VACUUM SYSTEM FOR B.N.L. 200 MEV LINEAR ACCELERATOR*

S. DiNaro, P. Grand and V. LoGrasso
Brookhaven National Laboratory
Upton, New York

ABSTRACT

This paper describes the vacuum systems for the pre-injector, low energy beam transport, accelerating tanks and high energy beam transport. Details on pumps, pumping speeds, controls, instrumentation and power supplies are included.

Vacuum Pumps

Rough Vacuum Pumps

Roughing Stations - The nine accelerating cavities are pumped from atmospheric pressure to 5 x 10^{-5} torr with vacuum stations supplied to B.N.L. by Leybold-Heraeus, Inc. (See Fig. 1). Each station consists of a DK-180 mechanical pump, automatic bleed valve, combination water-liquid nitrogen baffle, right angle gate valve, R-1600 blower and R-6000 blower. With the exception of tank 1, each cavity is approximately three feet in diameter and fifty feet long. The vacuum station is situated fifteen feet from the accelerating cavity and is connected with 12" tubing. The pump down time from atmosphere to 5 x 10^{-5} torr is approximately four hours.

The pre-injector, low energy beam transport (LEBT) and high energy beam transport (HEBT) are pumped from atmosphere to 5 x 10^{-5} torr with a turbo molecular vacuum station supplied to B.N.L. from the Sargent-Welch Scientific Company, Model #3102D. The pumping station for the pre-injector and LEBT is connected with 6" piping (See Fig. 2). It takes approximately two hours to pump either system down to 5 x 10^{-5}. The HEBT is rough pumped with a portable pumping station similar to that described above.

High Vacuum Pumps

All the accelerating cavities are maintained at high vacuum (1 x 10^{-5} torr → 5 x 10^{-8} torr) with sputter ion pumps supplied by Hughes Aircraft Company. Each cavity has six pumps. (See Fig. 5.)

The ion pumps have 28 pumping elements each, and each pump has a maximum rated pumping speed of 1500 liters per second for air at 20^{o}C. The pumping elements have an anode cell structure fabricated from stainless steel and two 1/8" thick cathode plates made of titanium. The anode has an operating voltage of 5000 volts.

Special consideration is given to the two sputter ion pumps for the pre-injector

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and the one sputter ion pump for the LEBT. Since they primarily pump H_2 gas emitted from the ion source, the pumps are modified. Each pump contains thirty elements. The anode cell structure remains the same as the accelerating cavity pumps, but the cathode plates become 3/16" thick and these plates are more rigidly supported so that they will not warp under high temperatures. The operating voltage remains at 5000 volts.

All the sputter ion pumps are required to pass an acceptance test at B.N.L. to guarantee the rated pumping speed of 1500 liters/second. The test procedure followed was developed at C.E.R.N. and adopted by the British Standards Institution. The test is titled 150/TC 112/WG3 - Measurement of the Performance Characteristics of Vacuum Pumps. A brief description of the test procedure follows. A test dome is constructed of stainless steel and is described in Fig. 3. The test dome and pump are baked to a temperature of 150°C for a period of 24 hours to outgas the materials. It is observed that sputter ion pumps have an enhanced pumping speed at low pressures following a bake-out, and this pumping speed is known as "regenerated pumping speed". A pump operating for a long period at higher pressures shows a deterioration in pumping speed and this pumping speed is known as the "saturated pumping speed". We are interested in measuring the saturated pumping speed. To determine the saturated pumping speed, it is first necessary to pump a total quantity of dry air in excess of (1/50) torr-sec for each liter per second of rated pumping speed. The gas pressure in the test dome during this operation can not exceed 1×10^{-5} torr in the upper chamber or 1×10^{-6} torr in the lower chamber, whichever corresponds to the lower gas flow rate.

After the above steps are complete, pumping speed measurements are taken. The provision for orifice plate dividing the dome into two volumes allows the measurement of gas flow. If the two gauges have the same sensitivity and are both linear in their operating pressure range, then the pumping speed is determined by the equation $S = C(P_1/P_2 - 1)$ where: P_1 = pressure in the upper chamber; P_2 = pressure in the lower chamber; C = conductance of the orifice in liters/second.

Instrumentation

Each accelerating cavity is equipped with three instrument packages. One instrument package contains a diaphragm gauge, thermocouple gauge, ionization gauge, and a bleed valve. All three gauges are read remotely on the opposite side of the shielding wall. The second instrument package contains a mass spectrometer and a bleed valve. The third instrument package contains a two liter per second vac-ion pump. The pre-injector, low energy beam transport and high energy beam transport are equipped with similar instrumentation.

All the vacuum gate valves are equipped with differential pressure switches to prevent the valve from opening when the pressure differential across the valve gate is greater than 2" Hg. These switches are wired in series with the solenoid on the valves, and used for protection only. They do not act as a valve control.

The Leybold-Heraeus pumping stations are also equipped with protective instrumentation. Single direction pressure switches are installed in the rough vacuum line to prohibit the valve from operating with a large pressure differential across the valve gate. Automatic resetting temperature switches are also installed on the liquid nitrogen baffles and interlocked with the start of the R-1600 and R-6000 blowers. This assures that there is liquid nitrogen in the traps while the blowers are operating to prevent oil from back streaming into the high vacuum system.

All leak checking operations are performed thru a bleed valve located between the mechanical pump and the blowers at all the rough vacuum pumping stations. This, we feel, gives us the greatest sensitivity for leak checking.

Vacuum Monitoring and Controls

The local control stations for the accelerating tanks are located adjacent to the rough vacuum pumping stations (See Fig. 4). The top map board allows control and displays status of the ion pumps and valves. Directly under the map board are the controllers for the ionization gauge and thermocouple-diaphragm gauge. The bottom instruction map board controls the rough vacuum pump station. There is a similar display control rack for the LEBT, pre-injector and HEBT.

The two liter per second vac-ion pumps are used to interlock the vacuum system with the beam line valves, rf, and the pre-injector. Since the log-log plot of pump current vs pressure is linear in the operating pressure range of the machine, the current corresponding to a pressure of 5×10^{-5} torr is used to trigger the interlocks.

The 1500 liter per second pumps can also be controlled from a control rack situated along side the high voltage power supply. This panel will control the pumps and display pump status.

High Voltage Power Supplies

The vac-ion pumps are powered by three 5 kV dc, 12 ampere power supplies which connect to each individual pump through an 1875 ohm series resistor and a vacuum switch. The value of resistance was chosen to limit the maximum dissipation in a pump to 3.3 kW. The current drawn by each pump is approximately 0.1 ampere at 5×10^{-6} torr and is linear up to a pressure of approximately 10^{-4} torr. The pumps will start after the vacuum system has been roughed down to approximately 5×10^{-5} torr. Individual pump voltage interlocks disconnect power to the pumps when pressures go beyond 5×10^{-4}. The current at this pressure is approximately 2.3 amperes and with 12 pumps used for starting (2 tanks) and the balance of the pumps holding at 5×10^{-6} the maximum current drawn from the supplies is 33 amperes.

The power supplies and the resistor banks are housed in standard rack-type cabinets (approximately 2' x 2' x 7' high) with three resistor banks to each cabinet. The connections are arranged so that no more than one resistor bank in any one cabinet will be connected to a pump on starting since the power dissipation in the bank is 10 kW at 2.3 amperes. The resistor banks are cooled with forced air and interlocked with thermostats that monitor ambient temperature in the cabinet.

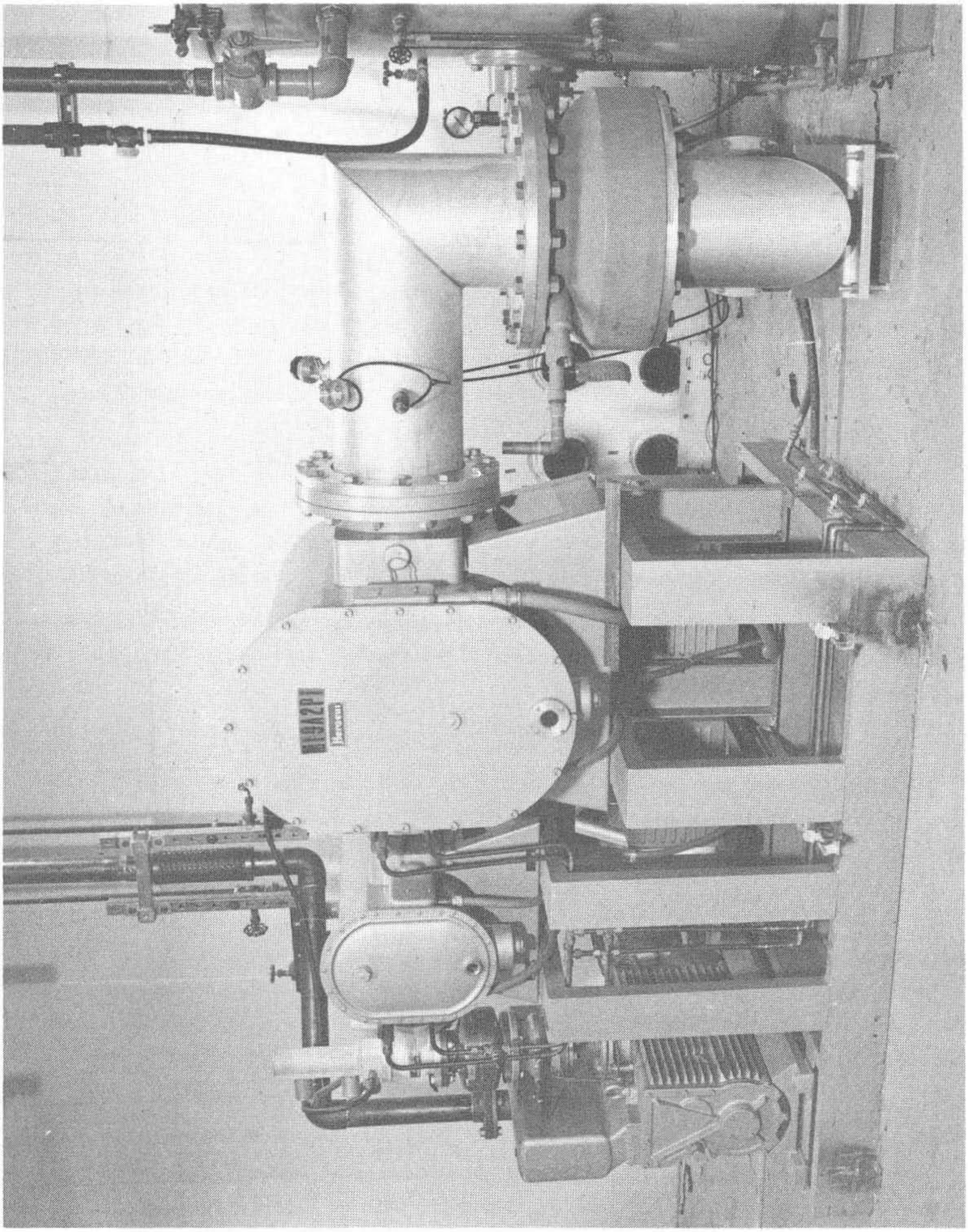

Fig. 1. Roughing Station for Accelerating Cavities

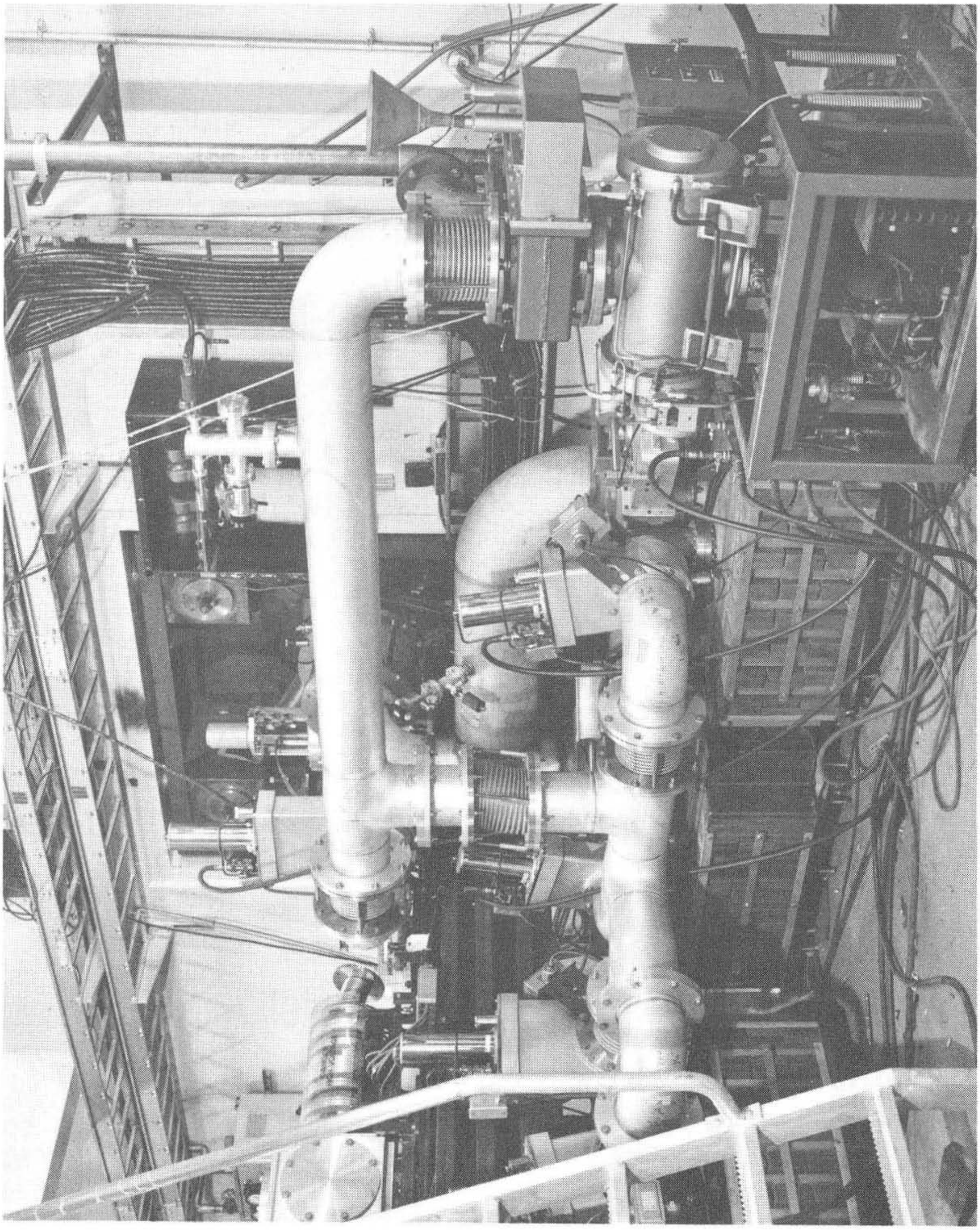

Fig. 2. Roughing system for LEBT and ion source.

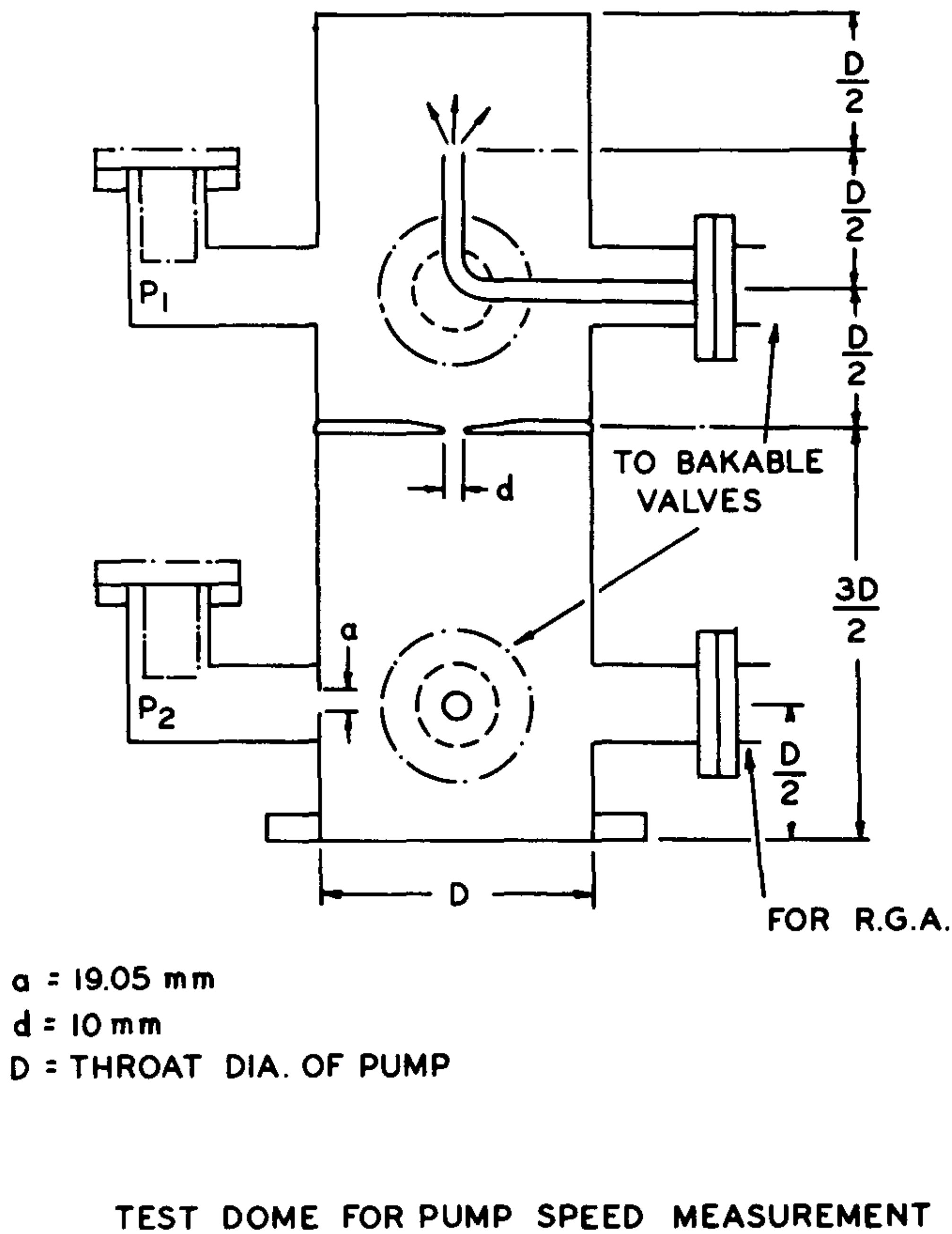

Fig. 3. Test Dome.

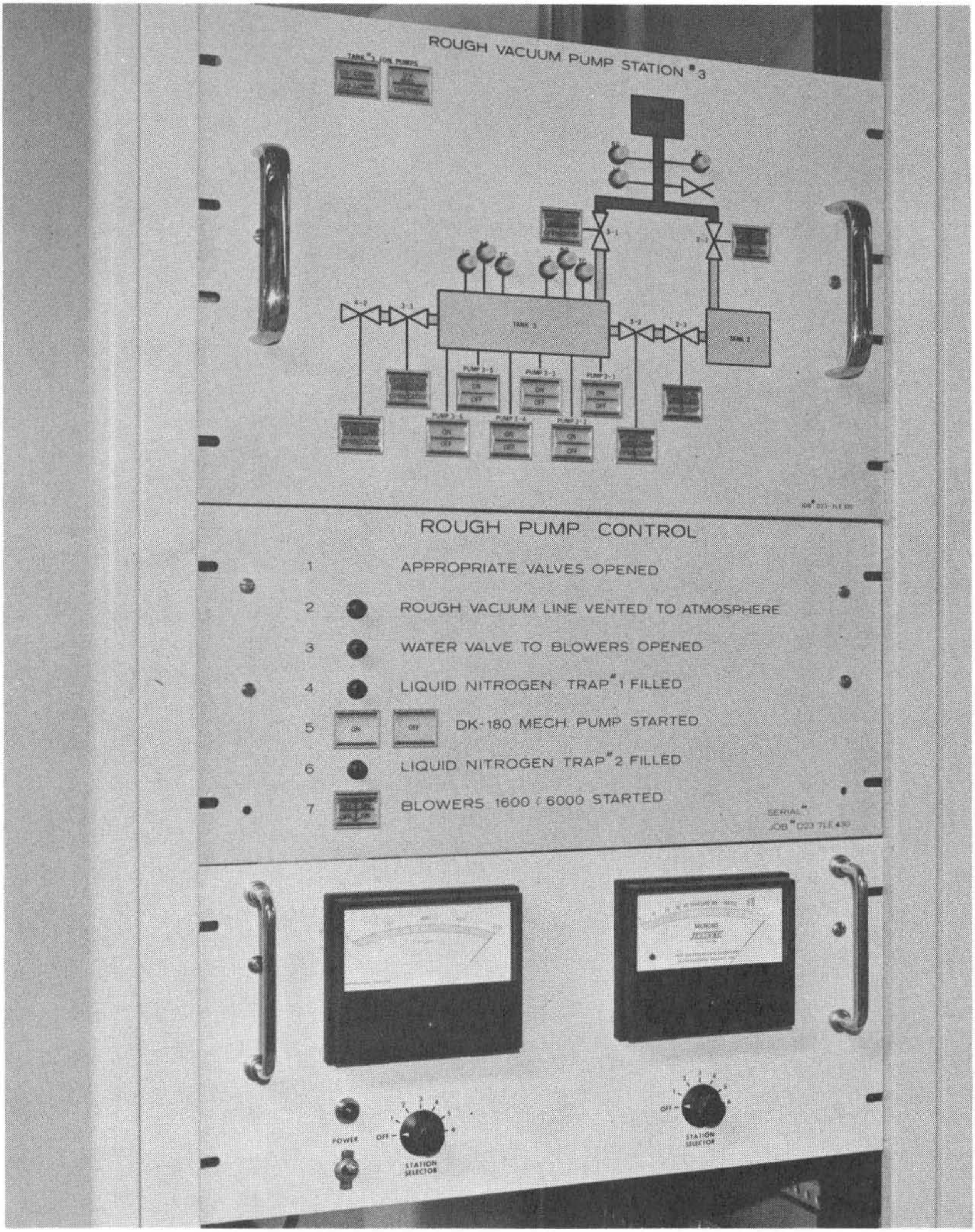

Fig. 4. Local control racks for accelerating cavities.

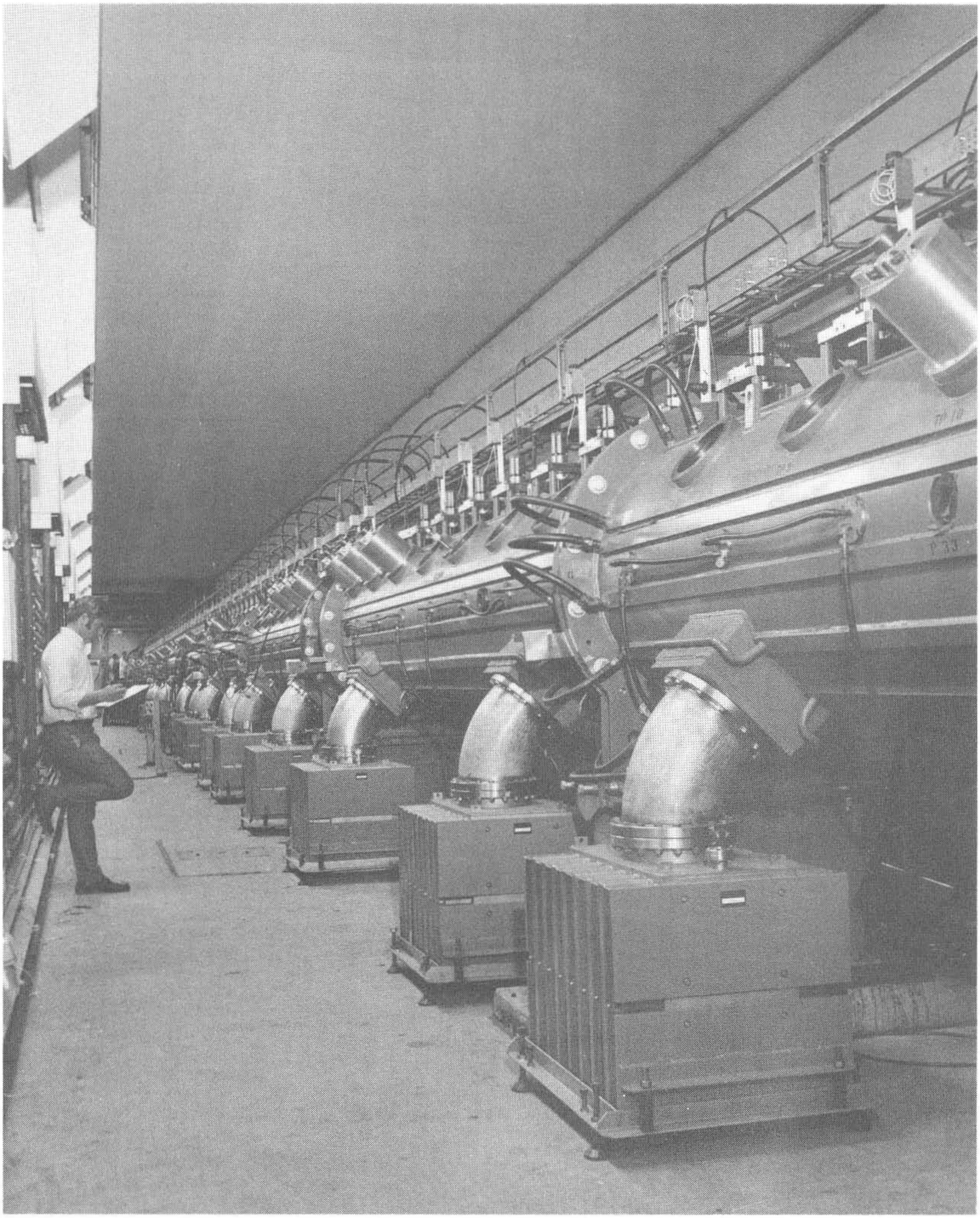

Fig. 5. Tanks with ion pumps.