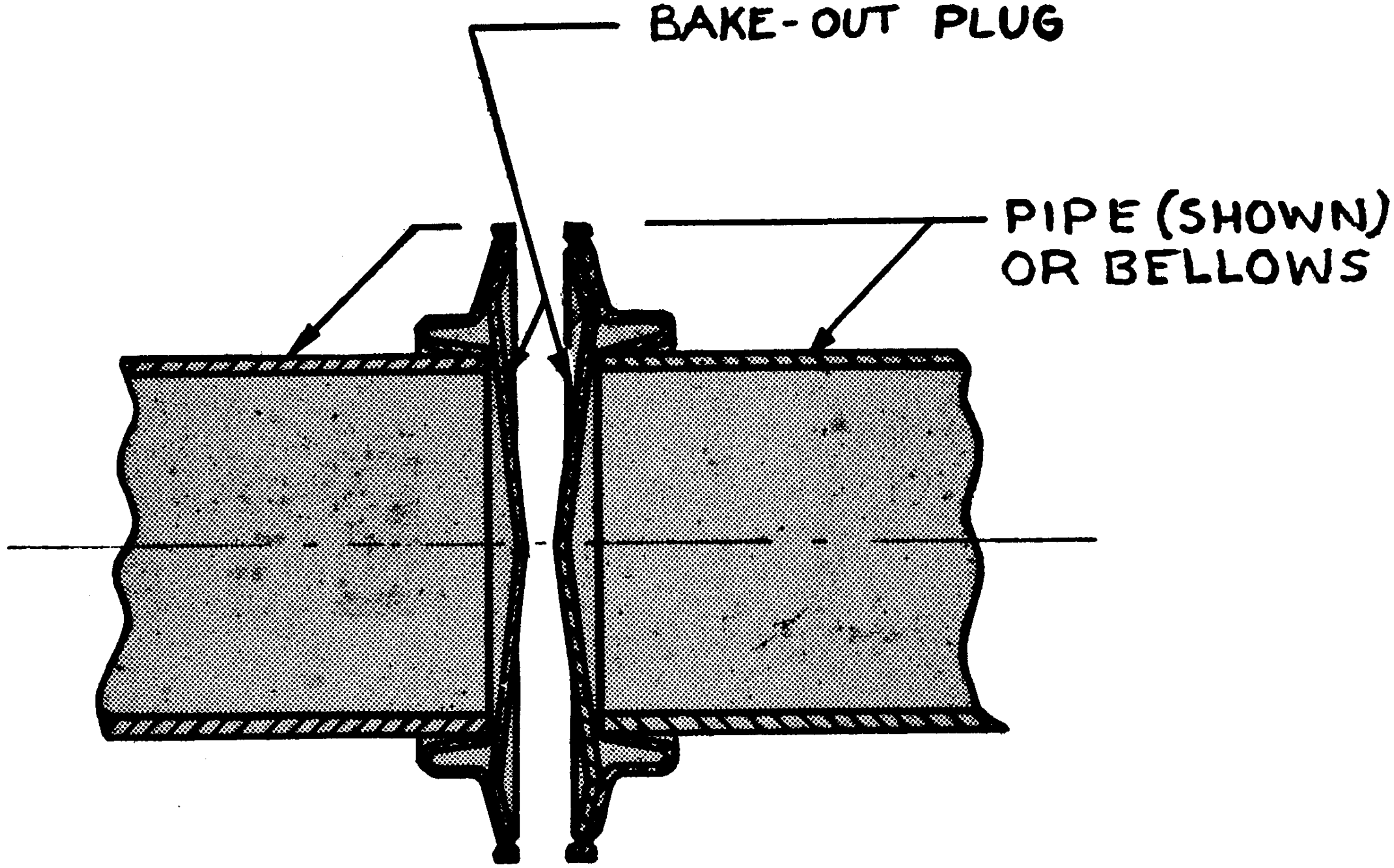
FIG. 21



8" BELLOWS ADAPTER

145-11-A

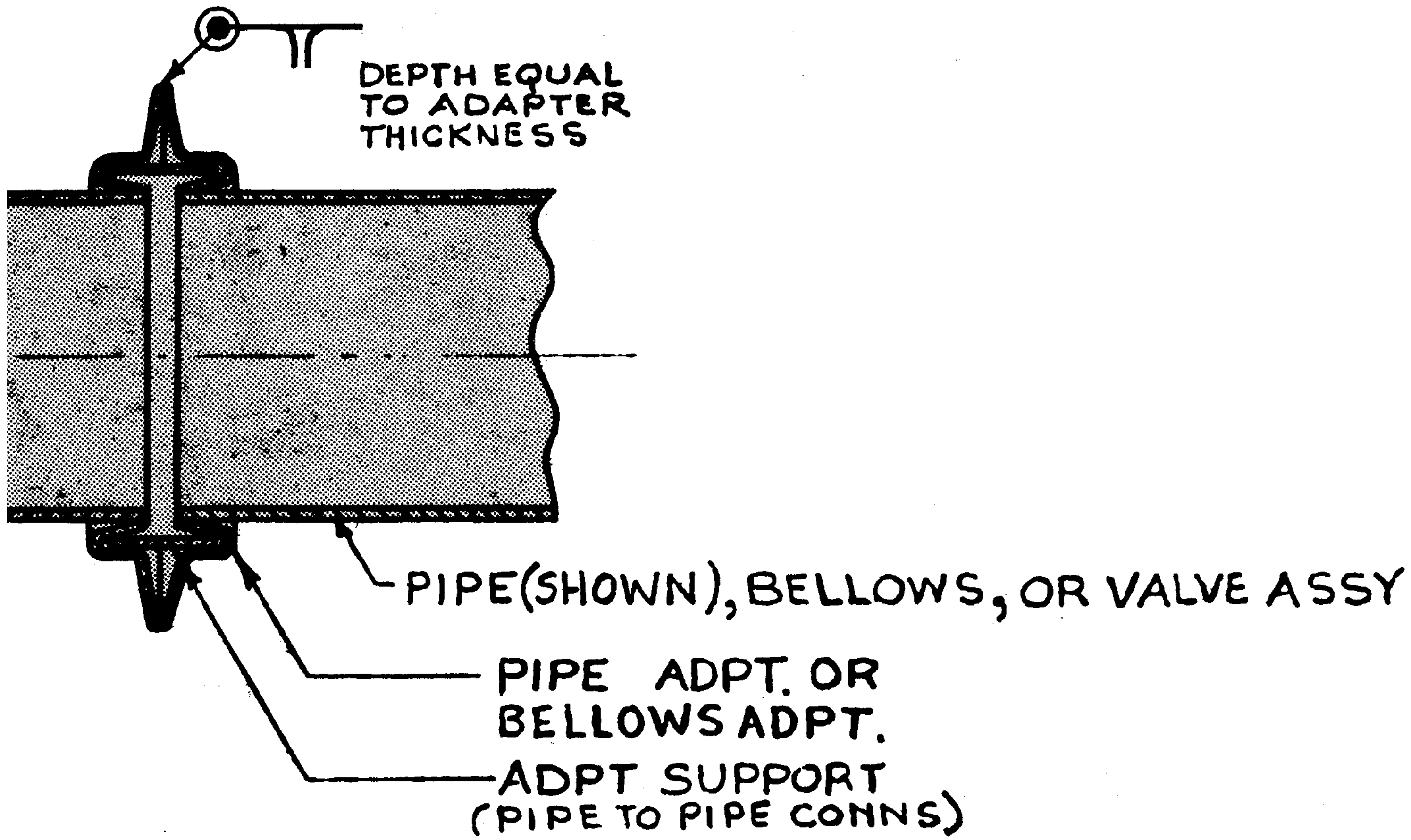
FIG. 22



SHOP WELDED ADAPTERS & BAKE-OUT PLUGS BEFORE FIELD ASSY.

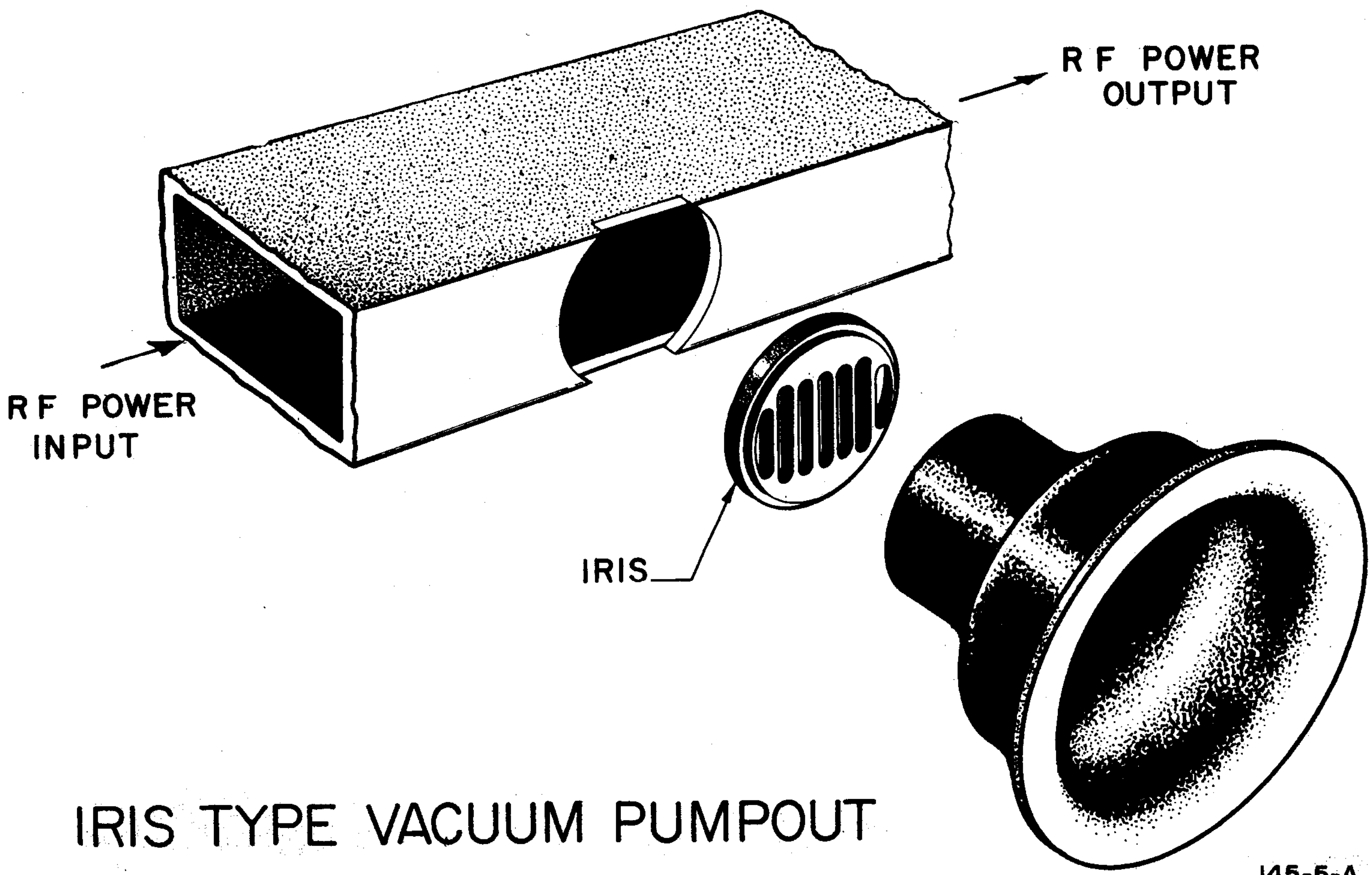
145-13-A

FIG. 23



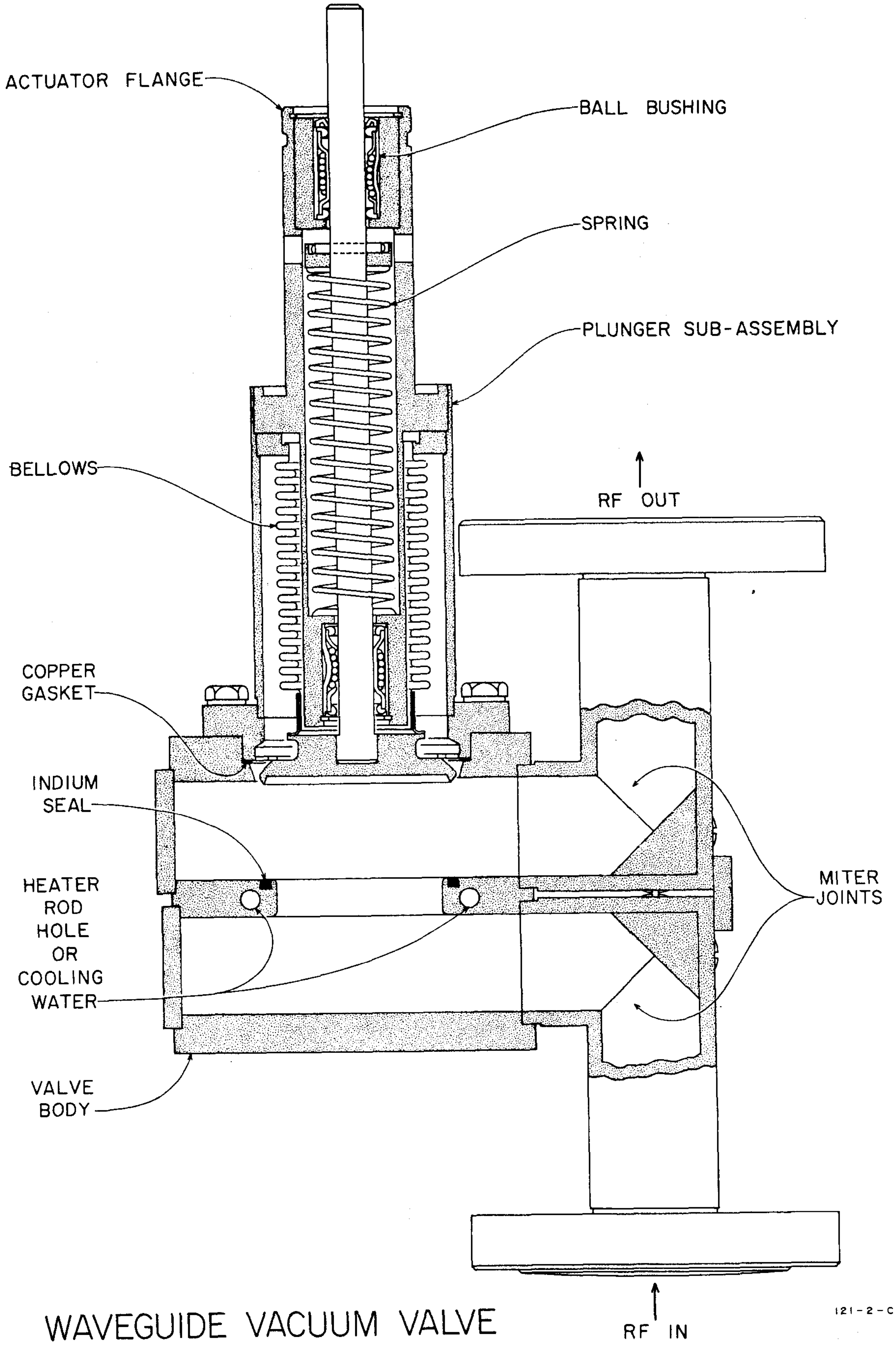
/LD WITH ADAPTERS &
:PTER SUPPORT

FIG. 24



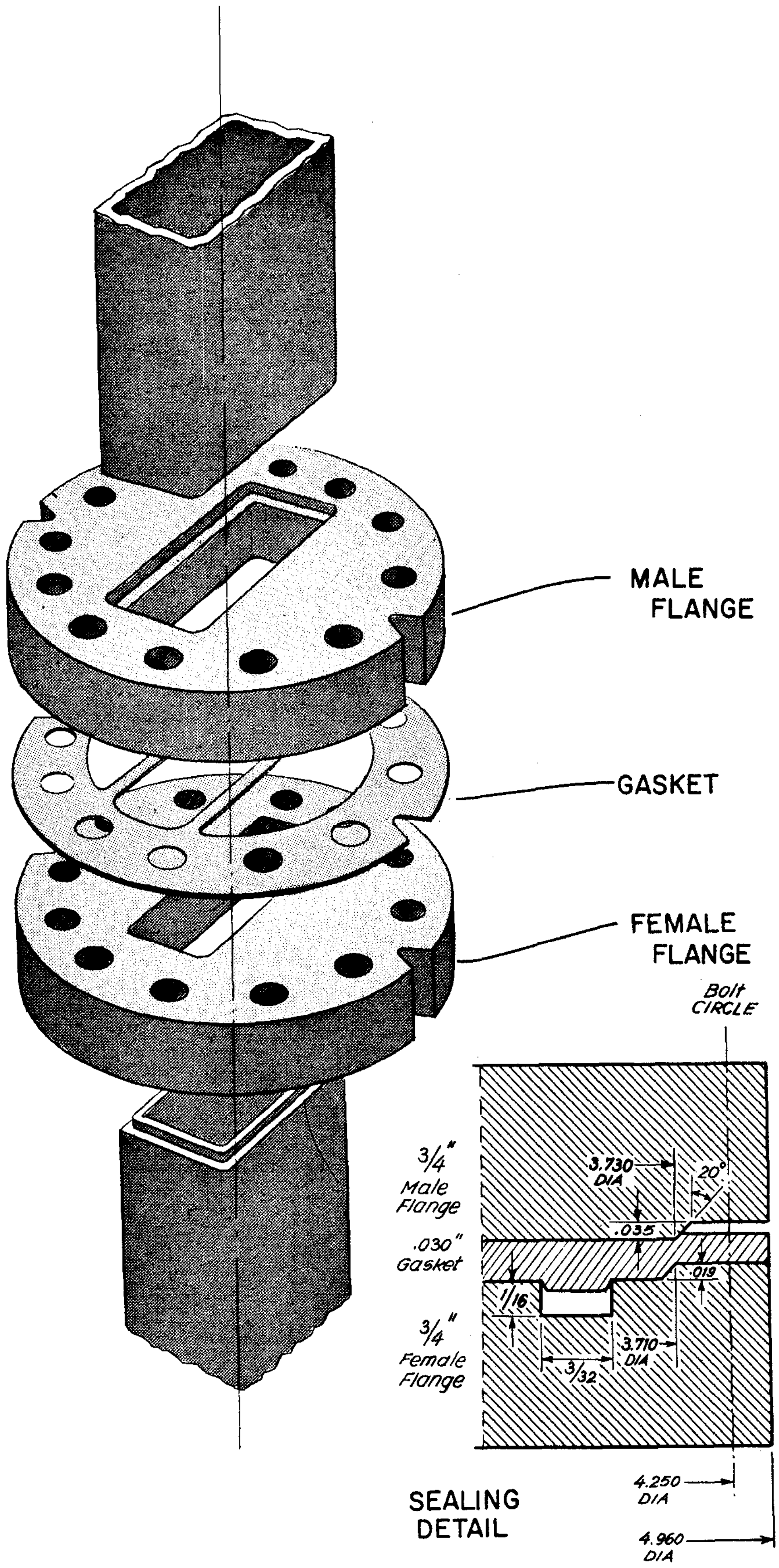
IRIS TYPE VACUUM PUMPOUT

FIG. 25



WAVEGUIDE VACUUM VALVE

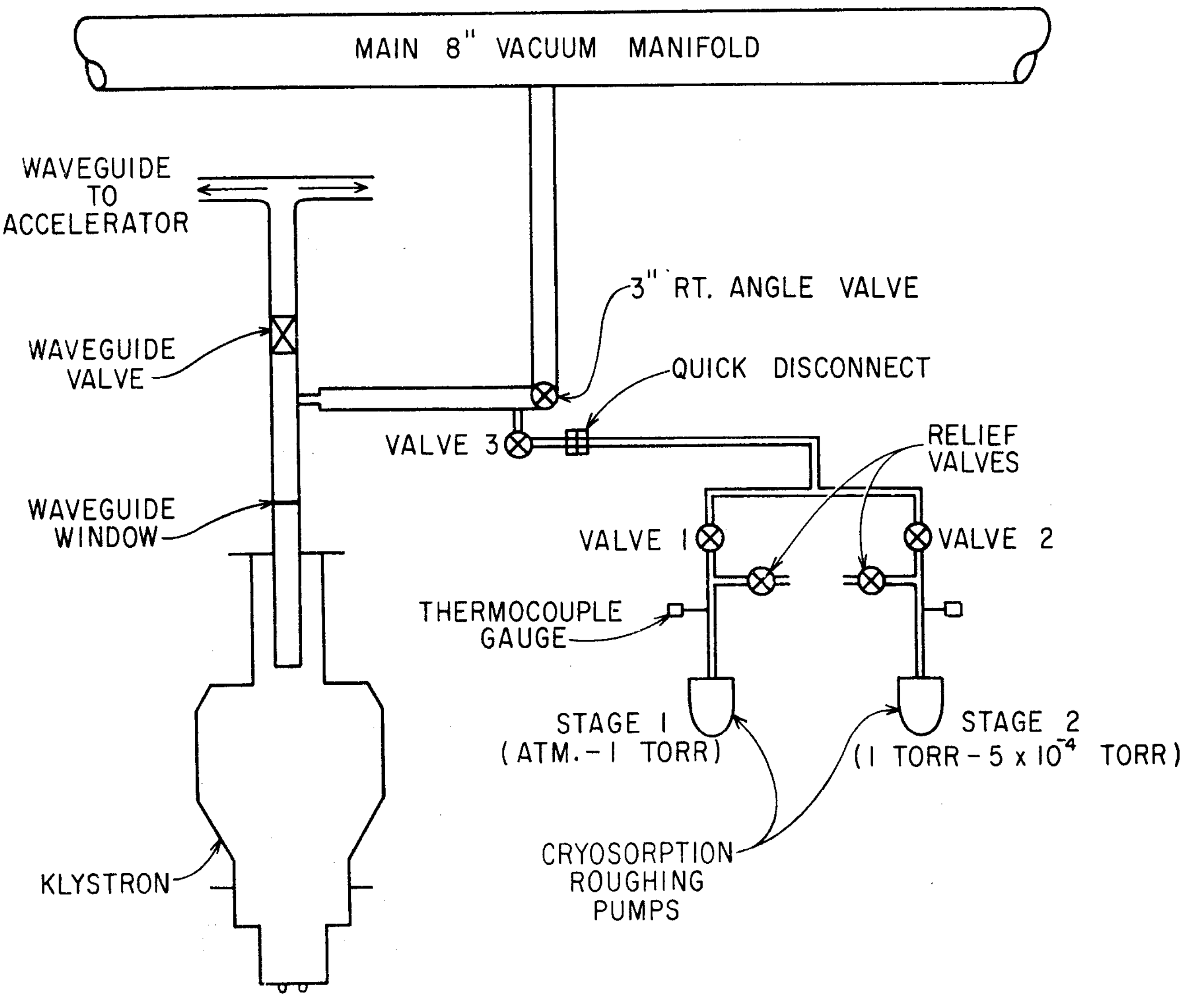
FIG. 26



WAVEGUIDE FLANGE VACUUM SEAL

FIG. 27

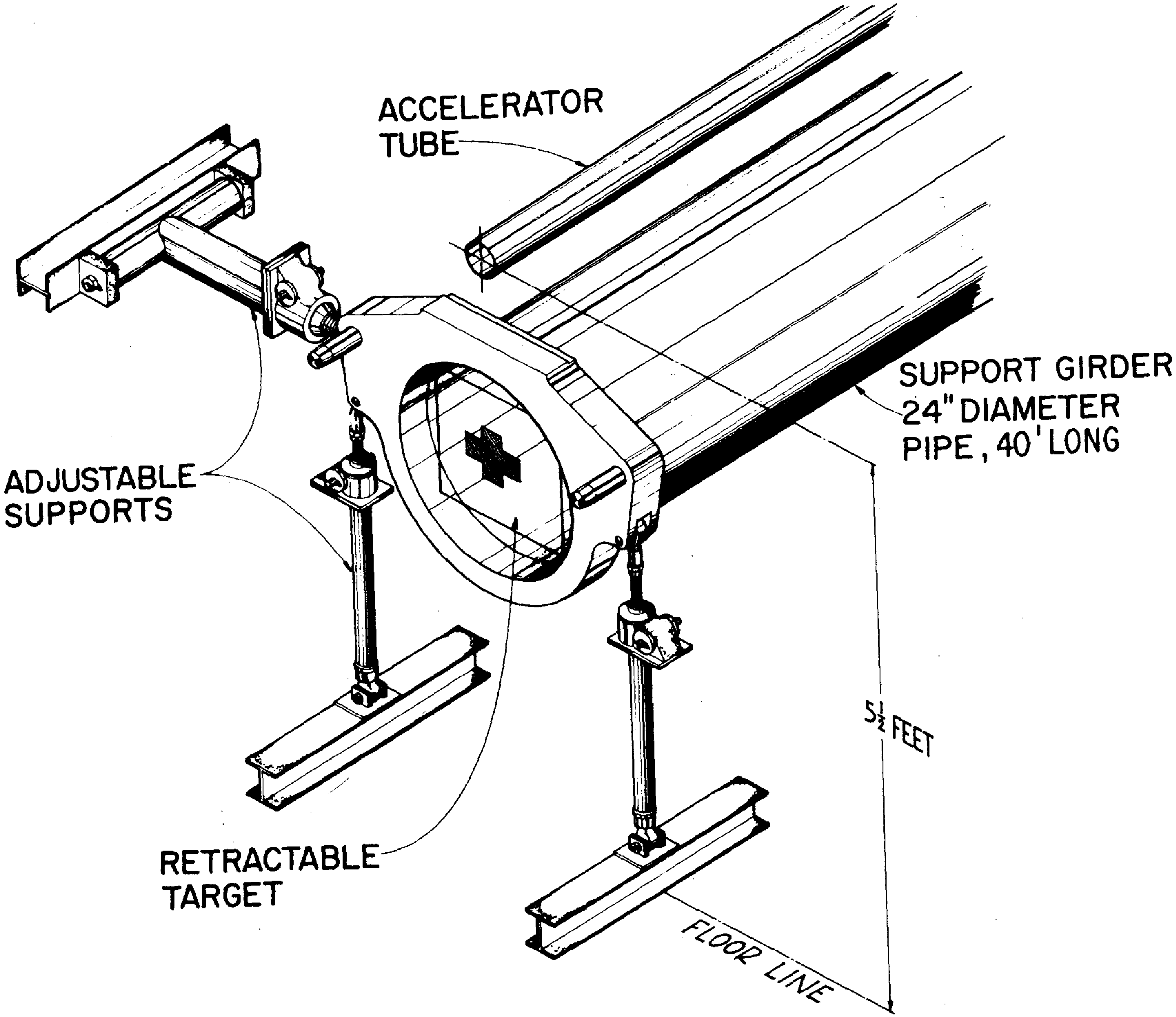
145-6-8



PORTABLE CRYOSORPTION ROUGHING SYSTEM FOR KLYSTRON WINDOW - WAVEGUIDE VALVE REGION

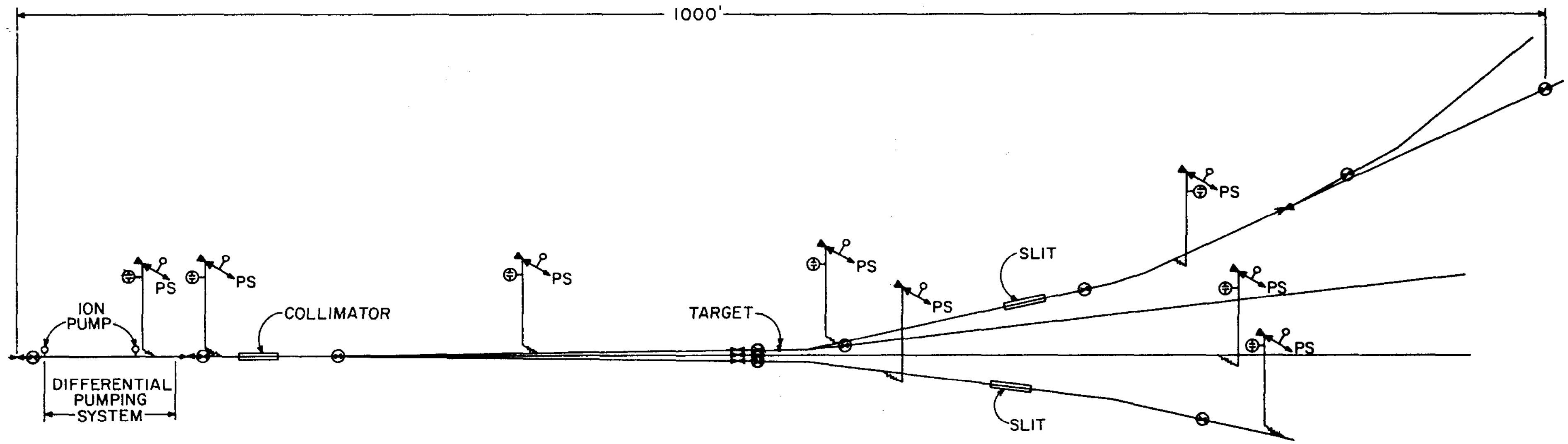
145-9-A

FIG. 28



SUPPORT AND ALIGNMENT SYSTEM

FIG. 29



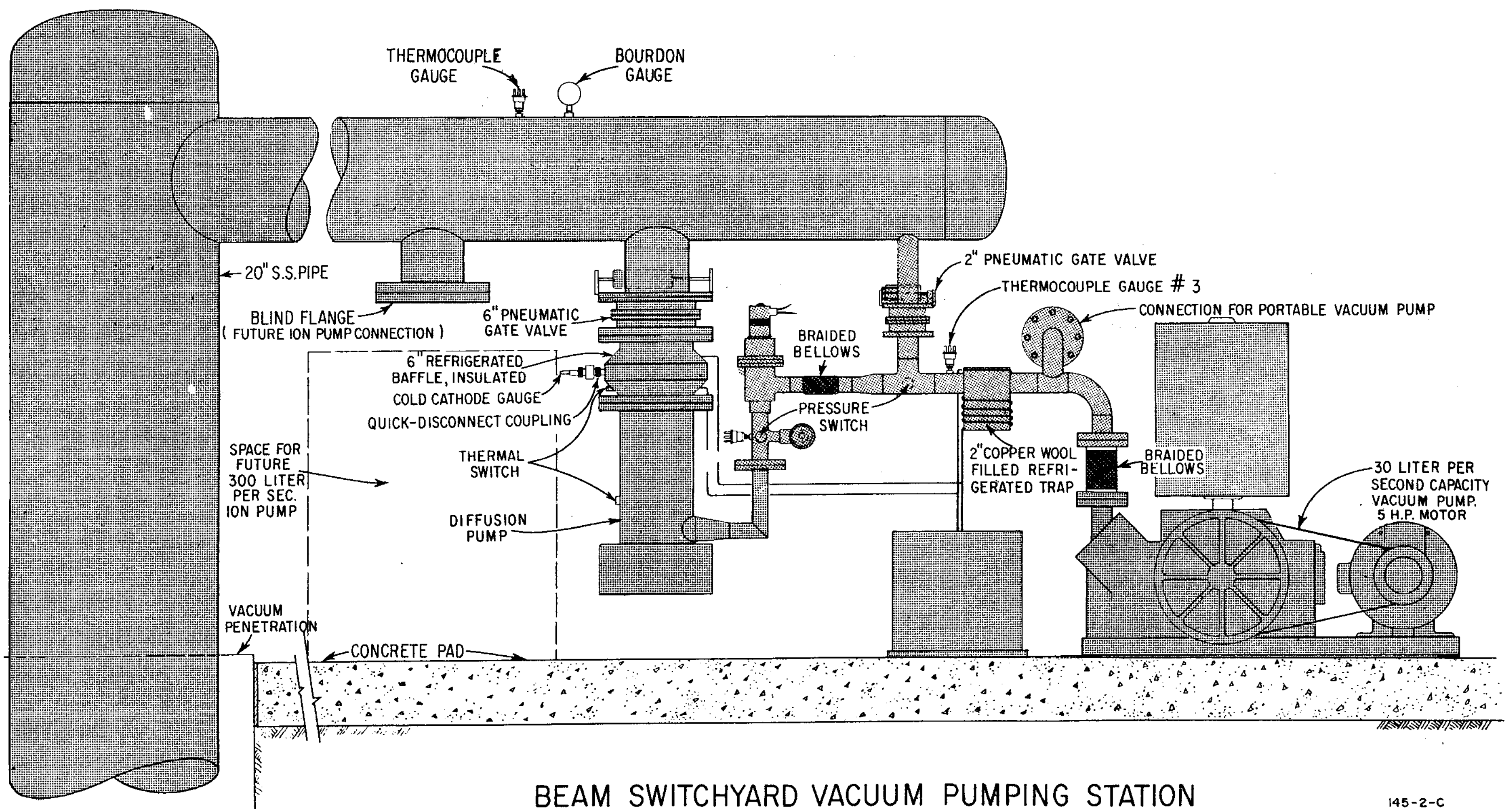
LEGEND

o	PENETRATION (27" O.D.)
⧓	FAST VALVES
⊖	VACUUM ISOLATION VALVES
⧓	PUMP SYSTEM VALVES
⊕	VACUUM GAUGE
⚲	PUMP GAUGES
PS	OVERHEAD PUMP SYSTEM

145-3-8

B.S.Y. VACUUM SYSTEM SCHEMATIC

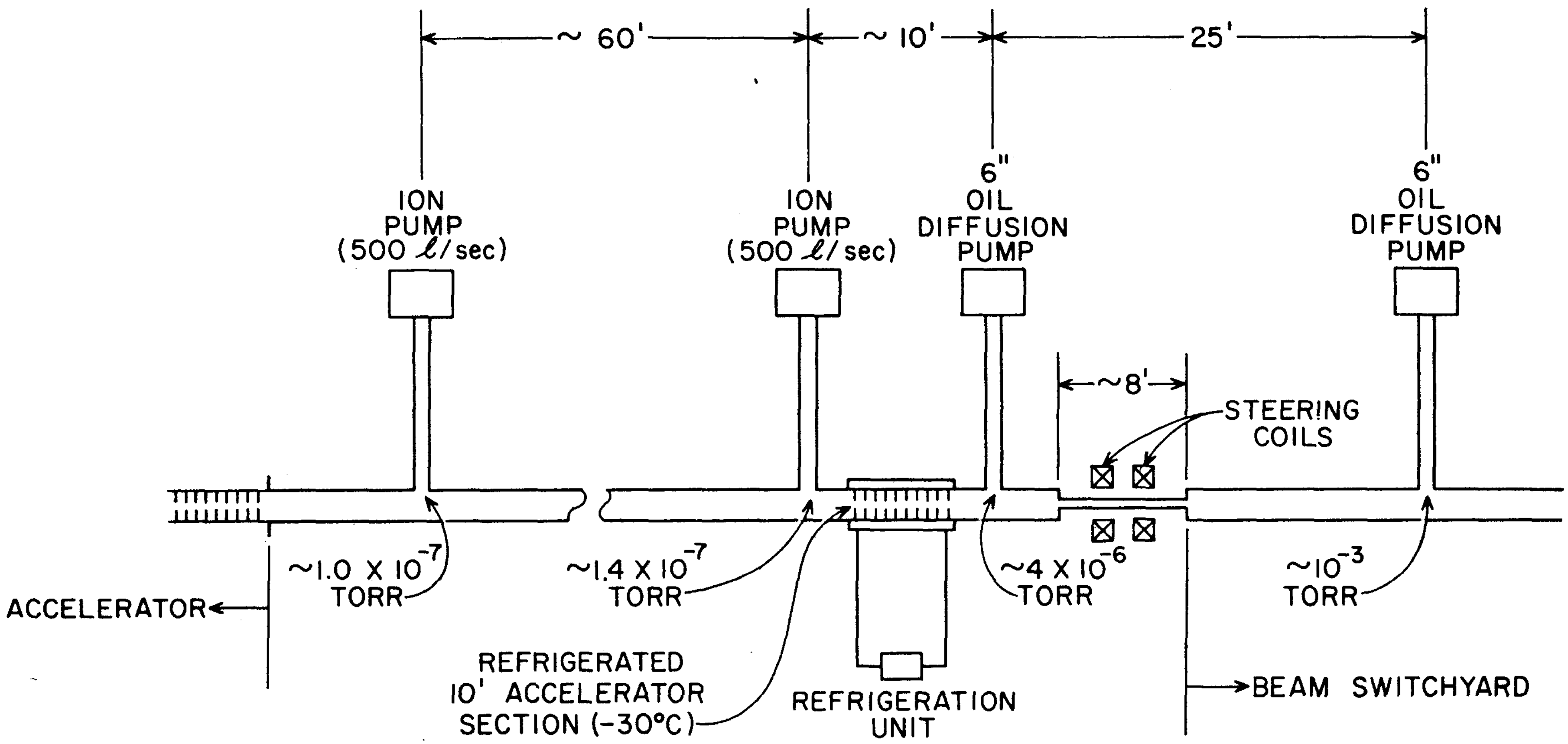
FIG. 30



BEAM SWITCHYARD VACUUM PUMPING STATION

145-2-C

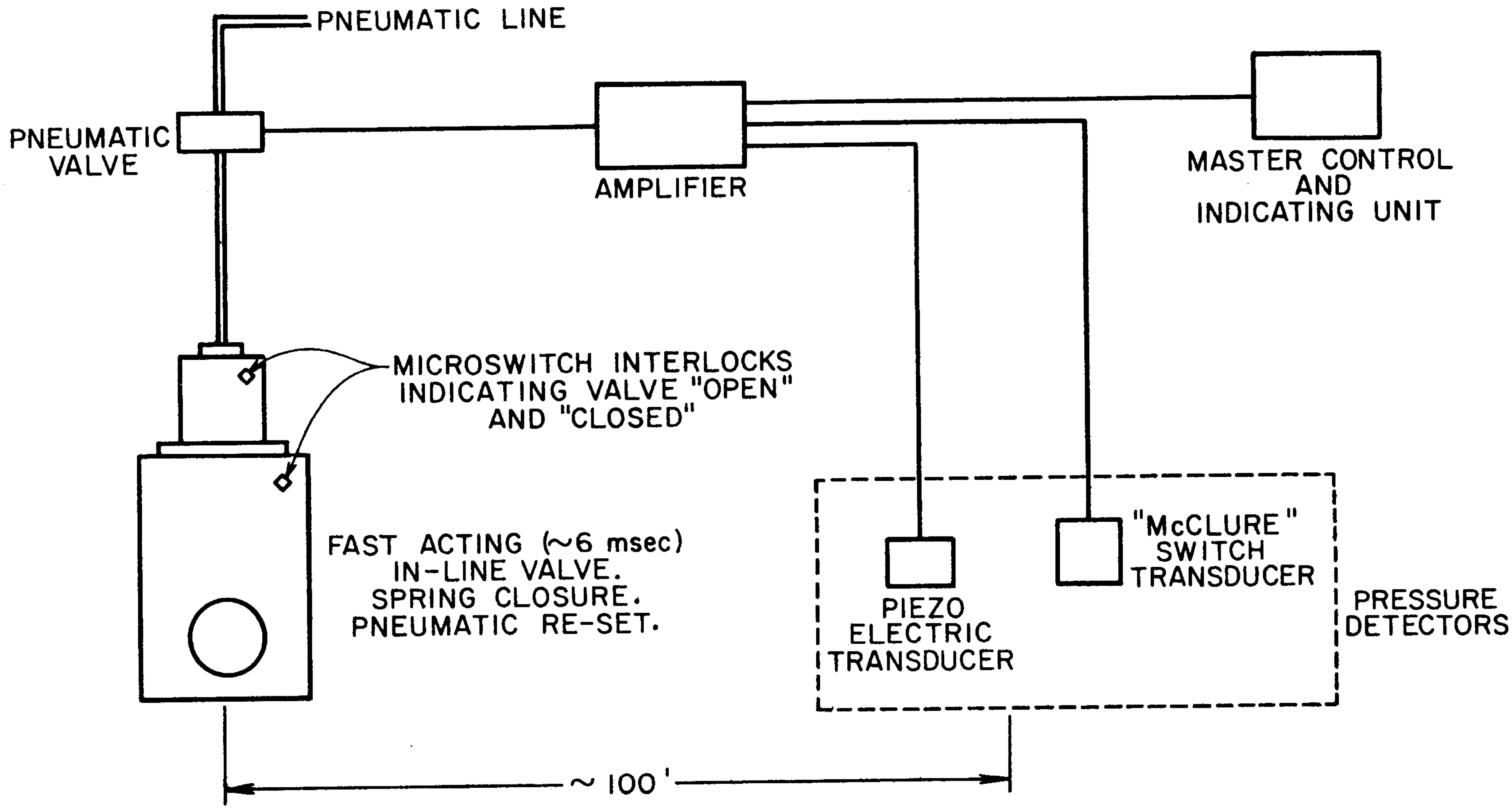
FIG. 31



145-1-A

DIFFERENTIAL PUMPING STATION

FIG. 32



BEAM SWITCHYARD
FAST VACUUM VALVE SYSTEM

FIG. 33

145-8-A