

3. Vacuum System

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Since the circumference of the ISR is $1\frac{1}{2}$ times that of the PS, one beam pulse transferred from the PS fills only $\frac{2}{3}$ of the ISR circumference. Therefore, if nothing special is done, 10 out of the 30 r.f. 'buckets' generated by the ISR r.f. system would remain empty, resulting in a corresponding loss in the maximum intensity which could be attained in the stacked beam. It was originally intended to fill in the missing part of the beam by means of a second injection from the PS prior to starting each stacking cycle. This idea has now been abandoned and instead, a device that suppresses the unwanted empty buckets by switching off 10 out of every 30 r.f. waves will be incorporated in the r.f. system. This is possible since it needs to be done only towards the end of each stacking cycle, when the r.f. voltage is relatively low. The feasibility of this method has been successfully demonstrated and a prototype system is under development.

The r.f. group is also responsible for the beam observation system of the ISR. The main part of this is a system which makes it possible to measure the vertical and horizontal beam position at over 50 places in each ring by means of capacitive induction electrodes (generally called 'pick-up stations'). The signals from these stations can either be displayed directly or fed (after suitable treatment) to the ISR central control computer. The design of the pick-up station itself is complete, orders have been placed and the first batch of series delivery from N.V. Neratom (Netherlands) is expected to arrive before the end of 1968. Part of the design of the signal processing system is complete and the rest is in an advanced state.

The rings

The most important performance figure of storage rings for the experimentalist is the luminosity which determines the number of particle interactions which will occur per second. Not only should the luminosity be as high as possible, it should also decrease as slowly as possible after both rings have been filled with protons and the experiments have started. Calculations show that the main cause of the decrease in luminosity is the gradual blow-up (increase in the cross-section of the stored beam) due to multiple scattering of the protons on the residual gas. At an average residual gas pressure of 10^{-9} torr, which is the design value of the ISR, the luminosity will fall in 20 hours to one half of its initial value. This is satisfactory taking into account that it needs less than one hour to fill both rings with protons.

In calculating the 20 hours half-life it is assumed that the beams are allowed to grow from an initial height of 10 mm up to a maximum height of 14 mm at the interaction points. However, physicists planning experiments with the ISR want beams which do not increase in height and, correspondingly, in angular spread. The larger the angular spread, the more difficult it is to interpret an observed event.

It is quite feasible to confine the beams by means of 'scraping targets' which eliminate all protons whose oscillations exceed the desired beam size. However, this would cause the luminosity to decrease much faster. Consequently, although it will be a considerable feat to achieve the design value of 10^{-9} torr for the average pressure in the rings, a further decrease towards 10^{-10} torr will almost certainly be called for, since this will improve the overall performance of the ISR.

The main problem in the construction of the ISR vacuum system is not the required low pressure — the technology to achieve a 10^{-9} to 10^{-10} torr vacuum is, by now, very well known. The problem is the sheer size and complexity of the system. The total length of the stainless steel chambers of the two rings is almost 2 km, subdivided into sections varying in length between 30 cm and 7 m. More than six thousand

demountable flange seals are required for joining the chambers together and for connecting pumps, gauges and other equipment.

The pumping system will consist of 80 turbomolecular pumping stations with about 60 l/s pumping speed for pre-evacuation down to 10^{-6} torr, of 300 sputter-ion pumps with 350 l/s speed as main pumps and 100 titanium sublimation pumps as auxiliary pumps at critical places where higher pumping speed is required. More than 500 ionization gauges will be installed for total pressure measurement as well as 25 residual gas analysers. Some 1 200 clearing electrodes with high voltage feed-throughs must be installed within the coil overhangs of all magnets for the extraction of electrons from the beam region. Forty gate-valves will make it possible to divide the rings in sectors of 30 to 80 m length so that repairs or modifications can be done by letting only one sector up to atmospheric pressure and not the whole system. Furthermore, 130 roughing valves are required. The chamber will incorporate many hundreds of flexible stainless steel bellows, which will allow the vacuum chamber to follow the lateral motion of magnets and lenses by a few millimetres during their alignment without introducing mechanical stresses.

Finally, all chambers, pumps, gauges, valves, etc. will be equipped with heating elements, thermo-couples and thermal insulation. This equipment is needed for the bake-out of the chamber, sector by sector, so as to reduce the gas desorption from all internal surfaces.

An important aspect in selecting the equipment for the vacuum system is reliability and a great effort has been made over several years to find the most reliable pumps, the most reliable design for demountable seals, the most reliable electrical feed-throughs and so on. The contracts for the supply of all the major components have now been placed and the first units have arrived at the ISR site. The arduous task of testing every component as thoroughly as possible before it is installed is now beginning. It is necessary to detect faults such as leaks, insufficient cleanliness, malfunctioning of pumps, incorrect reading of gauges, and so on. The pressure which is finally achieved in the ISR will not

Acceptance tests on the first batch of sputter-ion pumps which have arrived at CERN. Each pump must demonstrate an ultimate pressure below 5×10^{-11} torr before it is accepted. The pumps are fully encapsulated by bake-out ovens with water-cooling of the outer walls.

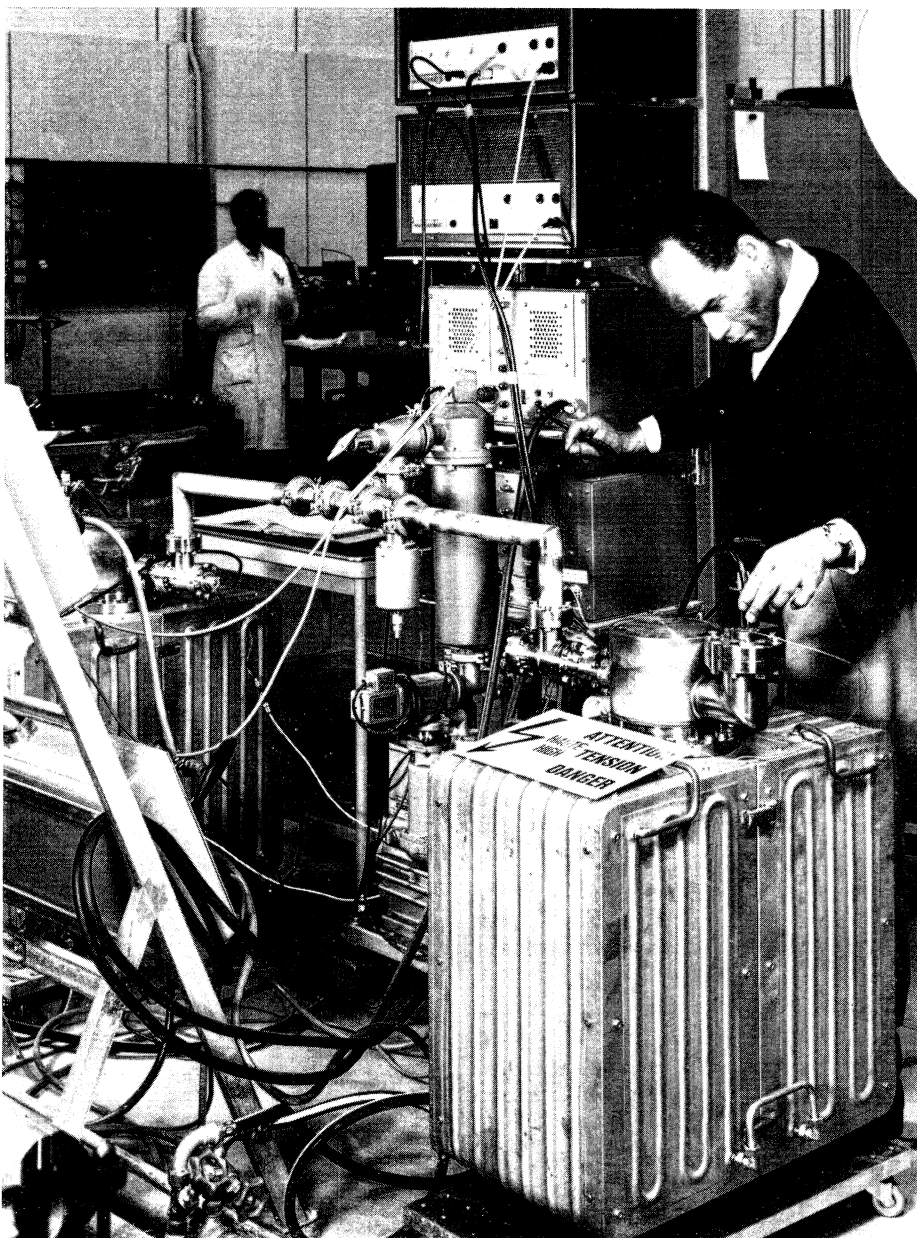
depend on the ideal conception of the vacuum system but on all types of faults which it has not been possible to avoid or to repair.

The interaction regions

Unusual vacuum problems must be solved for the interaction regions where the proton-proton collisions have to be distinguished from the background of collisions with the nuclei of the residual gas. This background will be at an acceptable level if the partial pressure of hydrogen in the interaction region is not higher than 10^{-10} torr and the partial pressure of nitrogen, carbon monoxide and gases of similar molecular weight not higher than 10^{-11} torr. By now, two different types of pump for obtaining such low pressures are built and have been tested at CERN. One pump uses surfaces cooled by liquid helium to about 2.7°K , the other uses titanium getter films at 78°K (the temperature of liquid nitrogen).

Unfortunately, for most ISR experiments the physicists do not want to have the intersection point cluttered by voluminous pumps. There is therefore a second requirement that the pumps to produce the very low pressure be placed as far away as possible from the interaction region. They will be installed alongside the four nearest bending magnets. Under these conditions, the gas desorption from the chamber wall becomes the limiting factor dictating the lowest pressure that can be achieved. The technology has been studied and developed for reducing the desorption rate of hydrogen from stainless steel down to 10^{-13} torr litre/s cm^2 and that of all other gases to below the detection limit. It involves high temperature ($800\text{--}1000^\circ\text{C}$) vacuum annealing for several hours during the manufacturing process. The residual gas in the interaction regions will be 99 % hydrogen.

A third requirement concerns the thickness of the vacuum chamber wall. Protons or secondary particles from a proton-proton collision change their direction of flight while passing through the chamber walls due to multiple scattering. This change of direction should be smaller than the angular spread of the circulating protons in order not to introduce additional imprecision in the detection of the particles.



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Stainless steel walls with a thickness of a few tenths of a millimeter seem to be both acceptable and technically feasible.

Beam transfer channels

The vacuum system for the beam transfer channels between the PS, ISR and West Hall is relatively simple, since it is sufficient to have a pressure below 10^{-5} torr. Nevertheless, with 1.5 km total length it is twice as long as the vacuum chamber of the synchrotron itself. The guiding principles in designing the vacuum system of the beam transfer lines have been to build a system which will need practically no attention once it is completed, and to suppress all organic matter which might be damaged by radiation.

From the end of 1967, the contracts for the supply of all the main components for the vacuum system have been agreed.

The main contracts have been placed as follows:

ISR vacuum chamber
steel — Avesta Jernverks A.B. (Sweden)
machining — Noratom-Norcontrol A/S (Norway)

bellows — Société Calorstat (France)
assembly — Jean Gallay S.A. (Switzerland)
tests — Société générale du Vide (France)
370 sputter-ion pumps — Varian (Italy)
90 turbomolecular pumping stations — Pfeiffer GmbH (Federal Republic of Germany)
550 Bayard-Alpert ionization gauges — C.S.F. (France)
42 sector valves — Leybold-Heraeus (Federal Republic of Germany)
150 Roughing valves — S.R.T.I. (France)

The first batch of twenty sputter-ion pumps arrived in October 1968 on the ISR site, where the pumps are to be thoroughly tested in the West Hall before acceptance. This month, November, the first batch of turbomolecular pumping stations and also the first complete chamber sections are scheduled to arrive. In March 1969, the first chambers will be installed in the gaps of those magnets which will be, by then, already in their places in the ISR tunnel.