

A diagram of the proposed pre-injector. The tank contains sulphur hexafluoride gas at a pressure of seven atmospheres with the exception of the volume centre right where the beam energies. The different components are:
1. High voltage generator; 2. High voltage electrode; 3. Accelerator tube; 4. Central cylinder; 5. and 6. Base-plates; 7. Capacitive screen;

8. Insulating supports; 12. Intermediate electrode; 13. Protective resistor; 14. Motor; 15. Insulating shaft; 16. 2000 Hz alternator; 17. 400 Hz alternator; 18. Equipotential rings; 19. Anode (containing the ion source); 20. Accelerating electrodes; 21. Cathode containing a focusing triplet; 22. Equipotential rings.

1.4 MeV pre-injector

When thought was being given to the programme of improvements at the 28 GeV proton synchrotron, the performance of the Linac feeding the accelerator was, of course, one of the items examined. The 'bottleneck' in terms of Linac performance was considered to be the first part of Tank 1 — the first of the three large r.f. cavities in which proton beams are accelerated to a final energy of 50 MeV. The present ion source, one of the most powerful operating on a proton accelerator, delivers a higher quality beam than can be exploited. A redesign of Tank 1 was therefore considered and it was also realized that achieving higher intensities would be easier if the beams into Tank 1 were of higher energy than those provided by the existing 500 keV pre-injector. This possibility was also considered interesting in connection with the 300 GeV project. Studies have been carried out by a team from the Linac group in close collaboration with the Institut de Physique Nucléaire, Lyon, and with Saclay.

They have now advanced to the stage where a project for a pre-injector of energy 1.4 MeV can be formulated.

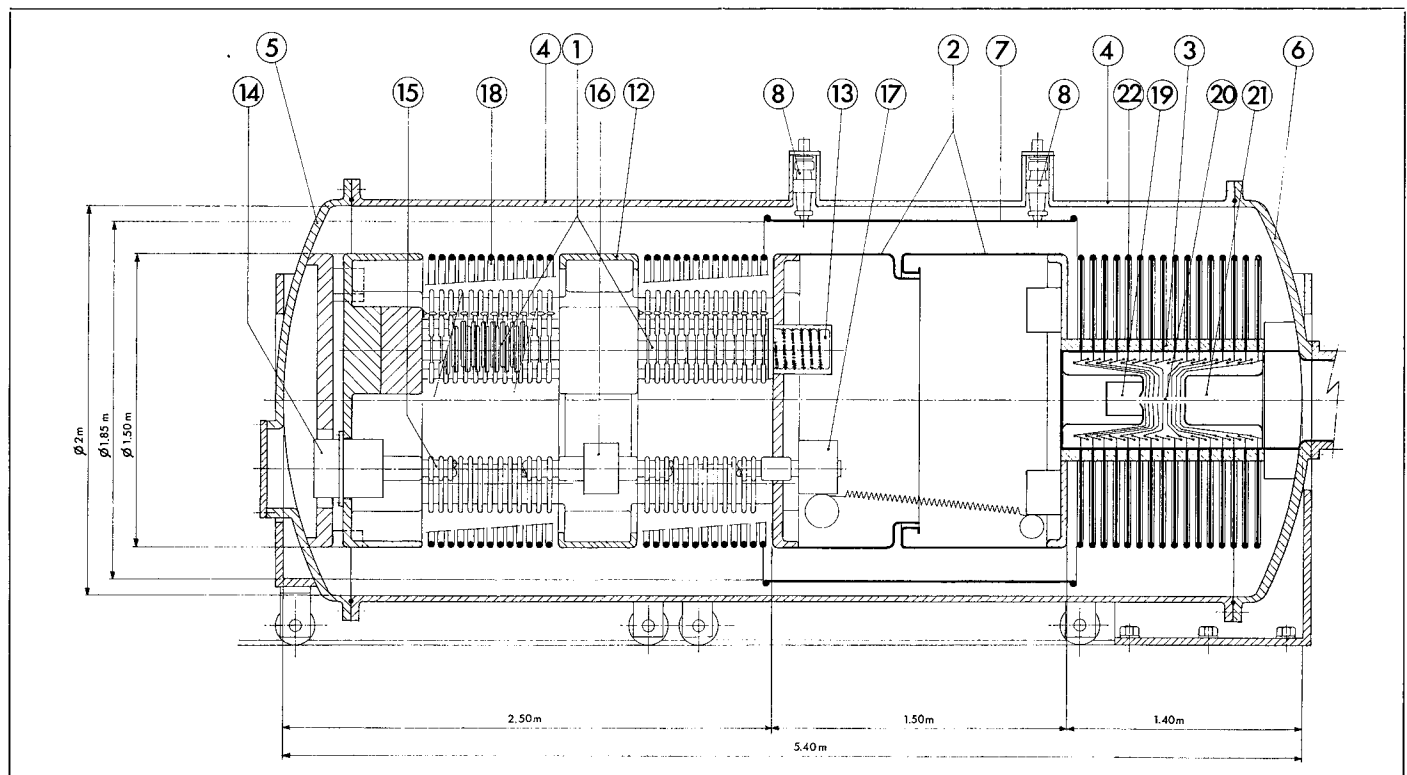
The collaboration with Lyon enabled CERN to use a high voltage installation at IPN (constructed in connection with a French heavy ion linac project with a 1 MeV electrostatic injector) for testing high gradient accelerating structures, while enabling Lyon to benefit from the CERN experience in accelerating tube construction and running. (The high cleanliness CERN tube design and assembly technique has been adapted by Brookhaven and commercialized recently by HVEC to cope with the demand of the Heidelberg heavy ion linac group who ordered three of them.) The collaboration with Saclay arose spontaneously from the close relationship between the two Laboratories and enabled CERN to benefit from the experience accumulated at Saclay during the construction of their well engineered new injector for Saturne (see CERN COURIER vol. 9, page 138).

The size of the present Faraday cage at the PS prohibits moving to higher

energies with an 'open air' design — the cage is not big enough to contain, without breakdown, equipment taken to much higher voltages. Thus a design for an enclosed pressurized system as used at Saclay was chosen. As far as possible, well-proven techniques were selected for the various components. For example, the ion source and accelerator tube are similar to those used on the PS and the high voltage generator consists of two Saclay-type units in series. It is for this reason also that the energy is limited to 1.4 MeV. Higher energies could have involved considerable development work on new techniques and have resulted in a more expensive project. The major features of the proposed design are as follows:

Pressurized tank

All the major units of the pre-injector are grouped together inside a pressurized tank containing sulphur hexafluoride under a pressure of seven atmospheres. The tank (a horizontal cylinder 5.4 m long and 2 m diameter) contains the high voltage generator (two 750 kV generators



The prototype accelerator tube was tested under a cylindrical container filled with sulphur hexafluoride at atmospheric pressure. The units indicated are: 1. Insulating casing; 2. Upper high voltage electrode; 3. Anti-corona rings; 4. Resistor; 5. Lower cone; 6. Chassis; 7. Pumping set. (Photo IPN)

Installation of the dome forming the roof of the large Faraday cage at the Institut de Physique Nucléaire, Lyon, where the prototype accelerator tube was tested. The construction of the Faraday cage involved novel and inexpensive techniques. (Photo Huguenin)

in series), the ion source, the accelerator tube and almost all their associated equipment.

A 2000 Hz alternator, driven by an insulating shaft, provides the power required for one of the generators (the first is supplied from a source at earth potential), and another 400 Hz alternator, driven by the same shaft, provides power for the various components of the ion source.

The tank opens at the joint between the baseplates and the central body. The accelerator tube sub-assembly is fixed in relation to the Linac, while the central body is movable on rails, as also is the generator sub-assembly.

Ion source

The ion source is required to provide a current of about 500 mA for 100 μ s with a current density of about 200 mA/cm² at a repetition frequency of 2 Hz. This performance is already achieved by the present PS source (see CERN COURIER vol. 6, page 88) which can therefore be used almost as it stands with the exception of the electronic circuitry which is miniaturized.

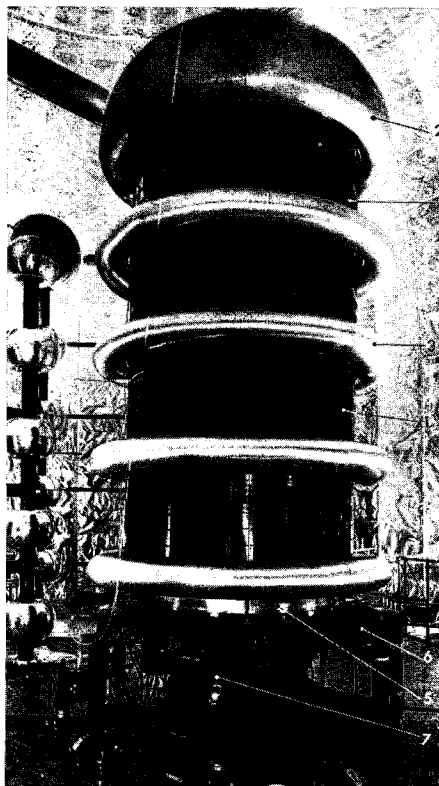
The hydrogen feeding the source is stored inside the tank in a light-metal bottle containing enough gas for 3000 hours of operation. Monitoring and control of the source is carried out via an infra-red link by a method already in use at CERN (see CERN COURIER vol. 9, page 103).

Accelerator tube

This part of the project required the most thorough experimental investigation in view of the very high voltage and voltage gradients. Experiments have been carried out (the 'Berthe' tests described below).

The accelerating structure is not finally decided but may be of the Pierce hybrid type which offers considerable flexibility and is satisfactory from the beam optics point of view. The electrodes are made of titanium alloy.

The central apertures are machined to be as close as possible in profile to the theoretical equipotential. They are supported by three oval-shaped bars leaving plenty of room for vacuum pumping. This



is important because of the leakage of hydrogen from the source, and degassing of the electrodes during high voltage hardening.

A pump with a speed of at least 1000 l/s designed to cope with the hydrogen leaking from the source, is to provide the vacuum, which must reach 2×10^{-4} torr. Several types are now on test.

High voltage generators

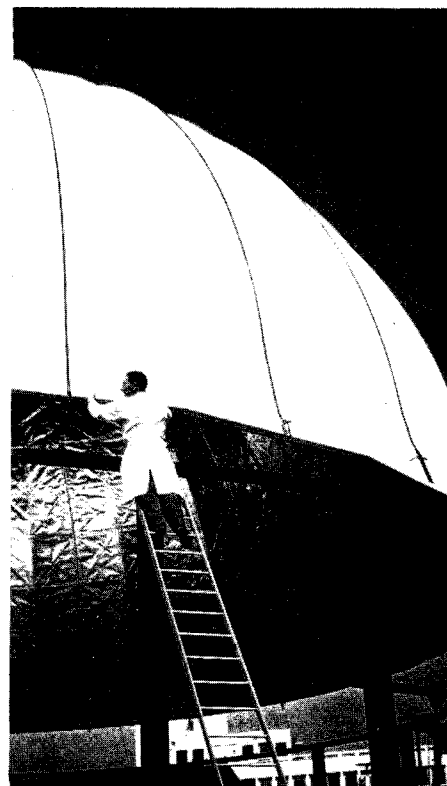
There are two 750 kV generators, almost exactly like that used in the Saclay pre-injector. They must be capable of providing 500 μ A d.c. and an instantaneous current of ten times this value. They are of the series cascade type with selenium rectifiers and ceramic capacitors. A protective resistor is provided to limit the power in case of a breakdown.

The negative terminal of the first generator is earthed, and it can therefore be supplied from an external unit. A 2000 Hz alternator at a potential of +750 kV driven by the insulating shaft provides the supply for the second generator.

'Berthe' tests

Prototype tests on the accelerator tube, known as the 'Berthe' tests, have started in Lyon. CERN has provided a high voltage test facility to be used in a Faraday cage constructed by IPN who also provided a 1.5 MV generator (Haefely set). Scientists from both centres participated in the tests.

The Faraday cage is of novel construction. It is topped by a large dome 16 m in diameter and 12 m high the inside of which is coated with aluminium. The



dome is made from a very light metal framework and glass fibre reinforced polyester foam. This provides a very light structure at a low cost.

The prototype accelerator tube is of the type used at the CERN PS. The cathode, anode and intermediate electrodes are all adjustable in position for test purposes. For tests above 850 kV it was placed in an insulating environment of sulphur hexafluoride at atmospheric pressure.

The tests were concerned first of all with the voltage holding properties in vacuum of titanium alloy electrodes as the distance between two electrodes is varied. Average voltage gradients of 200 kV/cm over 1 cm and of 130 kV/cm over 6 cm could be achieved. A model accelerator tube structure with five electrodes (anode, cathode, three intermediate electrodes with a central aperture where the proton beam would pass) was then put under voltage. On 20 January 1970, the summit of 1 MV was topped with great joy, the first time this had been achieved with such a system. A week later, after adjustments 1230 kV was achieved without difficulty. The d.c. inter-electrode current was less than 0.01 μ A and gave rise to X-radiation below 0.1 mR/h at 10 m distance. After a shutdown over Easter when several modifications will be carried out, the tests are scheduled to begin again until next summer.

The results so far have confirmed that the advanced technology of accelerator tube construction, the use of titanium electrodes, and of a very clean vacuum system (turbo-molecular pumps were used in the tests) make it feasible to construct a high energy pre-injector.