

# Preparatory Work

The following section covers some of the preparatory work which has been done on the ISR project. It includes information on the major components of the storage rings (magnet, r.f., vacuum, beam transfer and site work), research using the electron storage ring at CERN, and storage rings elsewhere.

## 1. Magnet

**L. Resegotti**

The magnet system of the ISR is in principle similar to that of the CERN proton synchrotron but has some distinctive features because of the requirements of particle accumulation and of colliding beam experiments. In particular, the gradient of the magnetic field in the gaps is a linear function of the radial coordinate and is different in focusing and defocusing magnets, which form separate units. Also, the pole face windings, besides compensating for the effects of steel saturation, have to enable a wide variety of field conditions to be set up.

The main ISR magnet is more than twice as long as that of the PS, but the construction programme requires it to be built in approximately the same time. Therefore, it was necessary to acquire the information for its design and to investigate materials and manufacturing methods at an early stage. It was also essential to ensure the interest and collaboration of manufacturers so that time schedules and budgets could be realistic.

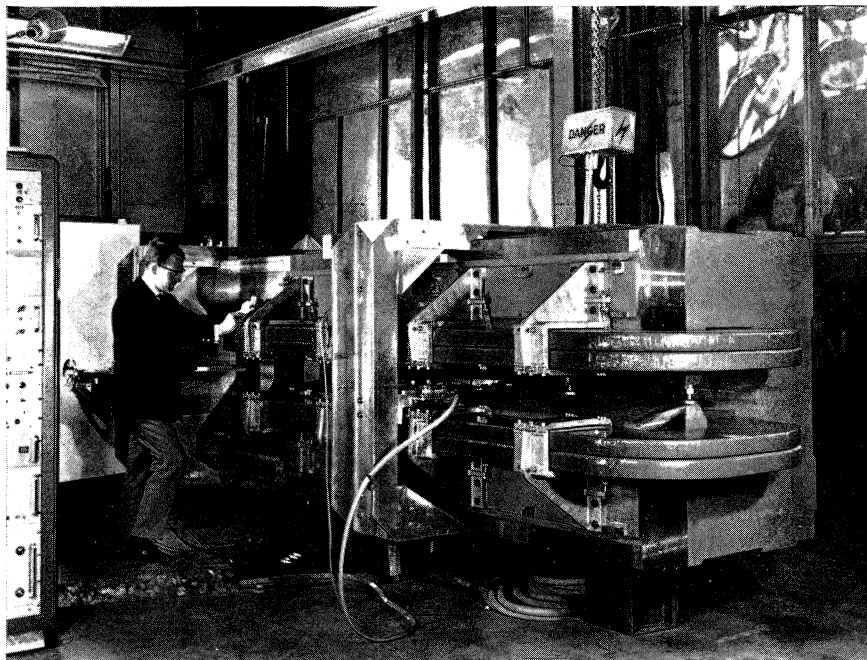
A preliminary survey of the European steelmakers revealed several who were prepared to supply very-low-carbon steel sheet to magnetic specifications. Semi-automatic measuring equipment was prepared in the magnet laboratory at CERN and a large number of samples from seven firms have been measured. Although most of the satisfactory samples came from small scale tests rather than from the production plants, it became clear that the problem was generally understood.

Considerable interest was found among the manufacturers of large electrical machines for the construction of the magnets. Most of them favoured the use of large welded stacks of punched laminations (similar to the magnets of the AGS at Brookhaven) rather than small glued blocks; savings in cost and time are claimed. In order to gain experience with this method of construction, two full-scale model cores were built, corresponding to short magnet units, of the focusing and defocusing type respectively.

The problem of the design of the magnet profiles also had to be faced at an early stage. Computer programs were developed which could solve the two dimensional magnetostatic problem to the required accuracy by the method of successive approximations and these programs were used to arrive at the shape of the pole profiles for the two models.

In the production of the steel sheets, the influence of various treatments on the geometrical, mechanical, and magnetic properties was studied. The construction of the cores gave valuable experience on the problems of precision stacking of the laminations, of compensation for variations in thickness and of welding under pressure. The profiles of the dies had to be checked and adjusted with extreme care in order to meet the required tolerance of 0.01 mm. A measurable amount of twist appeared in both cores, but was within tolerable limits.

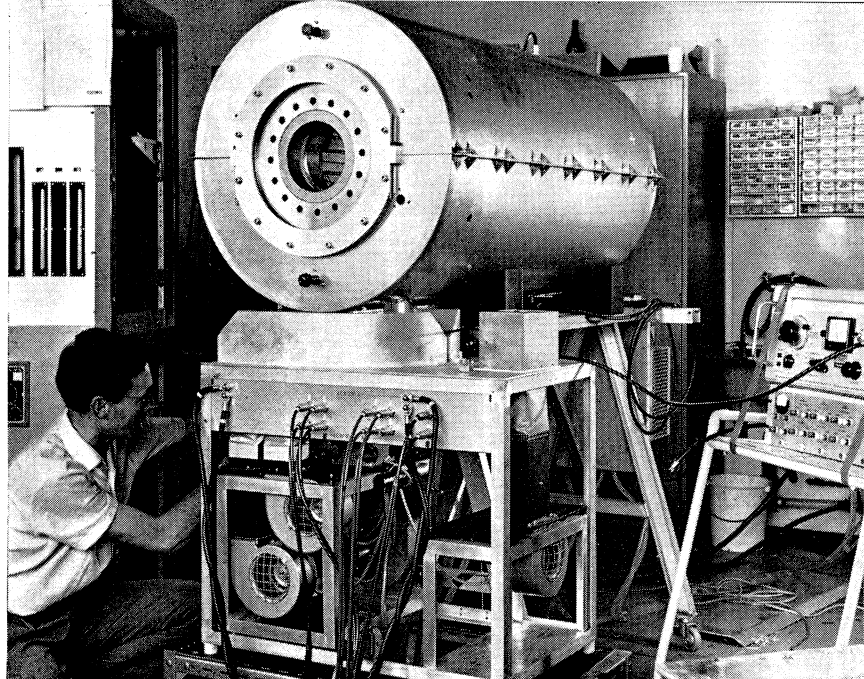
A set of excitation coils and one of pole face windings were ordered, and a suitable power supply was installed. The experience obtained in constructing and mounting the pole face windings, which are a rather delicate item,



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Magnetic field measurements in progress on magnet model 2 for the ISR; the model is similar to magnet model 1 (pictured in CERN COURIER, vol. 5, no. 12 (December 1965) p. 192) but is a defocusing sector. The large coils which power the magnet can be seen running along its length (2.5 m). Construction and testing of the two model magnets have provided valuable experience for the final design.

Tests in progress on a model r.f. cavity for the storage rings. Six of these cavities will be used in each ring of the ISR to accelerate the protons from the orbit where they are injected to the orbit where they will be stored. The radio-frequency system in the ISR is different to that of a conventional synchrotron and preliminary work with the model cavity and its associated electronics is serving to develop the necessary techniques.



lead to substantial improvements in the design. Tests on radiation damage for many types of insulating resins, which could be used for the pole face windings, were carried out at a reactor centre. The tests have led to the rejection of some types of resin and have indicated others which will probably be satisfactory.

The field distributions in the central part of the models were found to be in good agreement with the computed values. Also, end effects were measured at several excitation levels. These results provide the necessary guidance for the final design. In the near future, the two models will be mounted together on a girder and excited by a common coil, to simulate a long magnet unit of the storage rings. Methods of alignment will be tested and junction effects will be measured. Before the end of the year, all the information needed for the final design should be gathered.

Design work is now moving onto the auxiliary lenses (quadrupoles, sextupoles, etc.) while the detailed study of the lay out of the whole system is continued.

## 2. Radio-frequency system

**W. Schnell**

The purpose of the radio-frequency system is to accelerate the particles from the injection orbit to the stacking orbit where they are deposited by turning off the r.f. voltage. This stacking cycle is repeated every time a new set of particles is injected from the PS until a sufficient number of protons has been accumulated.

Two different kinds of stacking schemes are possible and there will be provision for both at the ISR. In the first scheme, the position where the particles are deposited is changed by a small amount in successive cycles, until all the space available inside the vacuum chamber (about 60 mm) is filled. In the second, the injected particles are always dropped at the same place. Those particles that have been deposited earlier are automatically displaced inwards an appropriate distance by the r.f. If the stacking process is conducted with

maximum efficiency about 20 A of circulating current can be accumulated.

The r.f. system differs rather substantially from that of a normal accelerator. At the beginning of each stacking cycle, a maximum total accelerating voltage of about 20 kV per turn is required to give sufficiently rapid rates of acceleration so that the injected pulse will be stacked before the next pulse arrives from the PS. However, towards the end of the stacking cycle the voltage must be reduced to values below 100 V per turn, in order to cause the minimum of disturbance to the beam already stacked.

This large variation of voltage, which has to be carried out in a smooth and well-controlled fashion, is all the more difficult to achieve as the r.f. cavities are heavily loaded by the accelerated beam. The latter problem is overcome by means of strong negative feed-back that makes the accelerating voltage virtually independent of beam-loading.

A first high-power, full-size model has been built and tested. Full r.f. voltage has been achieved while the negative feed-back system has been working with full loop-gain. Difficulties encountered with higher order resonances in the loading capacitor of the cavity have been overcome by suitable design of the capacitor and by the use of ferrite that has little influence at the fundamental frequency of the r.f. cavity (10 MHz) but provides damping at higher frequencies.

The mechanical design of a second model, intended to be the last prototype prior to construction of the actual ISR cavities, has been completed and construction of this model is about to begin.

The requirements of precision, stability and freedom from noise of the low-power control systems for r.f. frequency and amplitude are rather stringent. The frequency may be generated either by a programming system alone or with the help of a phase-lock system similar, in principle, to the one used on the PS. But the use of phase-lock on the storage rings is complicated by the presence of the stacked beam and a method has been devised to overcome this problem. It involves leaving one or more r.f. 'buckets' empty to act as a marker.