

The extraordinary transport vehicle designed to carry magnets down the transfer tunnels where there are no cranes. It has to protect the magnets from any shock which would disturb its precise assembly and has to descend steep hills since the tunnels rise up from below the level of the ISR. When it reaches the desired position it stops with a precision of 1 mm and then moves exactly at right angles to its initial direction. It stops again with precision and jacks are inserted to lift the magnet clear. It then moves out and the proper magnet supports are put in position.

tions, valves, etc. Large quantities of welding samples, including plasma welding for thin wall stainless steel membranes, have been produced.

For the Magnet Group, the workshop built cutting devices to take samples from steel sheets for permeability measurements, high precision calibrating and measuring coils for magnetic measurements, precision tools for pole profile measurements etc. Furthermore, it carried out a series of qualifying tests on magnet supporting jacks and, recently, a checking section has been set up to make dimensional checks on the large series of magnet components.

For the Radio Frequency Group, it contributed to the construction of r.f. cavity models, pick-up stations, etc.

3. Cooling and Air Conditioning

This section is responsible for the design, ordering, installation and putting into operation of all the cooling and air conditioning installations required in the ISR and beam transfer systems. The work has been divided into the following components :

- a) Air conditioning system of the ISR Ring Tunnel — a total volume of about 140 000 m³. To retain accurate alignment of the machine components, the temperature must be maintained at $20 \pm 1^\circ\text{C}$ which imposes severe requirements on the air distribution and regulation system. A proportional-integral temperature regulator was chosen to satisfy these tight temperature tolerances. The air is recirculated through nine air treatment plants, situated in specially elevated roof structures of the ring-tunnel, and distributed through round ducts of 80 cm diameter. Installation has already started in Octant 3.
- b) Air conditioning system of the beam transfer tunnels — a total volume of about 15 000 m³. The temperature conditions are similar to those in the ring and the same regulation system has been adopted. There will be 14 air-conditioning units, situated in enlarged tunnel sections along the various transfer channels. The installation work is scheduled to start this month.
- c) Re-cooling plant — serving the various

closed cooling water circuits of the magnet systems and the air conditioning systems. Since natural cooling water is rather scarce on the CERN site, a system using water chillers with centrifugal compressors and cooling towers has been adopted. The total design capacity is 26.4 Gcal/h and the cooling water temperatures, at full load will be 13 to 33°C for the magnet systems and 5 to 12°C for the air conditioning systems. The plant will be one of the largest of its kind in Europe.

The tenders for the complete installation have been received and a contract will be placed shortly. Installation will start in May 1969.

- d) Piping system — distributing cooling water to the various users. It includes also the hot water pipes of the air conditioning systems. The installation consists of 22 km of low carbon stainless steel pipes carrying demineralized water to the magnet cooling systems, and 8 km of normal steel pipes for the air conditioning system. Installation will start this month.
- e) Distribution network for general purpose and drinking water, and for compressed air — serving the ISR and beam transfer tunnels. Specifications for these items are in preparation.

4. Coordination and Planning

The group is responsible for the coordination and planning of the installation of the machine. An important part of coordination is already done in the drawing office, to the extent that it must avoid interference between the many components it designs. For this purpose, it executes also the layout and assembly drawings.

Modern planning methods (PERT programming) are employed, using computer programs developed at CERN for the CDC 6600 computer. A first installation programme has been established for Octant 3 and the adjacent service tunnels, where installation work has started. A Technical Committee, with two members from each group, was set up early this year. All constructional aspects involving several groups, and all problems concerning installation are discussed and approved in this committee.

7. Controls

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The ISR project involves a very large complex of sophisticated equipment and requires a considerable effort to study and solve the control problems in detail. A Controls Group was therefore set up about two years ago. Work on self-contained parts of the control system is assigned to project engineers or physicists who link a specific ISR Group with the Controls Group. But general development and standardization of control techniques, such as data acquisition and transmission, and planning of the control cable network, is carried out centrally according to overall requirements.

The location of the storage rings control centre (SRC) can be seen on the Figure. It will be combined with the switchyard (SY) and West Hall (E₁) control centre, to facilitate communication between operators and to avoid duplicated controls for the beam transfer channels.

Safety aspects

The personnel radiation protection system (or access control system) has to take into account four basic modes of operation of the ISR complex, as indicated in the Table. It will subdivide the entire tunnel system into four main zones (see Figure) with either restricted or authorized access, depending on the mode of operation in use.

The radiation safety of the staff working inside one or several zones will be ensured by the following main elements (in addition to the general provision of shielding and radiation warnings) :

- remotely controlled access doors and safety keys ;
- beam dumps, stoppers and concrete separation walls in the transfer tunnels ;
- 'off' status of power supplied to some of the beam transfer bending magnets ;
- beam dumping mechanisms in the storage rings.

The first elements to be installed, during the next programmed shut-down of the PS, are dump D1 and stopper ST1, both in front of separation wall W1.

The design study of the ISR access control system has been completed. A model of a typical control and monitoring panel has been built in order to simulate the logic applied to door interlocks.

Beam transfer channels

The necessary deflection of the ejected PS or ISR beams through both horizontal and vertical angles results in complicated beam optics and about 70 beam monitors of various types are required to set up and monitor the beams in the beam transfer channels. New versions of beam profile and position monitors based on the principle of secondary emission are under development and construction.

The type shown in the Figure is designed for beam emittance measuring and matching purposes. It uses a row of horizontal and a row of vertical thin aluminium foils and the electronic circuits connected to the individual foils deliver quantitative signals on the beam intensity profile. They are designed to work with both fast and slow ejected beams. A prototype secondary emission monitor (SEM) has been successfully tested at the PS in a fast-ejected beam; tests in slow-ejected beams will follow. Besides quantitative information, this monitor offers the advantage of introducing smaller multiple scattering than

monitors involving an inorganic luminescent screen and TV camera (although the latter will also have to be used in some places to observe the beam size).

Another new type of profile monitor uses two SEM probes, which are driven by stepping motors, to find the edges of the beam or to plot the intensity distribution.

Since these monitors are beam-intercepting types, they are normally moved away from the beam path. Some of these devices must also be used in the storage rings proper for adjustments of the beam on its first revolution and, therefore, must be suitable for ultra-high vacuum.

Vacuum problems

The Controls Group is providing the power supplies and control units for the sputter ion pumps (325), roughing stations, Bayard Alpert ionization gauges (300), sublimation pumps, clearing electrodes, sector valves and scanners for bake-out temperature measurements. Most of these units must be remotely controlled and require careful attention in design specifications and prototype tests (in particular, the control

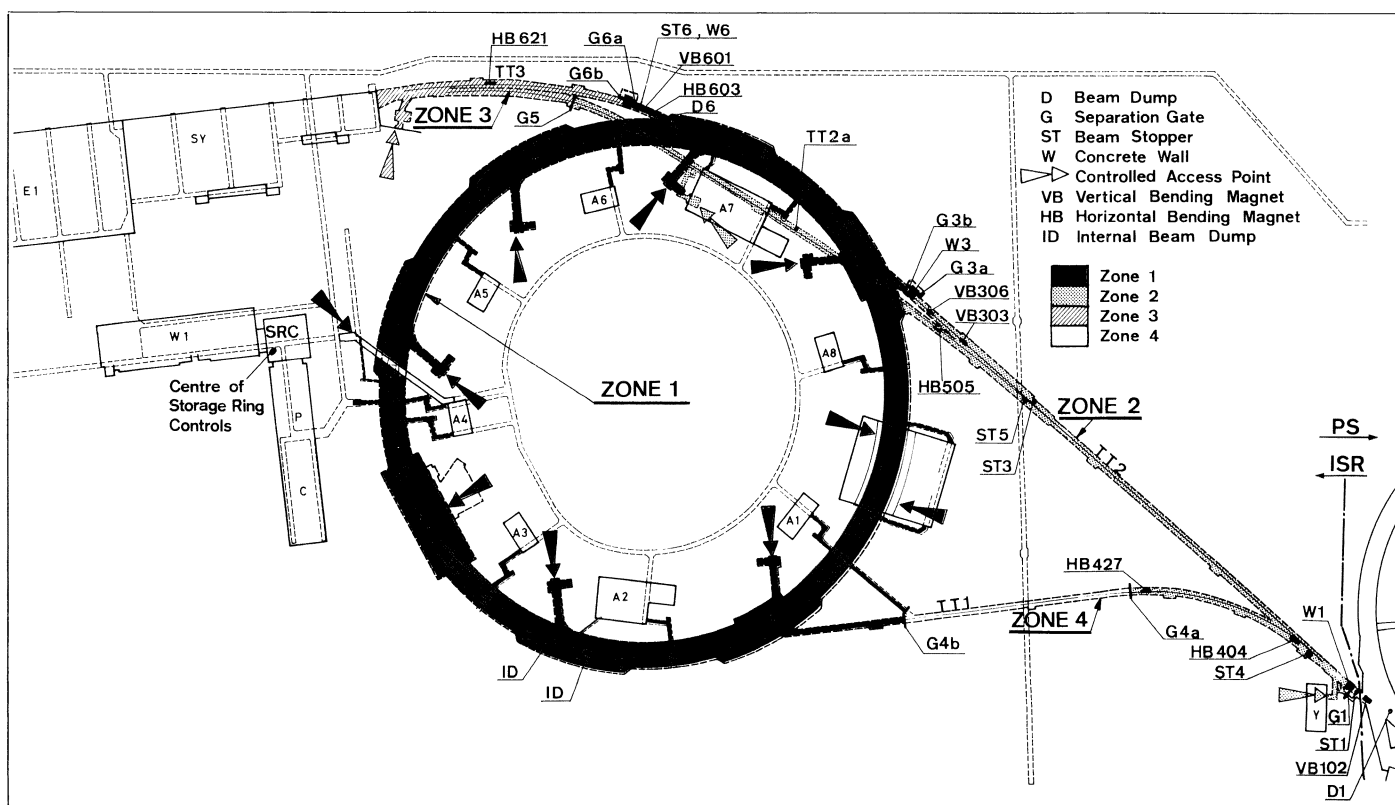
units for ionization gauges). 300 of these units were recently ordered from Balzers (Liechtenstein). Tenders have been received or are being prepared for the other items.

Signal transmission and monitoring

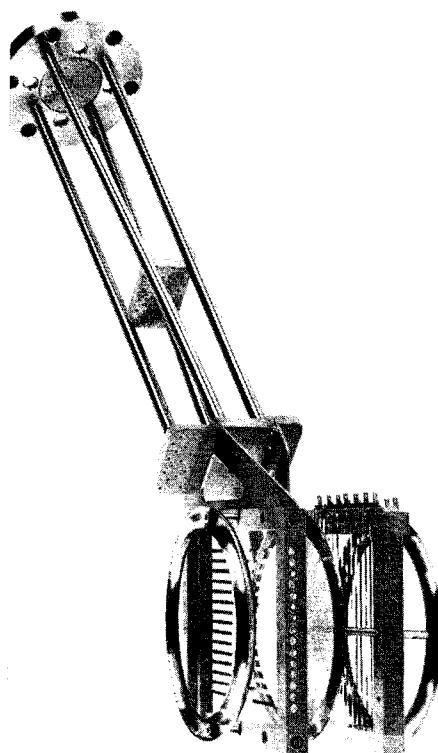
The requirements for signal transmission to or from the ISR control centre include:

- safety elements (access doors, keys, radiation monitors, beam dumps);
- information on PS ejected beams;
- beam steering and matching in the beam transfer channels;
- ultra-high vacuum system performance;
- ISR timing system;
- measurement and display of orbits and Q-values during injection and stacking;
- closed orbit and beam profile correction via pole-face windings, auxiliary magnets, and position adjustments of magnets;
- acceleration or deceleration of stored protons;
- steering and monitoring of intersecting beams.

It is obvious that the operators of this complex need an electronic robot to help



A secondary emission monitor (SEM) developed for quantitative beam profile measurements in the ISR and the transfer channels. 15 horizontal and 15 vertical thin foils are connected to individual 100 pf capacitors, and signals, varying from 5 to 500 mA, are sequentially gated into a cable after passing through 'sample and hold' circuits.



CERN/PI 89.8.68

collect, select, display and evaluate the necessary information for their tasks. Therefore, a major part of the ISR controls will be based on a digital process computer system. The computer's main functions will be :

- accurate setting of magnet power supplies ;
- gathering, evaluation, display and recording of data on circulating beams and various ISR components.

The computer system must be capable of recording magnet currents and of adjusting about 300 magnet power supplies. About 100 of these are involved in the beam transfer system which requires quick and reliable changes in settings for different modes of operation (e.g. filling the ISR, or transfer of beams to the West Hall). The 200 power supplies used in the storage rings themselves need coordinated incremental adjustment during acceleration or deceleration of stacked protons.

Typical examples for data collection, evaluation and display via the computer are beam position monitoring by signals originating from the 108 pick-up stations in the storage rings, and monitoring of the ultra-high vacuum system by signals coming from the ionization gauges.

Obviously, in a control system of this type, the computer itself must be extremely reliable. The ISR computer system will have the central processor and critical peripherals duplicated to ensure the permanent availability of a minimum configuration for the vital functions. A

specification for the computer was issued during 1968 and it is expected that the order will be placed by the end of this year.

A considerable amount of work is also going into component and circuit standardization, production of electronics, audio and video inter-communication systems, and development of techniques for data collection and multiplex signal transmission.

Finally, an installation service for the control cable system has recently been set up and detailed requirements are being worked out. Installation will start with Octant 3 and its related equipment building A3 and will build up to a peak in 1969 and 1970. The installation labour required for the ISR control system is of the order of 150 man-years. The length of cabling involved is estimated to be 1500 km.

8. Site Work

F. Bonaudi

During the summer, some of the ISR staff occupied their first buildings on the ISR site. These included the largest of them all — the huge (10 000 m²) West experimental Hall (numbered Hall E1 on the site layout drawing). It is in this hall that all the components for the ISR will be assembled and tested before final installation. The hall had priority in the construction programme so that it would be ready to receive components, which have already started to arrive. As it is the largest experimental hall of its type in the world, it is useful to recall its main characteristics (see Table on page 281). Photographs of the exterior and interior of the hall can be seen on pages 182 and 183.

The construction effort on the rest of the project has now reached its peak, notably on the machine housing and on the beam transfer tunnels.

The circular tunnel in which the ISR rings will be housed has a diameter of about 300 m. It is much wider than is usual in the case of an accelerator, firstly because it must contain two magnet rings instead of one, and secondly because of the special geometry of the rings which involves eight 'bulges' in the orbits. In the centre of each of these 'bulges' the orbits of the two rings are nearly 9 m distant from each other. Therefore the net inside dimensions of the ring tunnel are 15 m wide and 6.5 m high. The machine has an eightfold symmetry (which, in the days of unitary symmetry, seems most appropriate for a particle physics project) and in principle it could be made in eight identical sectors. However, there are many other requirements (injection and ejection regions, pits under some intersection points to give more space for experiments, experimental halls etc.) such that there is little uniformity around the ring and the construction is quite complicated, each octant having its own special features. Two of the intersection points are to be initially equipped with experimental halls. I4 will have a hall 70 m by 25 m ; I1 a hall 50 m by 55 m with flexible shielding arrangements which can be readily adapted to different experimental requirements.

Since the ISR is a new type of experimental equipment, it is necessary to build it in as flexible a way as possible so that changes, or even major modifications, can

Basic modes of ISR Operation	Restricted Zones	
	1	2, 3, 4
1. Setting up an ejected beam from the PS, with the beam not entering the transfer channels	No	No
2. Filling, re-filling or running the ISR with alternate supply of beams to the West Hall or the switchyard directly or from the ISR	Yes	Yes
3. No beams in the transfer channels but circulating beams inside the storage rings	Yes	No (2, 3) Yes (4)
4. No circulating ISR beams, but transmission of PS beams to the switchyard and the West Hall	No	Yes