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Vacuum Techniques for Linacs

The BNL linear accelerator is a single wall system which consists of 11 individual straight cylindrical sections, which together form a 110 ft long, 3 ft diameter cylinder. Including miscellaneous parts, this means a total volume of about 28000 liters with a total surface area, including various items, as "O" rings surfaces, etc., of 2×10^6 cm^2. To pump down this system to operational vacuum 20 Evapor-ion pumps are being used. The tank is roughed out by two pairs of Heraeus Roots-type pumps and 2 Kinney oil pumps. To illustrate the pumping capacity after a short time at normal pressure (dry nitrogen) it takes 18 minutes to reach 10 mm Hg pressure where the Heraeus pumps start, 15 minutes more to reach 10^{-4} mm Hg pressure where the Evapor-ion pumps are opened and then 12 more minutes to reach 2.10^{-5} mm Hg pressure.

Each Evapor-ion pump has a pumping speed for air of 1500 $\ell/_s$ at 10^{-6} torr, resulting in a total pumping capacity of 15000 liters per second when the baffles are considered.

Considering the materials involved the outgassing rate was estimated to be 8×10^{-9} mm liters per second per cm^2. This leads to a required pumping speed to reach 1×10^{-6} mm Hg pressure

$$\frac{(8 \times 10^{-9})\ (2 \times 10^{6})}{(1 \times 10^{-6})} \cong 15000\ \ell/\text{sec.}$$

During initial operation the minimum pressure was limited to 2×10^{-5} mm Hg. Rate of rise measurements showed that leakage rate and outgassing amounted to 5×10^{-8} mm liters per second per cm^2, instead of the figure mentioned above. At first a buildup of Argon was suspected (the Evapor-ion pump has a low pumping speed for Argon; < 5 liters per second) later it was found however, that a leak existed(in a ball tuner) which showed a response time of 45 minutes with a helium leak detector and was therefore difficult to locate. After all detectable leaks were sealed the figure for outgassing and leakage stands now at 2.5×10^{-9} mm liters per second per cm^2.

During normal operation only 16 Evapor-ion pumps are used. Titanium is fed for only 15 minutes followed by a period of 4 hours of ion pumping. Under conditions of ion pumping the pumping speed in the pressure range under consideration is only 5 liters per second for a total speed of 80 liters per second. In this case, the pressure rises slowly from about 2×10^{-6} mm Hg. to about 5×10^{-6} mm Hg. after which titanium feed is activated again.

The Evapor-ion pump as redesigned at BNL operates very satisfactorily. This pump behaves very well with a static system, with a dynamic system continuous titanium feed is necessary and operation is less reliable. Notwithstanding this, a comparison with different types of high vacuum pumps(in the pumping capacity range of 2000 liters per second) at the present time still indicates the Evapor-ion pump to be the most satisfactory choice for a linear accelerator.

Another high vacuum pump, recently available, is the "Vac-ion" pump. This pump is a sputter type pump and operates by means of a cold cathode discharge between titanium cathodes and an "egg crate" anode structure. The electron path is lengthened by means of a magnetic field. The problem with this type of pump seems to be that ion burial and sputtering occur at the same place with a consequent possibility of re-evolving gas which was pumped before. Also initiation of the discharge in the pump seems to be difficult under certain circumstances.

At BNL some experience has been obtained with a Pfeiffer pump. This is a mechanical pump with a turbine rotor operating at high speeds (16000 rpm). Terminal pressures are of the order of 10^{-9} mm Hg pressure on baked systems.

A modification of the "Vac-ion" pump is now being produced by Consolidated Vacuum Corporation. This is the "Dri-Vac" pump. Here a third (titanium) electrode, the so-called sputter electrode, is introduced between anode and cathode. The sputter electrode is of grid-like construction and ions passing through it are slowed down before impinging on the cathode, where ion burial takes place. Ions entering the sputter cathode at the correct angle hit the structure and this causes the release of titanium by sputtering; consequently ion burial and sputtering occur at different electrodes, in this way overcoming the problem of re-evolving previously pumped gases.