CERN

COURIER

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European Organization for Nuclear Research

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 1200 physicists draw their research material from CERN.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2850 people and, in addition, there are over 450 Fellows and Visiting Scientists.

Twelve European countries participate in the work of CERN, contributing to the cost of the basic programme, 244.1 million Swiss francs in 1970, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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Cover photograph: The prototype pancake of the superconducting coil for the European bubble chamber is being transported, after being wound, from the winding table to the stacking platform. The pancake rests on a perforated slab of glass wool impregnated with epoxy resin, which serves both as a support and an insulator. The coil winding process is described on page 38. (CERN/PI 163.1.70)

CERN/Serpukhov collaboration

A review of the progress of the collaboration between the European Organization for Nuclear Research (CERN) and the Institute of High Energy Physics (IHEP) Serpukhov.

On 4 July 1967 an agreement was signed, between CERN and the State Committee of the USSR for the Utilization of Atomic Energy, for scientific and technical co-operation at the Institute of High Energy Physics, Serpukhov near Moscow. A few months later, on the night of 13-14 October, the highest energy machine in the world, a 76 GeV proton synchrotron, was brought into operation at Serpukhov.

The main items of the collaboration between the two research centres are as follows:

1. CERN is providing a fast-ejection system for the Serpukhov accelerator which will become the property of Serpukhov. CERN is responsible for the design, construction, testing and installation of the system and for commissioning the fast-ejected beam at the accelerator.
2. CERN is providing radio-frequency particle separators which will be used at Serpukhov for at least ten years. CERN is responsible for the design, construction, testing and installation of these items of beam-line equipment and for their commissioning at the accelerator.
3. CERN can propose a succession of electronics experiments to be incorporated in the experimental programme at the 76 GeV machine. CERN scientists carry out such experiments in collaboration with their Soviet colleagues.
4. CERN and Serpukhov will collaborate in bubble chamber physics, CERN scientists participating in joint teams as for the electronics experiments.

More details of the agreement and some information on the formal arrangements whereby the collaboration is organized can be found in CERN COURIER vol. 7, page 123. But leaving aside the detail, the collaboration might be summarized as — on the one hand, enabling Serpukhov to draw on the accumulated expertise which has developed from the exploitation of the 28 GeV proton synchrotron at CERN; on the other hand, giving CERN scientists access for experiments to the highest energy machine in the world. In a broader framework, it puts into practice the spirit of close co-operation which exists between particle physics Laboratories throughout the world.

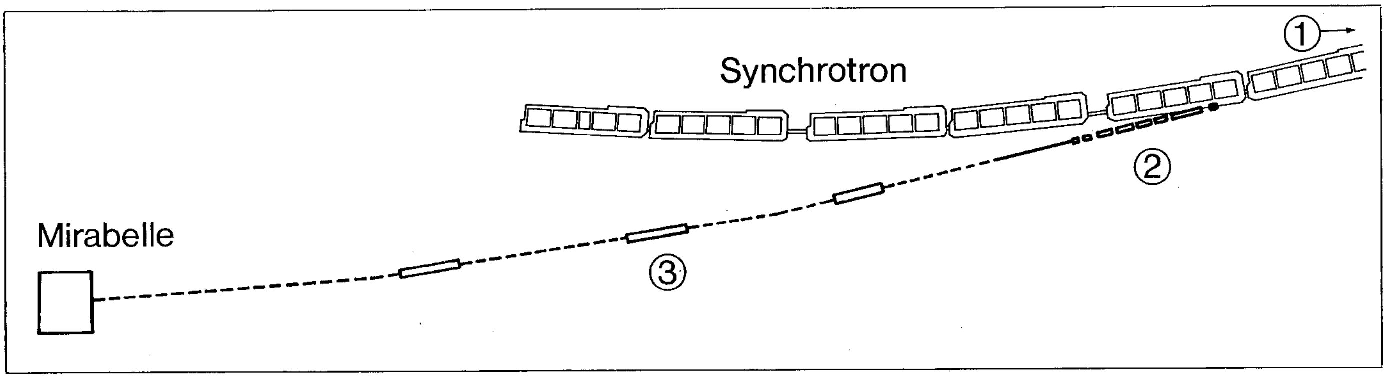
We now turn to the different items in the collaboration to see what form they have taken and how they are progressing.

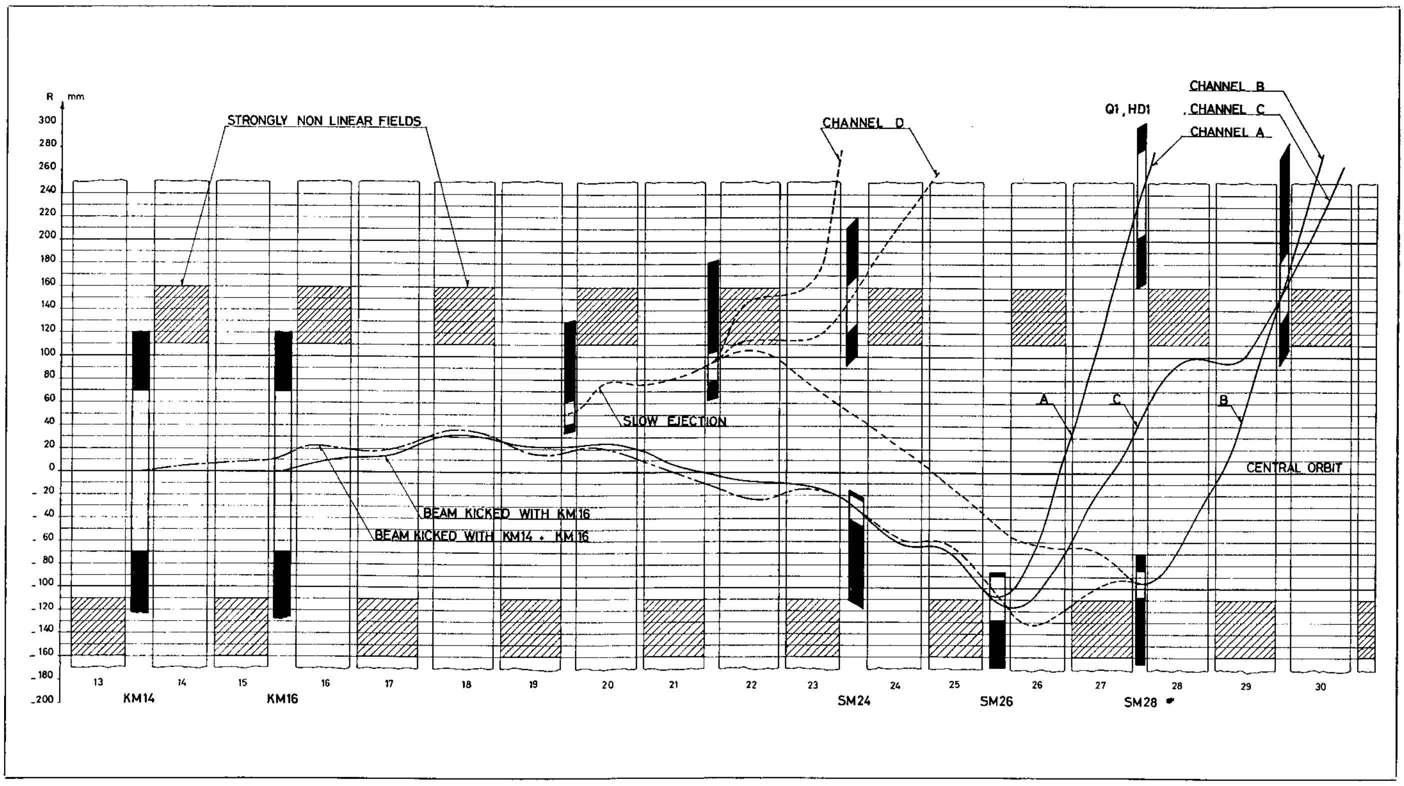
Fast ejection system

A fast ejection system ejects all or part of the accelerated proton beam from the synchrotron ring in times of the order of a microsecond. Two special types of pulsed magnet are usually involved — a kicker magnet which deviates the beam from its normal orbiting path and an ejection magnet (often called a septum magnet because it has a thin septum along its aperture) which receives the deviated beam and completes the bending out of the ring. The kicker magnet in particular needs to reach its required fields in between the passage of two bunches of the accelerated beam — in a time of the order of 0.1 μs — so as to allow one bunch to pass unaffected while being fully ready to eject the following one. (A description of the first operation of a fast ejection system can be found in CERN COURIER vol. 3, page 63.)

The system developed for Serpukhov was influenced by two special factors. The

A schematic representation (not to scale) of the beam-line at Serpukhov where CERN is participating in the design, installation and commissioning of equipment:
1. The fast ejection system for 'Channel A' involving a full-aperture kicker magnet, and two septum magnets downstream in the synchrotron ring.
2. The beam-line conveying the ejected proton beam a distance of about 30 m to a target.
3. The r.f. separator consisting of three cavities installed in the 500 m of beam-line between the target and the bubble chamber to separate particle beams for the chamber.
The bubble chamber at the end of the beam-line is the large hydrogen chamber, Mirabelle, which has been built at Saclay.





synchrotron has one huge experimental area and all beams for the experiments must emerge from the same region of the machine. The ejection system to be provided by CERN has therefore to be integrated with other systems. Also, with the comparatively slow repetition rate of the machine (9 pulses per minute) it is important to provide for the maximum amount of beam sharing so as to have the possibility to keep many experiments fed with particles on each pulse. The ejection system has therefore to be capable of 'multiple shot' operation (operating several times during one machine cycle and ejecting any number from one to thirty proton bunches.— thirty being the full number of bunches in the ring) and of 'multiple channel' operation (the field levels of the magnets being programmed to guide the protons into one or other ejection channel).

The interlacing of ejection systems is represented in the diagram above. To arrive at this scheme requires very close collaboration between CERN, Serpukhov and the Institute for Electrophysical Apparatus (Leningrad) who are constructing most of the equipment for the other channels. CERN is responsible for fast ejection down Channel A. This requires KM 16 (a full-aperture kicker magnet in straight section 16), SM 24 (a hydraulically plunged septum magnet in straight section 24) and SM 26 (a stationary septum magnet in straight section 26). In addition, there will be HD1 and Q1 (a horizontal deflector magnet and a quadrupole in straight section 28) to improve the beam optics and adjust the beam exit angle into the experimental hall. (These two elements are, strictly speaking, part of the external proton beam system described later.) The paths of the other fast and slow ejected beams can be traced on the diagram.

Channel A will be used for a radiofrequency separated beam (of which more later) to feed the bubble chamber Mirabelle which has been constructed at the Saclay Laboratory in France for use at Serpukhov. Channel B is intended for neutrino experiments and Channel C will feed a 2 m hydrogen chamber.

A three stage system — kicker magnet followed by two septum magnets — for Channel A avoids the necessity for closed orbit deformations such as are used on the CERN PS to move the orbit close to the septum. Multiple pulsing of the kicker (following the 'straight flush' technique developed at CERN, see CERN COURIER vol. 8, page 175) means that the kicker can be powered several times in one cycle of the accelerator; this may be done in steps of 170 ns duration for times between 15 ns and 5,1 μs the field of the magnet rising to its required value (or falling again to zero) in the interval between the passage of two bunches. The septum magnets can also be pulsed repeatedly to fields corresponding to ejection energies between 30 and 76 GeV.

All supplies and controls for the ejection systems are to be grouped in a special building close to the ejection area. The systems will be controlled from this point with only a few essential controls being repeated in the Main Control Room of the synchrotron.

The layout of the ejection channels was adopted early in 1968 and a detailed design study by CERN for Channel A was accepted in February 1969. Agreement was then reached on such things as acceptable minimum performance, equipment tolerances, and on the detailed division of responsibilities. Since then the Fast Ejection Group at CERN, led by B. Kuiper, which has been joined by two scientists from Serpukhov — O.O. Kurnaev and V.V. Komarov, has been busy with prototype studies which by now have resulted in the definition of the complete system. Contracts have been placed for the major standard items of the final system. Some other single items, which cannot easily be placed in industry, will be made in CERN.

A prototype module of the full aperture kicker magnet has been constructed and tested at full design voltage in vacuum. It has withstood over 3 million pulses without failure, being powered by a prototype delay-line pulse generator using triggered high-pressure spark gaps. The pulses are transmitted through 80 m of cable to simulate the conditions at Serpukhov.

The final magnet will be divided into ten modules each separately powered. Each magnet module will be powered by discharging a delay-line and the variable pulse length will be obtained by appropriate timing of two spark gaps so as to divide the pulse between the magnet module and a dumping resistor. The magnet aperture is 100 mm × 140 mm and the peak field is about 1 kG.

A prototype septum magnet, 1 m long with an aperture of 50 × 25 mm^2 has been constructed and tested at full voltage. The highest field, in the septum magnet SM 26, will be 14 kG for a 76 GeV beam and careful tests have to be made to look

The interlaced ejection systems on the Serpukhov synchrotron. The vertical direction is across the aperture of the machine, the horizontal direction (on a much more reduced scale) is around the ring. KM represents a kicker magnet and SM a septum magnet positioned in straight sections between the ring magnets. The possible paths of the beam for ejection down one or other channel are drawn in and it can be seen that many ejection magnet units are common to several systems. CERN is responsible for fast ejection down Channel A.

The pulse generator for a delay-line such as will feed one of the ten modules of the kicker magnet to be installed at Serpukhov. Variable pulse lengths in the kicker magnet will be obtained by triggering spark gaps dividing the pulse from the delay-line between a magnet module and a dumping resistor.

for any undesirable effects due to saturation of the magnet core. The septum magnet is powered by currents of up to 30 000 A, with voltage stabilized to better than one part in a thousand, by discharging a capacitor bank using triggered ignitrons. The prototype has been subjected to over 2 million pulses.

The two final septum magnets will have very similar construction but one will be plunged using an hydraulic actuator which must move the magnet typically over 10 cm in 0.3 ms placing it with an accuracy of 0.5 mm. A prototype actuator has operated satisfactorily and is to be used on the CERN proton synchrotron.

Work is also under way on vacuum aspects, on beam observation techniques and on the control system. The present aim is to have full-scale tests on the final equipment beginning at CERN at the end of this year. This will involve setting up (in the hall which used to house the electron storage ring model CESAR) the kicker magnet in its vacuum tank, its power supplies and delay line pulsers with some 4 km of cable, the two septum magnets in their vacuum tanks, the hydraulic actuator, their power supplies, the control system in a model control room. Beam observation units, such as will be used at Serpukhov, will be installed in straight section 77 and in the neutrino beam at the PS and their signals brought to the model control room. If all goes well during several months of thorough testing, the equipment will leave for Serpukhov by the middle of 1971.

Proton beam-line to target

CERN is providing the beam transport system to take the ejected protons from the synchrotron 33 m down Channel A to the target position. The beam will be guided and focused using 11 small-aperture quadrupoles and deflecting magnets.

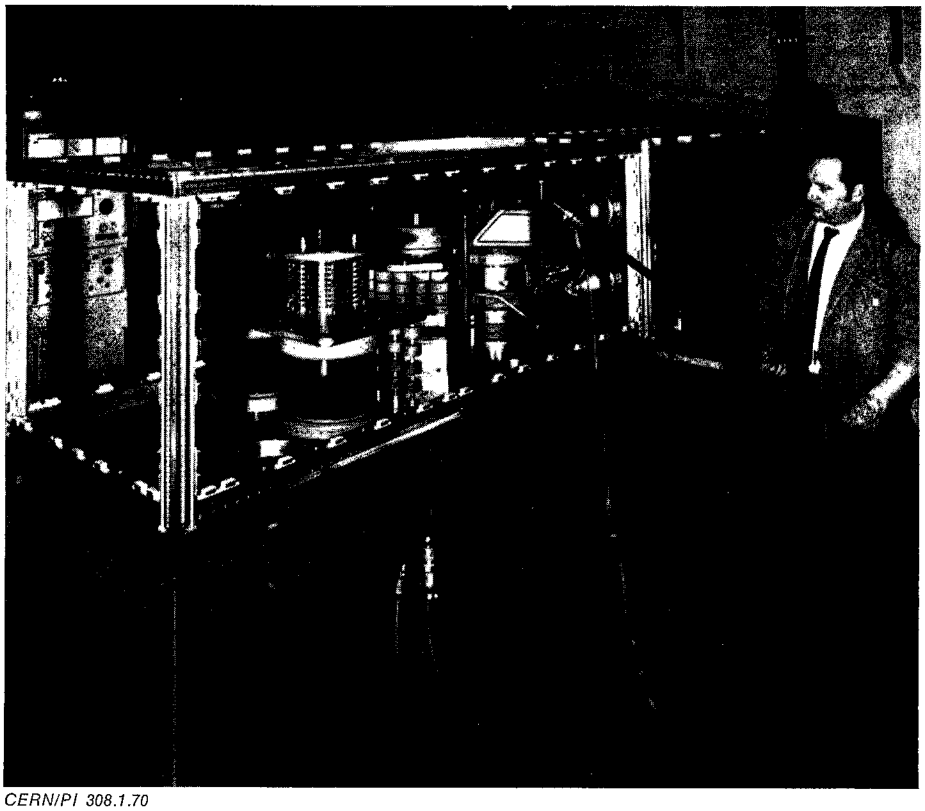
Because of space restrictions close to the synchrotron ring, a pulsed beam transport system was chosen, since it can provide the very high field gradients required in the quadrupole lenses, while at the same time giving compact magnet construction and economical use of power and cooling. Similar systems have been operated for several years on the CERN synchrotron and one is currently being used to transport the 28 GeV proton beam for 130 m to a target in the south-east experimental area.

The beam-line for Serpukhov has been designed to operate in the momentum range 30-85 GeV/c at repetition rates of between 5 and 10 s and with up to four proton bursts at 500 ms intervals during the flat-top of the synchrotron magnet cycle. The nominal emittance of the ejected beam at 75 GeV is π mm mrad in both horizontal and vertical planes, and the beam is to be focused onto the external target, of 2×1 mm^2 cross-section and 200 mm length, with a maximum divergence of $\pm$ 0.005 rad.

The selected trajectory theoretically involves no deflection of the beam, other than that from the stray field of the synchrotron magnets. Nevertheless five pulsed deflecting magnets, three acting in the horizontal plane and two in the vertical plane, are provided to ensure correct beam alignment. These can each give a deflection of up to $\pm$ 3 mrad at the maximum energy.

The focusing system consists of four quadrupole lenses. The first (Q1) is 750 mm long with a 30 mm aperture, situated in straight section 28. It compensates for the radially defocusing fringe field in the next synchrotron magnet, and gives an approximately 'round' beam at the entrance to Q2 which is the first quadrupole of an asymmetric triplet with 70 mm aperture lenses of 1.5 m modular length. Q2 is a single module unit whilst Q3 and Q4 are of two modules each in order to achieve the necessary integral field gradient.

The magnets are of laminated steel construction, generously dimensioned to give good uniformity at high flux levels. The multi-turn excitation coils, which are water cooled, are more bulky than would be ideal, since, in order to reduce losses on the long (300 m) cables from the power supply building, the current is kept as low as possible. The quadrupoles can reach gradients of 11 kG/cm for the 30 mm units and 4.5 kG/cm for the 70 mm units respectively and the bending magnets have a maximum flux rating of 20 kG. Most of



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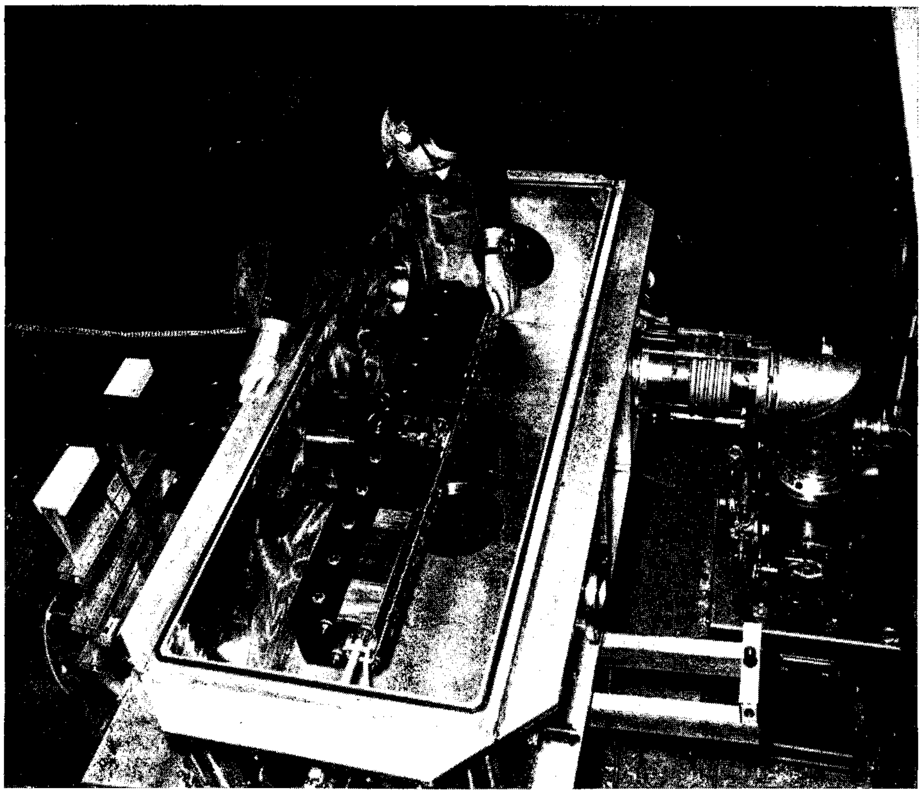

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The prototype septum magnet in position in the prototype vacuum tank. The magnet is powered by currents of a few times 10 000 A with high voltage stability. It has operated successfully for over a million pulses.

the beam line will be evacuated to about 1 torr to reduce scattering of the protons to a negligible level.

The pulsed current supplies are of the high voltage capacitor discharge type, switched by thyristors, with a pulse to pulse stability of ± 0.1 %. An appreciable amount of the energy is recuperated after each pulse with a low loss reactor and fed back to the capacitor bank.

Control electronics include pulse timing equipment, current and voltage measurement, and protection interlock circuits. For beam observation, beam current transformers and remotely controlled scintillating screens observed by closed circuit television will be provided at several points along the beam-line; other monitoring devices are also under consideration. The control station is located in the supply building, and this, together with the long cable runs presents some screening problems.

Contracts for all the major equipment have been placed: the prototype charging supply and discharge circuit are already under test at CERN and high voltage tests on the first prototype magnet have been completed at the manufacturers prior to dispatch. Magnets and charging supplies are being manufactured by Lintott Engineering Ltd. (UK), the discharge and recuperation circuits by Southern Transformer Products Ltd. (UK), and energy storage capacitors are being supplied by Ero-Starkstrom GmbH (Federal Republic of Germany) and BICC (UK).

It is planned that scientists from Serpukhov will join the group led by B. Langeseth to participate in the setting-up and testing of the final equipment at CERN in order to familiarize themselves with operation and maintenance of the system before carrying out the installation and commissioning at Serpukhov. The beam is due to come into operation to provide particles to the Mirabelle bubble chamber in 1971.

R.f. separator

When an accelerated beam strikes a target the resulting spray of secondary particles will contain not only many types of particle but will also contain particles with a wide range of velocities. Magnetic fields can be used to do a preliminary (and sometimes sufficient) selection from the spray by setting their values to allow through the required particles at the required momentum. As magnetic fields only distinguish momentum (mass multiplied by velocity), other particles (for example of higher mass and lower velocity) can pass with the required particles.

Particle separators then need to be installed in a beam-line when a pure beam is needed. They come in two types, electrostatic and radio-frequency, and it is the r.f. type (more suitable for high momenta) which interests us here since such a system is being provided for Serpukhov. They take advantage of the minute difference in the time of flight of particles of different velocity to subject each type of particle to r.f. fields which will give a different deflection to each type. Thus for example, using r.f. frequencies in the thousands of MHz range, in r.f. cavities separated by some tens of metres, kaons can be subjected to different r.f. fields to pions since they arrive at a deflector some fraction of a thousandth of a millionth of a second later.

When such systems were first brought into operation at CERN in 1965 they used two r.f. cavities (or deflectors) which restricted their application, when separating one type of particle from two others, to narrow momentum regions. Later development of a three cavity system can achieve separation over a wide, almost continuous, momentum range.

The r.f. separator for Serpukhov was studied at CERN in the group led by H. Lengeler with P. Bernard. There were many fruitful discussions with scientists from Serpukhov (two of whom, V. Vaghin and V. Zelenin, are working in the group) in evolving the parameters of the final system. The separator is of the three cavity type and is required to separate kaons and antiprotons of momenta up to 36 GeV/c, pions up to 60 GeV/c and protons up to 70 GeV/c.

The section of beam-line in which they will be installed stretches a total of 511.5 m from the target to the Mirabelle bubble chamber. The first deflector comes after a series of bending magnets, quadrupoles and collimators which select the required momentum. The distances between the deflectors are 88 m between 1 and 2 and 164.6 m between 2 and 3. A beam stop placed after deflector 3 collects the unwanted particles while the wanted particles are deflected around it. A further series of bending magnets and quadrupoles moulds the remaining beam into the required form for the bubble chamber.

The deflectors are to be driven at 2855 MHz (corresponding to a wave-length of 10.5 cm). 20 MW of r.f. power will be provided to each cavity, via a klystron, from a pulsed power supply giving 270 A at 270 kV in 8 μs pulses. The three cavities will be interlinked so that a phase comparison can be made as they are in operation and, if necessary, a phase shift can be introduced via a servo loop using a variable phase shifter.

One major problem was to develop r.f. cavity structures to take the 20 MW of power available from the klystrons. A lot of theoretical study and practical measurement has resulted in structures which perform entirely satisfactorily in very close agreement with the calculated performance.

The proposed system was given a thorough try out in the first week of February when virtually all the units for Serpukhov, with the exception of the actual cavities were incorporated in the three cavity r.f. separator in the u 5 beam from the CERN 28 GeV proton synchrotron to feed the 2 m bubble chamber. The tests were carried out at 16 GeV/c. 3.5 m cavities, two of them vacuum-brazed in the West-workshop (J. Augsburger) — were used. The powering system was identical with that for Serpukhov involving pulsed power supplies from Ling Altec (UK) and klystrons from Thomson Varian (France). The phase controls, vacuum system, mechanical system, interlocks, etc., were also identical. The separator worked well and the observed deflections agreed with theory.

The Serpukhov cavities will be each 6 m long and are being manufactured by CSF (France). Some of the CERN group went to the factory mid-February to begin acceptance tests. The first cavity is scheduled for delivery on 15 March and the other two will follow at monthly intervals. The separator is scheduled to be ready for operation early in 1971.

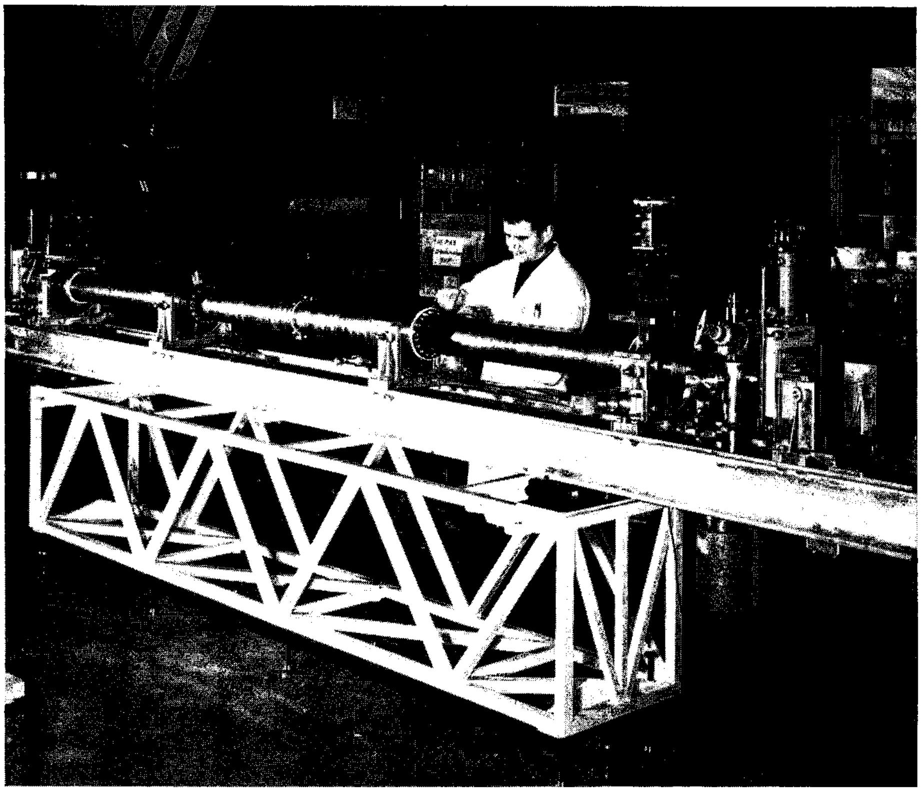
Joint experiments

The very first collaborative experiment between scientists from CERN and IHEP on the Serpukhov machine was a resounding success. The opening stage was to measure particle yields at the newly available high energies — finding out how many particles of the different possible types are produced when a target is hit by a proton beam with an energy of up to 70 GeV. The results have contributed to the knowledge of particle production mechanisms, have helped in the planning of secondary beams for the experimental programme at Serpukhov, and have given further information towards planning of beams at accelerators in the hundreds of GeV range. (The experiment and results were described in CERN COURIER vol. 9, page 99.)

The second stage of the experiment came up with very surprising results. It looked at the total cross-sections of negative particles (pions, kaons and antiprotons) on protons at high energies — measuring the probability that the negative particle interacts, in no matter what way, with a proton in a hydrogen target. These cross-sections could be predicted since their values were known at lower energies and since convincing theories required the cross-sections to reach constant values at very high energies. The experimental results however were not in line with the predictions and indicated that the constant values are reached at much lower energies. These results are causing much theoretical head scratching (see CERN COURIER vol. 9, page 232).

A new joint experiment is due to be setup at Serpukhov in the near future. A major consignment of equipment will leave CERN in a months time and a fuller description will be given in the next issue. It is a continuation of the search for neutral mesons at high masses using the missing-mass technique. This search has had a very successful history at CERN. Many new particles have been discovered and the ways in which they decay observed (see CERN COURIER vol. 7, page 31, vol. 8, page 8). One of these particles, called A2, has proved quite a mystery since it appears to be in fact two particles of almost identical mass (see vol. 9, page 233).

The newly observed mesons have appeared with remarkable regularity in terms of their mass (the square of the masses lying on a straight line). It is therefore possible to predict that many others with still higher masses will be seen by the joint CERN/Serpukhov team in the higher energy range opened up by the 76 GeV synchrotron.



A 3.5 m r.f. deflector complete with vacuum system and support structure; the waveguide entry is on the left and the r.f. load on the right. In the final installation the deflector is surrounded by a water jacket to ensure temperature stability. The photograph was taken towards the end of January just before the performance of the cavity, powered with 20 MW of r.f. power, was tested. The tests confirmed the reliability of the system chosen for the r.f. separator for Serpukhov.

CERN/PI 193.1.70

CERN News

On 1 February Professor H.F. Schopper took over the leadership of the Nuclear Physics Division in succession to Professor Preiswerk, one of CERN's pioneers, who had occupied the position for the previous ten years. Professor Preiswerk will remain at CERN helping Professor Schopper to settle into his new post and turning again to research — in his own words 'hoping to provide some competition for the young physicists'.

Herwig Franz Schopper was born on 28 February 1924 in Landskron. He read physics at the University of Hamburg. Since 1949 he has occupied successive posts at the Universities of Erlangen, Mainz and Karlsruhe. In 1961 he was appointed Director of the Institute of Experimental Nuclear Physics at the Karlsruhe Nuclear Research Centre, and from 1967 to 1969, he was President of the Scientific Council of the Centre.

His contacts with the international scientific world have been numerous. He spent six months in 1950 at the University of Stockholm, a year (1956-1957) at the Cavendish Laboratory at Cambridge working with Professors O. R. Frisch and D. H. Wilkinson on parity violation in beta decay, and several months (1960-1961) at Cornell University working with Professor R. R. Wilson on electron scattering. He is well known at CERN having worked here in 1967 and 1968 as a Visiting Scientist.

On computers

A further step (an 'interim solution') to keep the installed computing capacity at CERN in line with demand was completed in January. The CDC 6400, which together with the CDC 6600 provide the central computing service, has been converted to a 6500 with the addition of a second processor, an additional 64 K of core store and some peripheral equipment. In this way the capacity of the existing system is extended to cope with the foreseeable demand for about the next two years.

The amount of computing done at CERN doubled annually from 1962 to 1967 and a succession of ever more powerful computers had to be acquired. Since 1967 the growth rate has decreased somewhat to a doubling every two years and extensions to the CDC central computers have kept pace, and will keep pace through to about the end of 1971.

Study groups have looked at the computing requirements for the coming years, taking into account such predictable items as the number of bubble chamber pictures to be taken, the number of events from electronics experiments, the number of physicists at CERN needing access to computing, etc. Their studies have shown that a computer with several times the capacity of a CDC 6600 will need to be in operation from the beginning of 1972. Beyond that date the requirements are less clear but the coming into service of the various items of the improvement programme at the 28 GeV proton synchrotron and of the Intersecting Storage Rings suggests that by about 1975 the installed computing capacity will need to be about ten times that of a CDC 6600.

Preliminary approaches to computer manufacturers in this context began in 1967 and at the end of 1968 the first requests for tender were sent out. No single machine then being developed seemed likely by itself to meet CERN's long-term needs and a solution in a series of steps had to be devised. Step 1 has been the extension of the existing system completed in January. The proposed step 2 will be the acquisition for 1972 of a new computer, having about four times the capacity of a CDC 6600, while keeping the existing system in operation. Computer firms have recently been invited to tender for the new computer, the tenders to be at CERN by the end of February. It is hoped to put the proposed solution before the CERN Council at its June meeting. Step 3 cannot be defined very precisely at the moment but may involve the acquisition of another new computer about 1974-1975 while phasing out the existing system (CDC 6600 and 6500).

These developments will obviously have a big impact on the costs and manpower involved in the computing service. At present the service involves about 70 people and an expenditure of about 10 million Swiss francs per annum. By 1975 this could rise to 140 people and an expenditure of 20 million Swiss francs per annum. Costs would thus roughly double while the computing capacity would increase about fivefold. Figures of this order have been fed into the long-term financial planning for CERN Meyrin which has extended to 1975.

Fellowships in computer research

CERN has recently extended its Fellowship programme to take in areas of applied physics in addition to the long established Fellowship programme in particle physics. Initially, the new programme is on a modest scale in terms of numbers of Fellowships offered but it does provide new opportunities to scientists and engineers from the Member States to participate in aspects of CERN's work where the facilities and expertise are among the most highly developed in Europe. The field of computers is a predominant example and a limited number of scientists can now come to CERN to take up Fellowships for up to two years to do computer research.

It will have been obvious from the discussion above that the computing requirements of the Laboratory are often at, or beyond, the limit of the ability of commercially available equipment and systems. This has led to CERN carrying out considerable research in developing new computing techniques and in applying them to physical, mathematical or engineering problems. In recent years these developments have included — multiprogramming operating systems for the CDC 6000 computers, new compiling techniques (especially with reference to optimization for parallel processor units), permanent storage facilities, remote access computing facilities and file manipulation. Research is being made into quantitative performance analysis of these large systems with a long-term aim of performance prediction, an area which is becoming increasingly important.

The development of interactive graphical computing is another area where research is in progress, both from the point of view of systems and of applications. In this work CERN is exploring new ways of handling mathematical functions in a graphical form, processing visual data (such as photographically recorded experimental data), carrying out engineering design, etc. A CDC 3200 computer equipped with a large interactive graphical display unit will shortly be available for this work, and there will be an interactive display unit on the CDC 6600.

Closely related to this is research on pattern recognition, at present specifically aimed at the automatic processing of spark chamber and bubble chamber film. This, however, has many aspects in common with other applications, for example, medical data processing, character recognition, and it could easily be extended in these directions.

In the near future, it is planned to undertake research in the area of programming languages and of compilers (at present Fortran is used almost exclusively, for essentially historical reasons). This is becoming increasingly important in making machines accessible in the widest sense. Such research would complement that on interactive computing methods that is already under way.

In applied mathematics, original research has been done over the past few years on the theory of Romberg integration, the theory of approximations by Chebyshev series, Monte Carlo methods, multi-variant minimization, computation of Coulomb wave functions and polylogarithms.

Looking ahead, CERN is concerned with overall computer system design, and work is at present in progress on studying the problems associated with communication networks, multi-processor systems, large-volume permanent storage systems and multi-access systems. There is considerable scope for original contribution to the theoretical analysis or description of these problems, as well as to the practical work of making detailed system specifications and evaluations.

It is on some of these topics that the research Fellows will work.

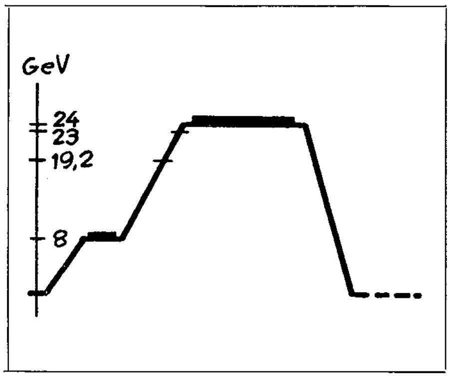
Computing school

This year, for the first time, CERN is organizing a 'Computing and Data Processing School'. It will be held at Varenna in Italy from 30 August to 12 September and is open to about 70 young computer scientists and high energy physicists coming principally from the CERN Member States.

The initiation of this school, which may well become an annual event, is a recognition of the emergence of computer science during the past two decades as a subject in its own right. On the other hand, physicists usually have recourse to computing in an ad hoc way looking for the solution to particular problems — mainly in the recording and analysis of increasingly large volumes of data. It is felt that considerable benefit will come, in both directions, from bringing together computer scientists and computer users. Computer scientists will appreciate more fully the problems of the experimental physicist and may see more clearly the lines of research which could ease the problems. Experimental physicists will appreciate more fully the possibilities and limitations of computers by seeing the current state-of-the-art in computer science presented in a broad framework.

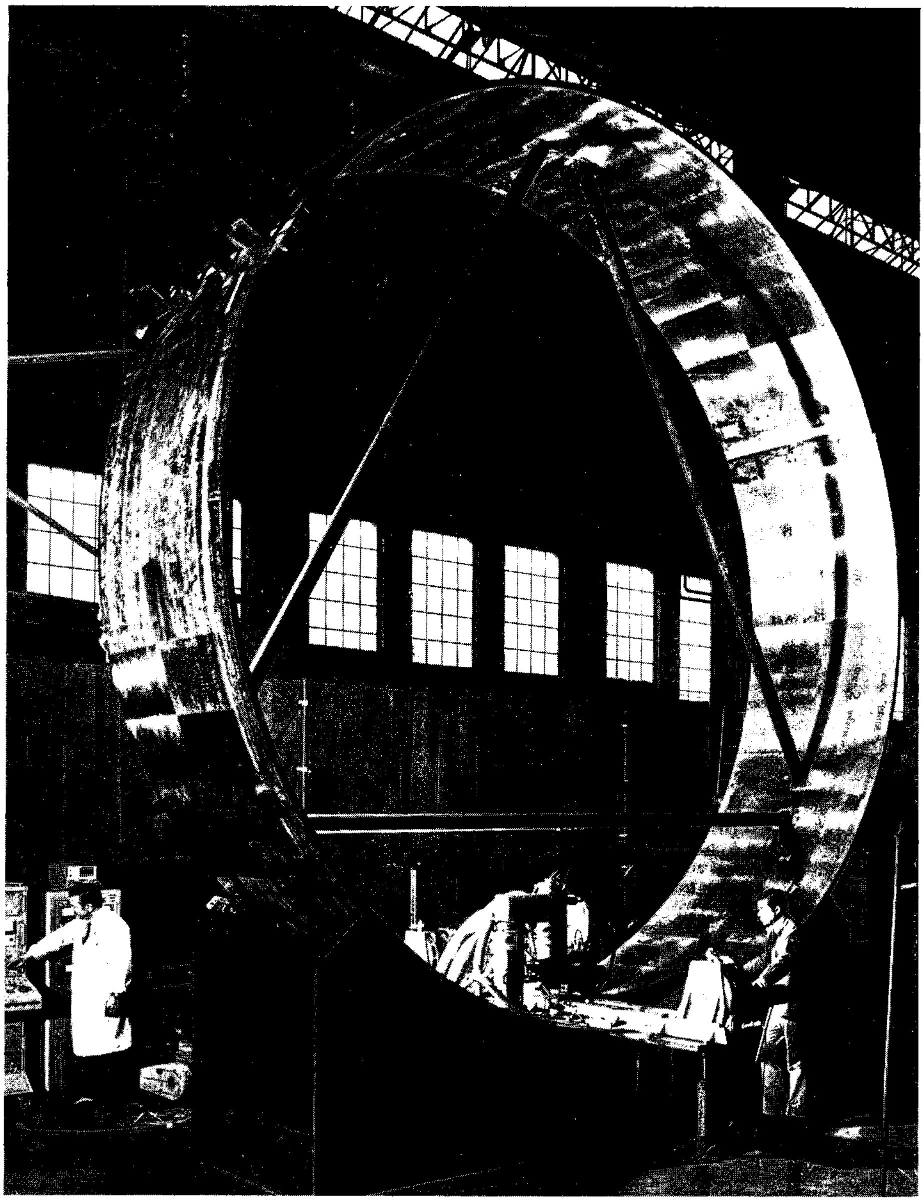
There is an Advisory Committee for the school with the following members, in addition to members of CERN staff: L. Bolliet (Grenoble), M. Cresti (Padua), A. Donnachie (Manchester), D. Harting (Amsterdam), F. Hertweck (Garching/Munich), P. Kirstein (London), B. Levrat (Geneva), C. Strachey (Oxford) and B. Zacharov (Daresbury).

The courses at the school will cover — Programming languages (J.J. Duby, IBM/Grenoble), Computer systems design (W. Miller, Stanford), Data processing in electronics experiments (B. Levrat, Geneva), Data processing in bubble chamber experiments (P. Villemœs, CERN), Simulation in high energy physics (F. James, CERN), Simulation in computer design (D.M. Gibson, IBM/Poughkeepsie), Algebraic manipulation (M. Engeli, FUF/Zurich), and Computer graphics (B. Zacharov, Daresbury). Evening lectures are being arranged on Artificial intelligence (D. Michie, Edinburgh), Impact of computers on nuclear science (L. Kowarski, CERN) and Computers in space research (a NASA official).



Operation of the 28 GeV proton synchrotron is going a long way towards pleasing all of the people all of the time. Mastery of beam sharing techniques is now so highly developed that eight experiments can receive particles from the same machine pulse.

The operating cycle for the first two weeks of February is illustrated schematically in the diagram which shows how the magnetic field in the synchrotron ring changes with time during one machine cycle. The cycle lasts 2.3 seconds. Protons are accelerated to 8 GeV/c and there is then a 'flat-top' of 150 ms duration while the beam (still distributed in 20 bunches) is guided onto an internal target in straight section 1 and provides secondary particles to experiments in the South Hall absorbing from 5 to 10 % of the proton beam. Acceleration is then taken further; at 19.2 GeV/c fast ejection 74 sends two bunches towards the heavy liquid bubble chamber in the neutrino area and at 23 GeV/c fast ejection 58 sends one bunch into the East Hall. Finally at 24 GeV/c the remainder of the proton beam is divided between internal targets in straight sections 1 and 8 providing beams into the South Hall during a flat-top of 520 ms.



Photograph taken in December 1969 in the Neyrpic (Grenoble) division workshops of Alsthom who were awarded the contract for the cryostats to house the superconducting coils of the European bubble chamber. The photograph shows welding, by electron bombardment, of a stainless steel collar 6 m in diameter and 45 mm thick used in the construction of one of the vertical walls of a cryostat.

The technique was developed in collaboration with the CEA (Commissariat à l'Energie atomique). The welding takes place in a local vacuum chamber which encloses the weld joint.

(Photo Neyrpic)

European bubble chamber

Winding of the superconducting magnet coil

The European bubble chamber (described in CERN COURIER vol. 7 page 143) will have a superconducting magnet, which is more than 6 m in diameter, to give a field of 35 kG in the chamber.

When the project was started, enquiries were made with firms likely to be able to undertake the winding of the magnet, and it was found that large sums would have to be spent on winding equipment. In view of the large depreciation factor contained in the price quotations, the prevailing economic situation (which delayed deliveries) and the delicate question of guarantee, CERN finally decided to carry out the winding on the site with equipment specially designed for the job. It was decided to locate the winding shop in a building to be used for exploitation of the chamber, near the West experimental hall.

In May 1968 an engineering contract was placed with Alsthom (France), to design the work area, the tooling and the various stations of the winding shop. The components were ordered from a large number of suppliers in Europe.

The workshop consists of:

— a winding line consisting of a 6.2 m diameter winding plate, two motorized coil winders 400 mm in diameter, two pneumatic tensioners, degreasing baths, swivelling guides etc., manually operated decoilers for the coil insulating strip, cooling strip and heating strip;

— a welding line consisting of a motorized, coiler, welding bench, straightening rollers, measurement table;

— a production line for the cooling strip (described below);

— a line for insulating the heating strip and for cleaning the cooling strip;

— two assembly platforms for stacking the pancakes and making the connections before the coils are transported to the chamber building.

Coils

Each coil is composed of 10 double pancakes each weighing 10 tons and composed of 176 turns. Each winding consists of 10 elements 1550 m long arranged as shown in Figure 2.

In view of the strong electromagnetic forces, only one side of the conductor strip can be exposed to cooling — the other side presses against a stainless steel strip which takes up the stresses. Between these strips are located the insulating layers and an aluminium heating strip to eliminate, if necessary, stray currents in the superconductor as the field rises.

Superconducting strip

This strip is composed of approximately 200 filaments of NbTi embedded in copper with a cross-section of 61 × 3 mm^2 and is delivered in 1550 m lengths (see CERN COURIER vol. 9 page 64). By the beginning of February, 9 km of strip had been delivered by Siemens (Federal Republic of Germany). The total length of this order is 66 km, representing a weight of 130 tons.

Reinforcing strip

This strip has a cross-section of 60 × 2 mm^2 and is delivered in 250 m lengths by CAFL (France). It is made of 316 L stainless steel. There are strict tolerances on dimensions, in particular the longi-

1. *Part of the cross-section of the superconducting magnet for the European bubble chamber. Each coil is composed of 10 double pancakes with 176 turns on each. The magnetic field in the centre of the coils is to be 35 kG, the rated current through the coil is 5700 A and the stored energy 830 MJ.*

2. *The various strips used in assembling the superconducting coil. The cooling strip (11) is in direct contact with the conductor (1) of the adjacent turn, along which helium is thus free to circulate. 1 is the conductor; 2, 3, 5, 6, 8, 9, 10 are thin insulators; 4 is the heating strip; 7 is the main reinforcement; 11 is the cooling strip. (Insulators 8 and 10 are used only for the first turn.)*

3. *View taken in February of the hall used for winding the superconducting magnet coils for the European bubble chamber. This picture shows the winding of one of the 'pancakes' of which the coil is composed. The various strips of which the coil is built up converge on a 6 m diameter drum where the actual winding operation takes place.*

tudinal camber (0.5 mm per 3 m). The same tolerances also apply to the superconducting strip. Total weight is 65 tons.

Cooling Strip

The cooling strip is machined at CERN (see below) and is supplied by Tréfimétaux (France) in 80 m lengths.

Coil insulation

This consists of 4 thin self-adhesive polyester sheets measuring 4 × 0.06 mm², which enclose the heating strip, and two polyamide films of 2 × 0.025 mm². After numerous laboratory tests it was decided to select these two materials, which are made by Sellotape (UK) and Dupont de Nemours (USA) respectively.

Heating Strip

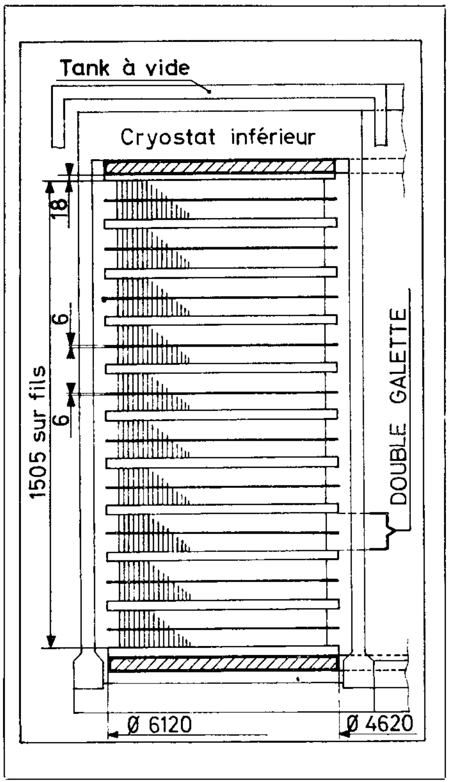
This strip is sandwiched in the coil insulation and consists of a thin (0.1 mm) sheet of aluminium supplied in 1600 m lengths by the firm of V. Neher (Switzerland). If necessary a 1200 A current will be fed through it for 0.2 to 0.3 s and the energy dissipated — several hundred kW — will cause the pancakes to lose their superconducting property momentarily thus eliminating stray currents.

Pancake insulation

This insulation, which weighs 10 tons in all, is composed of perforated slabs of glass wool impregnated with epoxy resin supplied by the firm Rommler (Federal Republic of Germany). These slabs have been machined by Micafil (Switzerland); their purpose is to act as an electrical insulator between the pancakes without preventing the axial flow of the liquid helium. They also act as a mechanical support during transportation of the double pancake from the winding table to the stacking platform (see cover photograph).

Winding

Now that the stations for the winding operation have been designed and equipped, industrial firms have been called in to supply the necessary specialist labour. The contract was awarded to Alsthom (France), who will provide three coil-winders and two mechanics to operate the winding, welding and cooling strip production lines. The welding line is being operated intermittently; (welding runs are made whenever the stock of 250 m lengths justifies calling in the welding specialists). Each weld is then X-rayed and inspected by Inrescor (Switzerland)



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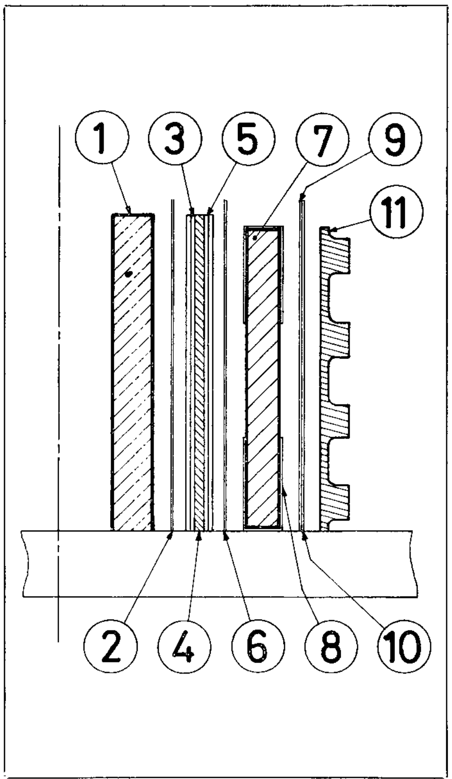

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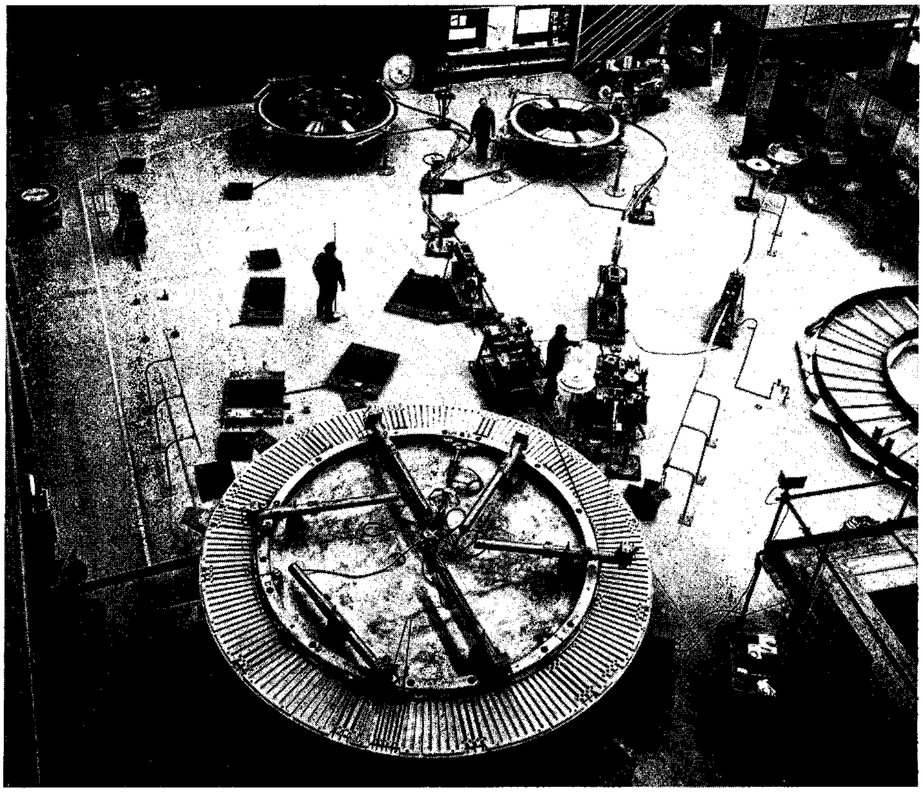
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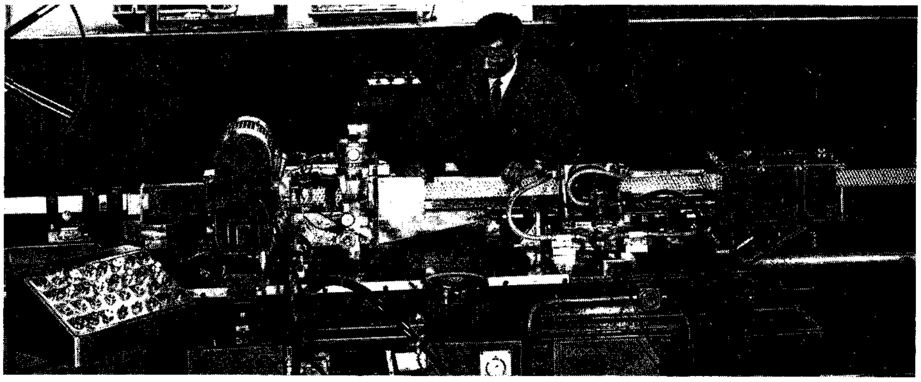
CERN/PI 3.2.70

Machining of the cooling strip for the superconducting magnet by an automated technique developed at CERN.

The photograph alongside which looks like a section of Lego board is a piece of cooling strip. The helium which retains the coil at a superconducting temperature flows between the small projections.



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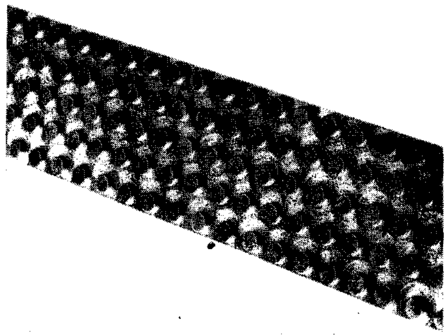

CERN/PI 513.10.69

independently of CERN and the supplier. The other lines are operated continuously.

The workshop has been in operation since October 1969. In December a prototype double pancake — in which the superconducting strip was replaced by a copper strip — was wound and immersed in liquid nitrogen to check its behaviour at low temperature. Certain adjustments were made and winding of the first superconducting pancake should start in February. According to the overall programme, winding of a double pancake should not last more than two weeks, which means that the winding operations should be completed at the end of 1970.

Automated machining of the cooling strip

The cooling strip, 1.9 mm thick and 60 mm wide, allows liquid helium to circulate along one face of the superconductor while ensuring the transmission of stress from one winding to another. The total length of the strip to be produced is about 70 000 m. The strip is in the form of a copper-ribbon machined on one side. Bosses, 7 mm in diameter, are uniformly distributed on the other side and the helium flows in between the bosses. The thickness of the remaining copper is between 0.25 and 0.35 mm.

When the geometry of the ribbon had been specified, invitations to tender were sent to fifty European firms. Three were interested in supplying the strip, but without machining, and only one submitted a proposal to supply the strip machine-finished. For various reasons this proposal was not acceptable and the Mechanical Workshop of the Physics II Department was given the task of constructing and commissioning a completely automatic machine able to supply the strip at the required rate for winding the bubble chamber coil.

This machine has as its main components:

- a hydraulically and electrically operated milling unit
- a device to hold the strip in position and to drive it along
- a planing device
- a cleaning and drying device
- two spindles, one of which takes the spool of copper to be machined and the other the drum of machined strip.

The milling unit has a head with ten spindles working in a horizontal position. It moves backwards and forwards along a groove powered by a hydraulic pressure piston, which develops 100 kg. A gripping device holds down the strip and guides the mills. The cleaning and drying device operates by sprinkling chloroethane on to the strip followed immediately by air drying.

The whole assembly is synchronized by a system of cams, switches, levers, valves, etc., linked to a control panel, which allows separate operation and control of each element of the machine.

The type of mill used and developed by the workshop gives very good results. The present machining cycle rate for each small section of the ribbon is 3 seconds, which ensures a production of over 30 m per hour. This work will continue for over a year and, eventually, just two people will be required for control of the machine and the regular sharpening of the tools.

With some modifications, this machine could be used for other similar applications.

Novel construction technique for the foundations

The mass displaced during each expansion cycle of the European Bubble Chamber will be considerable and the cycling time is short. As a result, the dynamic loads exerted during the bubble chamber cycle will be very great (in the region of 345 tons) and the foundations must withstand these without risk of any subsidence. The preferred solution was to lay the foundations down on a layer of very solid and stable molasse. However, at the point where the chamber is being built (the north-west end of the new west experimental hall) the molasse is 20 m below ground level and it is necessary to dig out a cylindrical pit, 13 m in diameter.

Using conventional construction methods would have meant scooping out a 'bomb crater' around the whole area, involving the removal of an enormous volume of material. To reduce the cost of the operation, the 'moulded wall' method was used. This involves digging a narrow circular trench, 0.8 m wide and 20 m deep around the pit to be excavated. Concrete is then poured into the trench and only the volume inside needs to be dug out.

To prevent the steep sides of the narrow trench from caving in, it is filled up as work progresses with a thixotropic mix (a colloidal suspension of clay) known as bentonite, which keeps a strong pressure on the sides of the trench. The excavating equipment digs out the trench under the bentonite which does not mix with the earth.

When the trench is finished the result is a wall of liquid bentonite. Concrete is then injected and being heavier than ben-

View taken at the end of January of the hole (13 m diameter, 20 m deep) in which the foundations for the European bubble chamber are being constructed. The bottom of the shaft is filled with unreinforced concrete, a 8.5 m thick block resting on the molasse rock. This block will support the foundations proper, which are planned to be finished by May.

A cross-section of the foundations. A is the unreinforced concrete block forming the main foundation. B is the foundation proper. C is the moulded cylindrical wall which encircles the foundations. D is surrounding earth.

tonite it settles to the bottom and gradually forces out the bentonite. In this way a concrete cylinder is erected surrounding the volume to be excavated. The pit can then be dug without any danger of the walls caving in, and the concrete provides support for part of the chamber building.

Excavation of the pit was finished by the middle of December and work started immediately on casting a block of unreinforced concrete at the bottom. The block is 8.5 m high and will support the true foundations of the chamber, which are composed of a 900 m³ structure of highly reinforced concrete. The molasse will therefore be subjected to the chamber's static and dynamic loads through some 5000 tons of concrete.

Design of this foundation required special care to avoid resonance phenomena. The contract for this was given to Professor Haeffli and to the Heierli firm of design engineers (Zurich).

Work on the concrete block started immediately to prevent the molasse from swelling once the load it had been sustaining was removed. This work absorbed practically the entire concrete production capacity of the Société Aixoise (who had been given the contract) on three shifts round the clock. Construction of the reinforced concrete foundations followed and work was well advanced by mid-February. All the foundations should be finished by the end of May.

Looking at neutral meson resonances

A collaboration of groups from Karlsruhe (led by H. Muller) and Pisa (led by I. Mannelli) began an experiment at the proton synchrotron in February to look for neutral meson resonances at high energies and to observe their decays into neutral particles. The experiment is scheduled to collect data during eight weeks.

The technique used is similar to that in the missing mass spectrometer experiment soon on its way to Serpukhov (mentioned on page 35) except that, whereas the CERN/Serpukhov team look for negatively charged resonances with high masses, the Karlsruhe/Pisa team look for neutral resonances. (A CERN/Bologna team and a CERN/Karlsruhe team have done a neutral missing mass experiment in the low mass range.)

The experiment, given the number S84, is fed by the d29 pion beam in the South Hall. Pion energies can range from 4 to 16 GeV but most data taking is likely to be at 8 GeV. The beam is directed onto a hydrogen target 40 cm long and 2.5 cm diameter where interaction points can be determined using the Cherenkov effect.

The interactions which are of interest are those of the form: $\pi^- + p \rightarrow n + X^\circ$ a negative pion interacting with a proton in the target to give a neutron and a neutral meson represented as X°. Knowing the parameters of the particles on the left hand side of the equation and measuring the emerging neutron gives information about the 'missing mass' X°.

As with the first missing mass experiment carried out at CERN up to the end of 1966, the method of observing Jacobian peaks in the angular distribution of the neutron is used. It can be calculated

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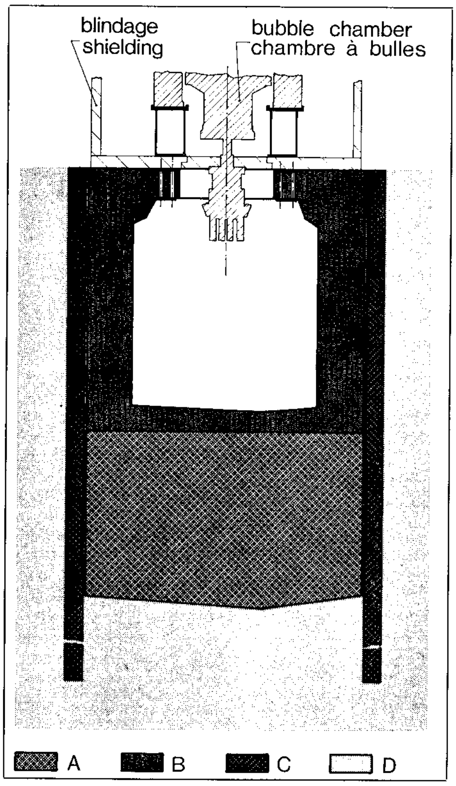
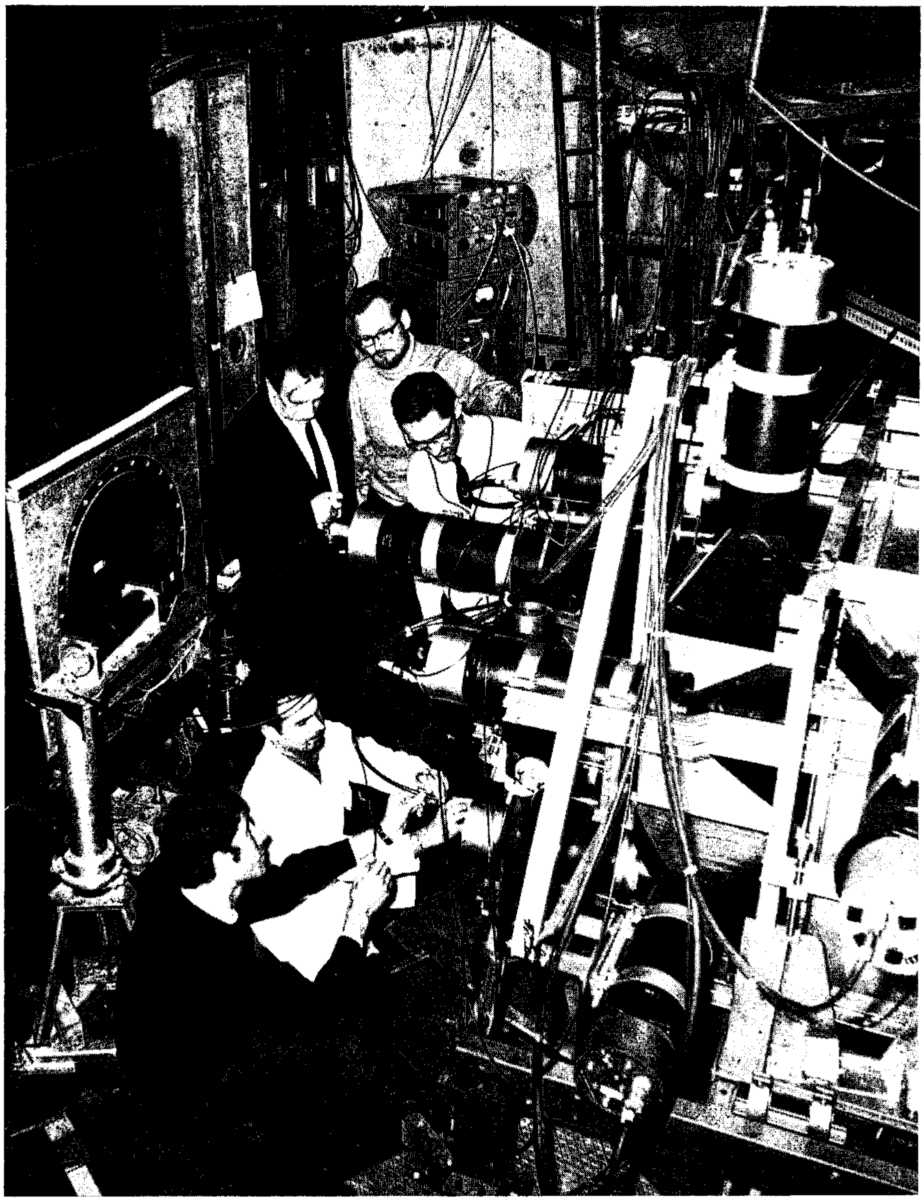


that associated with each neutral meson which can be produced in the interaction there is an angle at which a high percentage of the neutrons will emerge. Thus the number of neutrons recorded as a function of the position of the neutron detector will rise sharply at those angles corresponding to the production of a meson.

The neutron detector consists of eight counters, each 240 × 16 × 16 cm^3 of plastic scintillator, preceded by a 'veto counter' (a 260 × 140 × 1.5 cm^3 sheet of scintillator — the largest in use at CERN). Signals are only recorded if no particle is observed by the first sheet. This eliminates unwanted charged particles, without affecting appreciably the probability of observing a neutron which gives a 'knock-on' proton in the main block of counters. Photomultipliers positioned on opposite sides of the scintillators determine the position of the light flash and thus of the neutron (knock-on proton). The whole detector can be moved around through a range of angles with respect to the target.

Having identified the neutral meson via the neutron in this way, the experiment is then interested in observing the ways in which the neutral ·meson decays into neutral particles. The decays will give neutral pions, etas, omegas, etc., decaying to gamma rays; the gamma rays are detected when they convert to electromagnetic showers in an optical spark chamber array (1.5 m × 1.5 m × 1 m with 32 gaps equal to 18 radiation lengths) positioned behind the target with respect to the pion beam. The experiment will run on-line using a Telefunken TR86 computer. Karlsruhe are providing the computer and the neutron detector. Pisa are providing the target and the spark chamber.

It is hoped to take about 500 000 pictures in the spark chamber (with four views of each event). The pictures will be measured at Bologna using 'PROTEO', an HPD type measuring machine.



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The target assembly of the Karlsruhe/Pisa experiment which began taking data at the proton synchrotron in February. The experiment is of the 'missing mass' type looking for neutral meson resonances and observing their decays into neutral particles. Major items of equipment for the experiment have been brought to CERN from the two collaborating research centres and measurement of half a million photographs, which are to be taken, will be done at Bologna.

Superconducting quadrupole completed

A superconducting quadrupole built at the Oxford Instrument Company, UK, financed by the Ministry of Technology, is on its way to CERN on long-term loan having successfully completed commissioning tests in January. After further tests it is hoped to install the quadrupole on a secondary beam from the proton synchrotron — it may, for example, serve as the last lens on one of the beams to the large European bubble chamber (BEBC).

The project started at the beginning of 1968 (see CERN COURIER vol. 8, page 24). It has involved the collaboration of the Oxford Instrument Company (particularly

A cut-away drawing of the superconducting quadrupole, for use at CERN, which has just successfully completed commissioning tests at the Oxford Instrument Company. The major components of the assembly are indicated.

Winding of one of the poles of the quadrupole. The strip has 16 superconducting wires (niobium-titanium alloy) embedded in copper.

(Photo Oxford Instrument Company.)

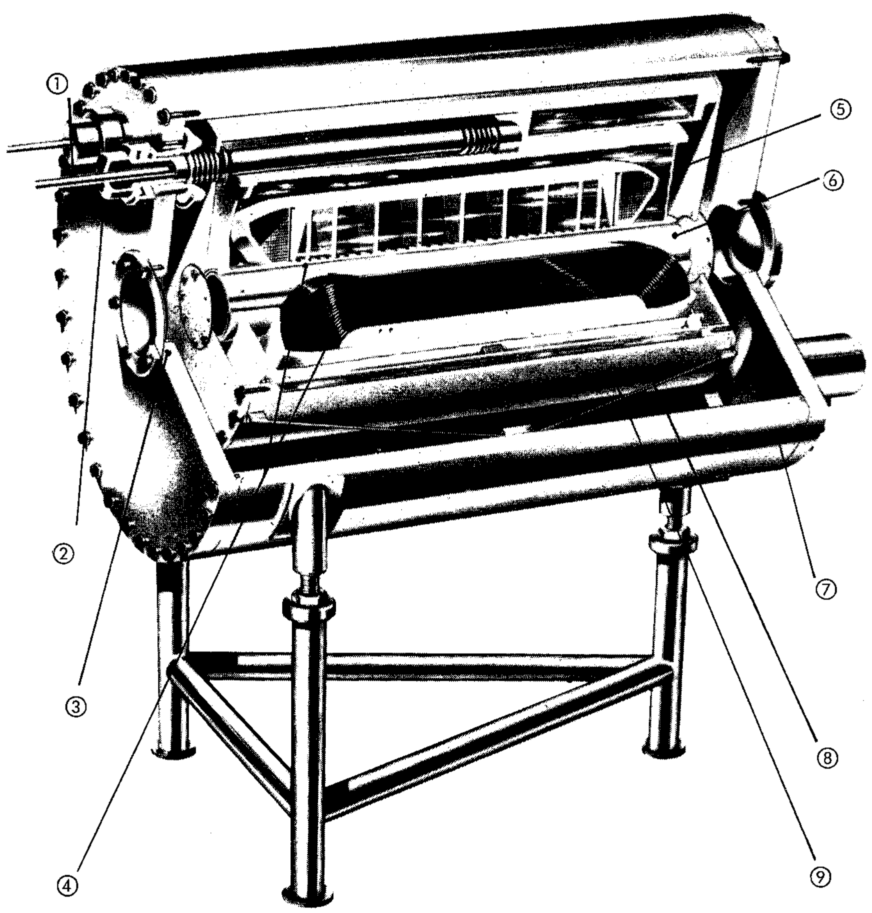
J. Williams), of people from the Culham Laboratory (particularly D. Cornish) and of CERN (T. Vuong-Kha and L. Vuffray in the group led by A. Asner). The aims have been on the one hand to provide industry with experience in superconducting technology and on the other hand to provide CERN with experience in the construction and operation of a superconducting quadrupole lens. The lens is the most powerful of its type to be built so far in Europe.

The design parameters are: cylindrical aperture 75 cm long, 10 cm diameter; magnetic field gradient of at least 5.3 kG/cm with a field level of 45 kG at the coil. This involves passing currents of about 830 A through the superconductor. The composite superconductor, supplied by Imperial Metal Industries, consists of 16 niobium-titanium wires of 0.25 mm diameter embedded in a copper strip 4 × 1.5 mm^2.

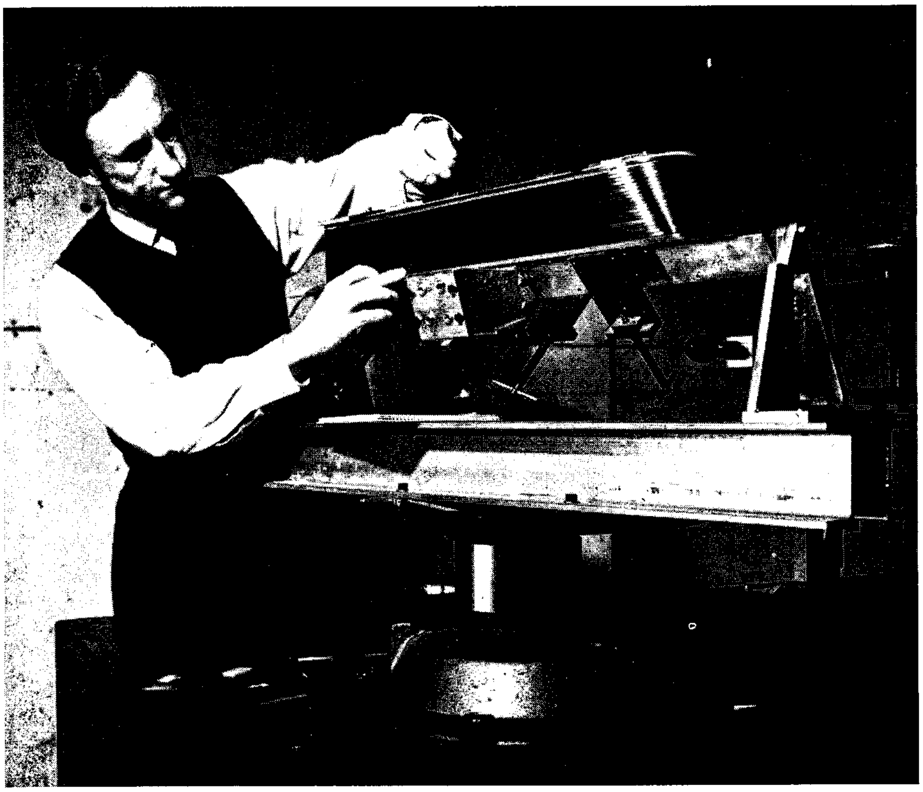
The tests in January on the completed quadrupole in liquid helium reached the design current of 830 A through the superconductor without any 'quenching' occurring. This corresponds to a field gradient in the useful aperture of 5.3 kG/cm and a maximum field at the coil of 45 kG. Power supply imperfections prevented the current being pushed to 900 A to give a gradient of about 6 kG/cm. Previous tests on two single poles have however reached 1000 A through the superconductor without trouble.

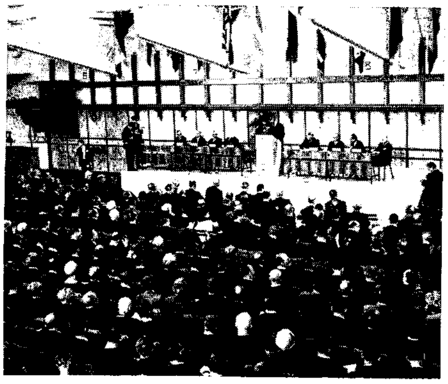
When the quadrupole arrives at CERN there will be an extensive series of magnetic measurements on field gradients, field uniformity, etc... The magnet will be mounted in a cryostat made and tested at CERN.

In the course of construction of the quadrupole problems with insulation were encountered on the third and fourth poles to be wound. The winding configuration was not at all easy to achieve and one advantage of the fine filament, intrinsically stable superconductor, which has been developed since construction of the quadrupole began (see page 48 of this issue), is that it gives a strip of smaller cross-section which is easier to wind. The CERN group is now studying the advantages of beam transport magnets built using intrinsically stable superconductor.



① Helium transfer line
② 1000 A current leads
③ Useful aperture
④ Winding
⑤ Helium Tank
⑥ Liquid helium
⑦ Vacuum tank and (magnetic shield)
⑧ Liquid nitrogen shield
⑨ Liquid nitrogen





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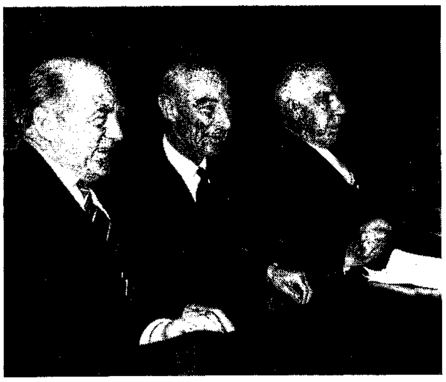

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Ten years ago. Three photographs from the official inauguration of the 28 GeV proton synchrotron on 5 February 1960.

1. The ceremony, held in the South Experimental Hall, was attended by many of the world's leading physicists and by representatives of the governments who had enabled Europe to be first in the field with a powerful new type of accelerator.

2. Three of the famous scientists on the platform — left to right, W. Heisenberg (Nobel prize winner from Federal Republic of Germany), the late J.R. Oppenheimer (leading physicist from USA), and the late N. Bohr (Nobel prize winner from Denmark).

3. Speaking during the ceremony is E.M. McMillan (Nobel prize winner from USA).

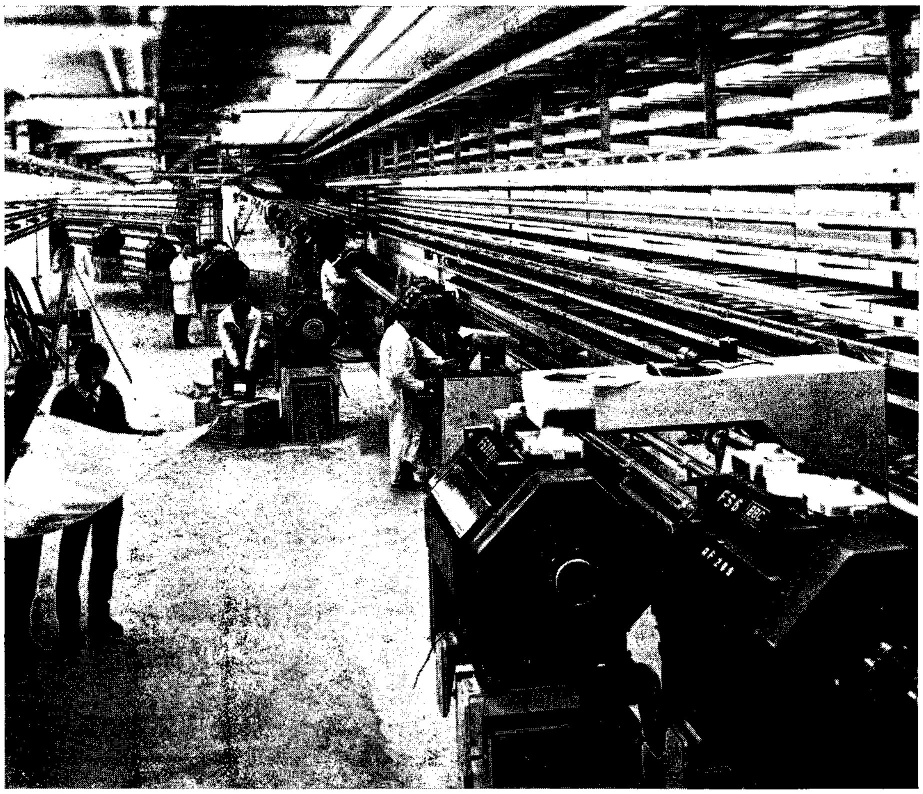
Here are some quotes from these scientists ten years ago which retain much of their value today.
Werner Heisenberg: 'The successful completion of the CERN proton synchrotron is one of the most exciting events in European Science since the last war. This is true first of all from the point of view of scientific interest: the physics of elementary particles is the basis of physics and natural science as a whole, for it enables to explain and understand out of a common basis, the interactions of various forces and the different kinds of matter which can be observed in nature. Moreover, this great and unexpectedly rapid success of the most powerful tool for research on elementary particles now existing in the world, shows how successful European Science can be if the joint effort of many European countries are concentrated on one important aim.'

Robert Oppenheimer: 'We wish you a future of new discovery of increased understanding of nature, as a bright example of that co-operation which is required of us, for our survival and for the flourishing of high culture... We salute the vision and devotion of those who have made possible the proton synchrotron. We recognize not only that it marks a technical achievement of high significance, but also that it is a symbol of the common enterprise of people from many nations to give to all mankind new understanding of the forces that shape our physical environment... May those that work at CERN in the years to come find there, in steadily growing knowledge of the wondrous order of nature and of nature's laws, ever renewed challenge for the questing mind and ever deepening satisfaction for the questing spirit.'

Niels Bohr: 'The main human lesson drawn from investigations of phenomena ever more removed from ordinary experience is the recognition of the inseparability of objective knowledge from our ability to put questions to nature by means of experiments suited to give unambiguous answers. It is therefore imperative that physicists taking part in such inquiry can have the opportunity of getting experience about all aspects of the situation. This would, however, be impossible for scientists from countries with more limited resources, if it were not by means of such cooperative efforts as those we are witnessing in CERN'.

Edwin McMillan: 'What happens in the field of higher energies ? The only way of knowing is to try, and this is what CERN and Brookhaven will do very soon. Now, there are proposals to build machines of still higher energies. And here another question arises: will more and more powerful accelerators supply more and more of the same data on fundamental physics ? In other words, is it worthwhile to supply more of the same ? What will happen up to 30 GeV will give a very good answer to this and will, no doubt, have an influence on future plans for accelerators. Thus, big accelerators like CERN's and Brookhaven's will perform a technical orientation job, besides doing fundamental research in the domain of the elementary particles. Whatever the findings may be, we can be sure of one thing: that high energy phenomena will be thoroughly explored, thanks to the co-operation between the owners of very high energy accelerators.'

Inside the tunnel linking the PS and the ISR during installation of the beam-transfer magnets. In the background can be seen the point where the tunnel forks so that beams can be guided to one storage ring or the other.


CERN/PI 22.1.70

Beam transport from PS to ISR

Installation of all the quadrupoles (90 % of the total) in the accessible sections of the tunnels linking the 28 GeV proton synchrotron with the intersecting storage rings has been completed and bending magnets are now moving in at the rate of 2 or 3 per week.

Protons leaving the PS will travel a distance of 50 m down a common tunnel before meeting a bending magnet which will either divert them down tunnel TT1, when it is powered, or allow them to continue down tunnel TT2, when it is not powered, thus feeding one or other of the storage rings. The total distance between the PS and the ISR is about 500 m and the tunnels are three dimensioned constructions since they climb up to 11.8 m above the height of the PS. TT2 branches just before reaching the ISR so that protons can by-pass the ISR travelling down tunnel TT2a through to the West Experimental Hall. And finally tunnel TT3 links the ISR directly to the West Experimental Hall.

The tunnels TT1 and TT2 will house 96 quadrupoles (manufactured by BBC, Federal Republic of Germany), 58 bending magnets (Alsthom, France), and four large steel septum magnets (Oerlikon, Switzerland) which inject the beam (two for each ring). These various elements have to be aligned to a precision of 0.1 mm with respect to a geodetic point of the PS. The first 50 m of tunnel which is common to both beam channels is now fully equipped (bending magnets, quadrupoles, cables, vacuum chambers, beam observation stations, etc.) and the first experiments taking beam into the tunnel to beam dump D1 are scheduled to begin in April. If the rate of installation is sustained, beams could be taken through to the ISR in September and the first protons could be injected soon afterwards.

The final stage in the equipping of the TT1 and TT2 tunnels will be that of installing the four large steel septum magnets. These magnets, which will bend the beam horizontally, and vertically for injection into the storage ring, will be located at the junction of the beam transfer line with the storage ring. The positioning of these magnets raises a number of problems. Their weight (60 tons) is greater than the capacity of a single travelling crane, and two cranes will have to be coupled together. Their height is within a few centimetres of the maximum height of the crane hooks. A dummy installation will therefore be carried out, inside the tunnel, at the beginning of March, using a full-scale wooden model.

Computers for Omega

The Omega project is to provide a large-scale 'universal' instrument for electronics experiments. It will consist of a huge magnet in which optical spark chambers or wire chambers can be installed to record charged particle tracks, photographically or electronically. The Omega project was described in detail in CERN COURIER, vol. 9, page 31. It is scheduled to come into service about the end of 1971 in the West Experimental Hall near the ISR.

Virtually all of the experiments with Omega will involve the computer-processing of a large amount of data. It was decided, therefore, to provide Omega with its own computer installation, comprising: (1) a small computer for data acquisition and controlling experiments; (2) a larger computer for on-line control of experiments by sampling, data acquisition, off-line processing of data, and final adjustments to programmes.

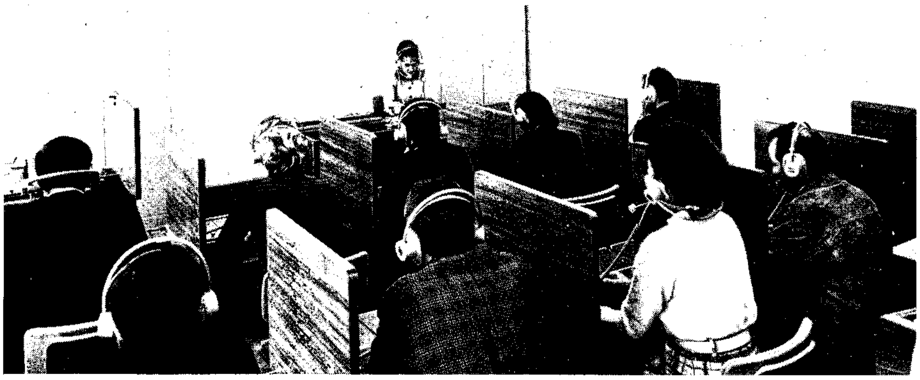
The contract for the small computer was awarded to Schlumberger (France/USA) for an EMR 6130 which came closest to the specifications and offered the highest processing speed. Its main characteristics are a core memory of 24 k words of 16 bits, memory cycling time of 775 ns, typical instruction time of 1.9 μs, three fast input/output channels each able to transmit one million bytes or words per second, peripheral equipment including — typewriter, card reader (200/m), card puncher (200/m), printer (600 to 800 lines/m), disc (2 million bytes), and two magnetic tape units (60 thousand bytes/s).

The contract for the larger computer was awarded to the Compagnie internationale pour l'Informatique (France) for a C11 10070. Its main characteristics are a core memory of 65.5 k words of 32 bits, memory cycling time of 800 ns, typical instruction time of 1.8 μs, three multiplexed input/output channels each able to transmit 0.4 million bytes per second, peripheral equipment including — typewriter, card reader (1200 cards/m), card puncher (300 cards/m), printer (600 to 800 lines/m), three discs (total storage capacity of 18 million bytes), and five magnetic tape units (60 to 120 thousand bytes/s).

The C11 10070 computer which is halfway in scale between the large CERN computers such as the CDC 6600 and the small ones such as the PDP 9, is manufactured and assembled entirely in Europe; it has the same logic as the American XDS Sigma 7 computer, but its circuits and components are different.

Returning to its main functions: The first is control of experiments by sampling. Experiments with Omega will be mainly carried out by groups from European universities and research centres who will process the data on their own computers. In one experiment a very large amount of data will have to be recorded and to avoid the risk of finding, on completion of the experiment, that some of the data is of

The 'language laboratory' in action. The latest audio-visual techniques have recently been incorporated in language courses at CERN.



CERN/PI 283.1.70

poor quality, samples will be taken during the experiment and processed immediately using the on-line computer. The computer must be very flexible, i.e., it should have a large reserve of programmes so that it can deal with all the cases which arise, visual displays for immediate interpretation, and typewriters to be able to interrogate the computer. The experimenters could then intervene in the progress of the experiment.

The second function is to record data when the volume of data exceeds the capacity of the EMR 6130. The third function is to do some data processing. The majority (probably 80 %) of the data will be processed in the universities of the Member States. The remainder will be processed at CERN mainly using one of the large central computers. As the C11 10070 will be free for part of the time (during the dismantling and installation of experiments) it could be used for this purpose, especially since the sampling control programmes will, in some ways, be identical to the processing programmes.

The fourth function concerns experiments with optical spark chambers. The task will be to elaborate methods and programmes for the automatic recognition (i.e. without human aid) of events appearing on spark chamber photographs; the analysis and measurement will be done by a flying spot digitizer known as the Omega HPD (a modified version of HPD 1). This work will be simplified by the peripheral equipment of the C11 10070 and by the display screens in particular.

When a major project is being planned, the choice of computers is rarely made at the outset. For Omega the question of the computers was raised when overall project concepts were under discussion and the result is that the computers will be better suited to the machine, and that there will be a considerable saving of time.

The general purpose magnet system and detectors to be installed at interaction region I 4 of the ISR (see CERN COURIER, vol. 9, page 102) has many similarities with Omega. The detectors are likely to be predominantly optical and wire chambers. For this reason it has been decided to use the same computer system for the ISR experiments at this interaction region as for Omega. Another of the smaller computers (EMR 6130) will be bought for the ISR system, but the C11 10070 will be common to both.

Undermining the Tower of Babel

A 'language laboratory' has been in use at CERN for just over a month. It is designed to cater for those who wish to learn English or French or Russian rapidly and it makes full use of the very latest audio-visual methods. Such methods give a facility, particularly in the field of pronunciation, which was almost unthinkable with more conventional systems.

Conventional language courses have been available at CERN, under the auspices of the Staff Association, since 1957. Nearly 350 pupils took these courses in 1969, and they are continuing this year. As soon as the 'laboratory' project became known, however, there was a rush to join the new courses, and there are now over 400 students enrolled in the audio-visual courses.

At present the courses, with the exception of French, last three months and consist of two 1 1/4 hour lessons a week. During the first lesson, the pupils are shown slides or films with a recorded dialogue — this is known as the 'receptive' phase. During the second lesson, the pupils move to the laboratory proper, in which there are sixteen booths facing the teacher. Each pupil has his own tape recorder on which he can listen to the course through earphones, repeat sentences and correct his own pronunciation by comparison with the 'master'. The teacher can speak to one or several pupils via the earphones as he wishes in order to give instructions or make corrections.

For the time being, the audio-visual courses are intended solely for beginners and replace the first year of the conventional courses. However, it is intended eventually to integrate the two types of teaching progressively. The first two years of instruction will become mainly audio-visual, while the third will continue to concentrate on the traditional teaching of the written language (grammar, etc.). Finally, for advanced pupils it is proposed to form a 'club', where the courses will be replaced by discussions, explanations and play-readings in which the pupils will actively assist the teacher.

Courses are conducted every day between the hours of 8.30 a.m. and 7.45 p.m.; thus, they can be followed during working hours. They are intended for people working at CERN (staff members, Fellows, Visitors, etc.) and any member of their families over sixteen years of age. This year, the subscription for a three-months course is 50 Swiss francs and the next series of courses will begin in March 1970. In response to a large number of requests, it is intended to start German courses as well.

This process of 'de-Babelization' is all the more welcome at CERN since the courses are almost completely self-financed. A Language Course Secretariat is part of the Education Services section of the Personnel Division.

HPDs and bubble chamber production

The Hough-Powell Device for digitizing film (enabling the rapid automatic analysis of photographs from bubble chambers or spark chambers) originated at CERN in 1959-60, and there are now some thirty of these machines in operation or being installed in various parts of the world. The basic principle is that a mechanically-generated spot of light sweeps across the film at high speed in a television-type scan, and the coordinates of any opacity (bubble, arm of a fiducial mark, etc.) are generated and transmitted to a control computer (at CERN, the central computing installation). Measuring rates of 50 to 120 events per hour are now typical, and HPD precision has become the standard against which other techniques are compared. CERN has played a leading role in developing the machine and the associated chain of computer programs. Production measurement for physics started in 1964 (with a spark chamber experiment) and the overall system has been described before in CERN COURIER vol. 6, page 7, vol. 8, page 79, see also vol. 7, pages 178-179).

The 'Full Guidance' System

Like the bubble chamber, the HPD is not selective. The complete picture (in digitized form) is sent to the computer, and it is up to the subsequent programs to perform the analysis. In the Full Guidance system (which has been the production system so far) a human operator has scanned the film previously for interesting events in the conventional way, and, in addition, for each event has 'predigitized' (with 20 to 30 μ accuracy in the film plane) three points per track, which permit a mask ('roads') to be placed over the HPD digitizings in the computer. A filtering program finds and follows each track in its road, and groups the digitizings to form an average point every 2 cm in space.

This system entered production in 1965 on HPD 1 (the first production HPD in Europe) which is slower and less precise than the later versions. HPD 1 has been used extensively for spark chamber film measurement, and to date has measured about 1 000 000 such events, plus, by the Full Guidance system, some 115 000 bubble chamber events (from the 81 cm hydrogen chamber). HPD 1 is now being upgraded to HPD 2 precision, primarily to measure film from Omega (see page 45). HPD 2 entered production in 1967, and has been used exclusively for bubble chamber film measurement. So far, it has measured some 300 000 events (from the 2 m hydrogen chamber); in 1969, 173 000 events were measured, this being a little over half the capacity of the machine, and half the CERN total for the year. (In the first three months of 1969, HPD 2 measured 70 000 events in full-time operation. Since then, the HPD has been 'scanning-limited' as explained later.) Figures given below refer to HPD 2.

The measuring rate is a function of the event density and type, and an average figure is 75 events per hour. About ten experiments of varied type are now completed or in progress, and the performance is rather satisfactory. Important features are the precision of measuring (accuracy and reproducibility are at the 1 μ level and the film plane error on tracks reconstructed in space is typically 3 to 5 μ) and the high quality of the automatic measurement of ionization (bubble density). This enables pions and protons to be resolved to around 1.6 GeV/c, and pions and kaons to 0.8 GeV/c or better. Scan table work in checking ionization is reduced by almost an order of magnitude, and typically two thirds of the events go on the Data Summary Tape automatically. Since the system entered production, considerable hardware and software improvement has occurred. The system has now reached the stage where operation has been put on a maintenance basis, and responsibility for it has been transferred from the developers in the Data Handling Division, to the users in the Track Chambers Division.

The 'Minimum Guidance' System

A problem with the Full Guidance system is the mismatch between the speed at which the HPD operates and the speed at which film can be prepared for the HPD (5 to 15 events per hour per table for combined scanning and predigitizing, the figure being dependent on the experiment). A more elegant solution than hiring more scanners is given by the Minimum Guidance system, which has been under development at CERN since 1966. In this, the event preparation rate is doubled by requiring the scanner to supply only the topology and vertex measurements, the filtering program having no further assistance. This system, which is being adopted by several other laboratories, has already been used at CERN for a small experiment, and is now being used for its first major experiment. Minimum Guidance will be the subject of a forthcoming article.

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A general view of the HPD 2 room. In normal operation one computer operator supervises the measurements.

Around the Laboratories

RUTHERFORD

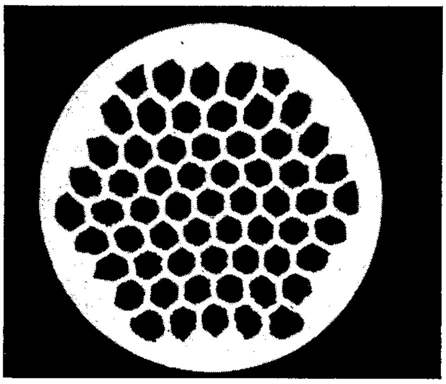
A few topics from the Rutherford High Energy Laboratory where research is centred on the use of the 7 GeV proton synchrotron, Nimrod.

Major effort on superconductivity

As reported several times before (e.g. CERN COURIER vol. 8, page 186, vol. 9, page 261), important contributions to the theory and practice of superconducting magnets have come from the Rutherford Laboratory. To recap — the group of P.F. Smith has shown how to produce superconductor which is 'intrinsically stable', eliminating the problem of flux jumps producing heat and destroying the superconducting property. The solution is to have a conductor consisting of very fine filaments of superconductor (less than 0.005 cm diameter) embedded in a normal metal (usually copper) and twisted (typically with a pitch of a few centimetres) to reduce circulation currents between the filaments. Such a conductor is much more compact than the previous types which were not intrinsically stable, required a large proportion of normal metal, and were limited to current densities in the region of 10^3 to 10^4 A/cm^2, besides being much more difficult to wind into coils and to cool to superconducting temperatures. The intrinsically stable conductor is capable of overall current densities approaching 5×10^4 A/cm^2 and gives compact coils with much simpler cooling systems.

Development work towards applying fine filamentary conductors to d.c. magnets, such as would be used in polarized targets and beam transport magnets, is well advanced. Emphasis in the research has now turned to a.c. magnets, such as would be used in a synchrotron ring. Again, the fine filament technique is applicable to achieve stability but account has to be taken of a.c. losses producing heat on each cycle. For fast rise-times (of the order of a second) it has proved expedient to have a resistive barrier between the superconductor and the copper, which is too ready to pass current, thus avoiding the need for a very small pitch when the filaments are twisted. The conductor then becomes a three-part composite — fine filaments of superconductor (with smaller diameters than for d.c. applications — about 0.001 cm) coated with cupro-nickel and embedded in pure copper (with a total diameter of about 0.05 cm). For slower rise-times (say about 5 s) a two-part composite with a higher resistivity copper should be sufficient. The production of such conductors (as of the others used in the Laboratory's programme) has been done in association with the research department of Imperial Metals Industries Ltd. There have been successful tests of small a.c. coils pulsing at a rate of once per two seconds.

The rest of this information covers the programme lined up for the next few years for a thorough investigation of the application of superconducting magnets in a synchrotron ring. Research at the Laboratory has previously been concentrated in a comparatively small group but a major effort is now being turned on in the Applied Physics Division led by L.C.W. Hobbis, to confront all the problems of integrating superconducting magnets into an operating machine. Machine aspects are being covered by N.M. King and D.A. Grey, magnet studies are continuing in the group of P.F. Smith under J.D. Lawson, and engineering support is under J. Marsh, H. Ashburn and B. Colyer. To give a practical aim under which to organize the research, work is directed towards producing a design for a superconducting conversion of Nimrod. Tentative parameters for such a conversion are to achieve an energy of 25 GeV with a beam intensity up to 10^{13} protons per pulse with a ring diameter set by the existing Nimrod hall as about 50 m. It will



A cross-section of composite superconductor which is intrinsically stable. It consists of 61 strands of niobium-titanium embedded in cupro-nickel. The overall diameter is 0.05 cm.

obviously be several years before anything like a detailed machine design can be drawn up. Nevertheless, it is generally accepted that any extension of the synchrotron beyond energies of a few hundreds of GeV will call for the use of superconducting magnets, and that, before such a machine could be confidently undertaken, there should be a sizable pilot project. Conversion of an existing machine is likely to be the most economical way of carrying out a pilot project. Also, if the ultimate goal is a very high energy European machine, then such a conversion, undertaken at one or other existing 'national' Laboratory, might qualify for consideration as a European project.

Basic research on the production of superconductors will continue with a view to improving the current density and to minimizing the cost of the conductor. There is also interest in the possibility of producing filamentary conductors using niobium tin alloy. (Niobium tin can retain its superconducting property at much higher fields and temperatures than niobium titanium but is brittle and cannot be drawn into wire.)

A series of coils of increasing sophistication will be built to carry further the investigation of d.c. and pulsed performance and to tackle mechanical problems. Most coils have up to now been potted in wax so as to recover the superconductor easily — new coils will have different cables and insulations.

A d.c. quadrupole (about 40 cm long with a 12 cm aperture to give about 40 kG peak) will be constructed by industry to develop their ability to produce operational magnets. Pulsed magnet dipoles will be built, beginning with a coil about 30 cm long with a 4 cm aperture to give a field of 50 to 60 kG and moving to a first full-aperture prototype synchrotron magnet with a 12 cm aperture and a field above 50 kG. The aim is to have this prototype operational inside a vertical cryostat by the end of 1970.

Questions remain to be answered as to whether superconducting magnets can give the accurate magnetic fields that are required in a synchrotron. Studies will cover optimum coil configuration; accuracy to which coils can be wound and potted; retention of accuracy when they are cooled to superconducting temperatures; accuracy of field configuration; effects of internal friction and mechanical heating on the superconducting property, etc. Much of this work will involve materials research to satisfy considerations of stress, mechanical and thermal cycling, heat transfer, and irradiation. The magnets have also to be insulated from room temperature, while being integrated into some type of cryogenic system.

On the cryogenic side, preference is at the moment for the use of supercritical helium. Test systems will be built and used with the magnets which are being produced to get some experience under operational conditions. A cryostat is scheduled to be ready by June.

The power supply for the magnets depends upon decisions on current, voltage and rise-time parameters. Some superconducting switching arrangement will be needed to introduce a flat top. There will also be tests of a new idea for superconductive energy storage which might prove the best solution for a superconducting synchrotron.

For the synchrotron itself, possible magnet lattices are being worked out including two ejection systems. Thought is being given to the problem of positioning the magnets (inside their cryostats) accurately around the ring, to optimum r.f. systems, to the possible need of iron shielding to avoid the effects of stray fields, etc.

There are obviously many problems to be solved and several fundamental questions need answers before the stage is reached where construction of a superconducting synchrotron could begin. Nevertheless the technological advances of the past few years, many of them emerging from the Rutherford Laboratory, are very encouraging. Pursuing this research could result in a command over superconductivity which will lead to it assuming an important place in everyday life, quite apart from its impact on the synchrotron.

Computer controlled ejected beam

A third ejected proton beam, X3, has been commissioned on Nimrod to feed the new Experimental Hall 3 (4300 m^2). A control computer was used in setting up the beam and now serves to monitor and control the ejection system and beam-line throughout machine operation. X3 currently serves two slow-spill beams — a pion beam (π 8) and a kaon beam (K 15) and will later be extended to a further target downstream to yield additional slow-spill beams.

The ejection system is of the 'energy-loss' type and consists of a Piccioni target and two plunged magnets — an ejection magnet and a quadrupole to give achromatic correction. (These units are 90° around the ring from the equivalent units which serve both the previously existing ejected beams.)

The X3 beam emerges from Nimrod diverging in both horizontal and vertical planes and a quadrupole multiplet is positioned immediately outside the machine to produce a parallel beam which then traverses about 50 m of drift space. A further quadrupole multiplet focuses the beam onto the target.

The beam was commissioned, and is now monitored and controlled, using a PDP-8 computer in the Nimrod Main Control Room. A STAR data-link system is used with special interfaces. The ejected beam intensity is measured by a secondary emission chamber (SEC) involving aluminized milar disks. Absolute measurements are obtained by comparison with aluminium foils exposed to a known flux. In setting up the beam, the computer can compare the ejected beam with the circulating beam and can select magnet currents in steps for all the components of the ejection and beam transport system until an optimum has been achieved. During operation the computer can warn when settings drift outside prescribed limits, and parameters can be changed via the computer. There is automatic print out and graph-plotting of selected magnet currents, collimator settings, etc. and important data is automatically collected.

A typical value for the ejected beam intensity is 5×10^{11} protons per pulse with a total beam cross-section at the target of 4×4 mm^2. This represents about 30 % ejection efficiency (Nimrod being a constant gradient machine).

Computer control of X3 has been so

reliable and efficient that work is proceeding to bring the other two ejected beams into the same system. The experience has been so fruitful that other candidates for computer control, such as a bubble chamber beam and operation of the 1.5 m hydrogen chamber, are likely to be tackled in the future.

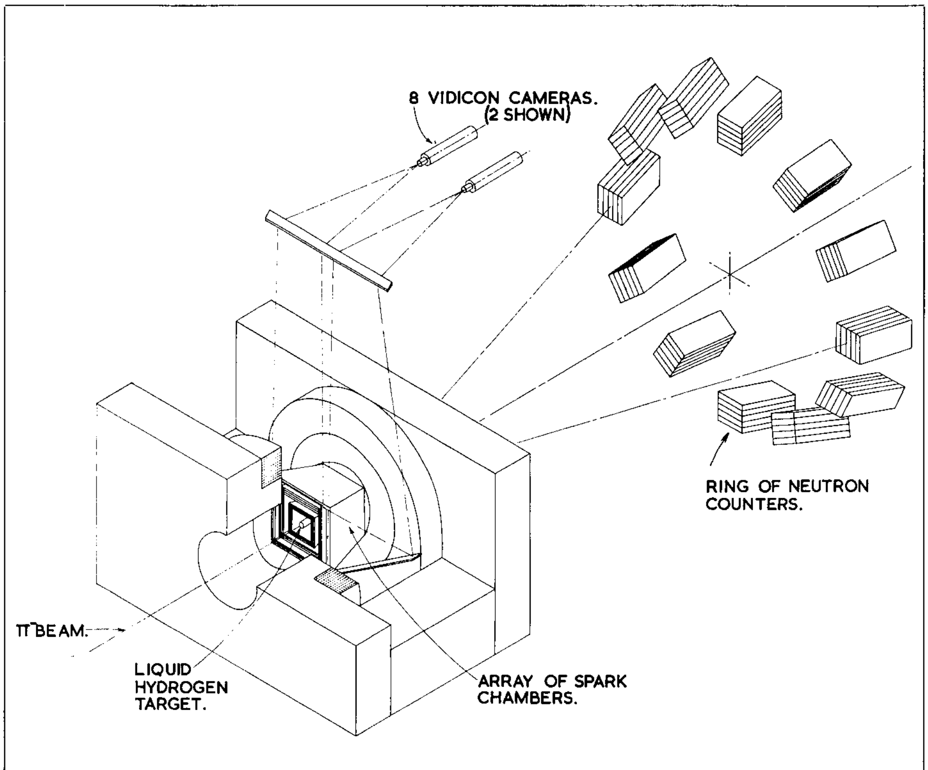
Further developments on ejection planned for this year are the installation of a 'thin' septum ejection magnet and resonant ejection. In the existing energy-loss systems, target thicknesses of about 2 cm of beryllium are needed so that the protons lose enough energy on passing through the target to take their subsequent trajectories into the apertures of the quadrupole and the ejection magnet, jumping across septa of 8 cm and 6 cm respectively. The resulting spread in energies gives a loss of about 10 % on each septum. A new ejection magnet with a 1 cm septum is to be installed which will enable the target thickness to be reduced somewhat, with the target repositioned, and dispensing with the quadrupole. A resonant ejection system has also been designed and some preliminary tests in Nimrod gave results remarkably close to the theoretical prediction.

Preliminary commissioning tests were carried out during the last week of January on the thin-septum system and results were extremely encouraging: a conservative estimate is that 9×10^{11} protons per pulse were delivered at the external target within a 1.0 cm diameter spot. This corresponds to about 45 % extraction efficiency, a factor 1.5 greater than the normal X3 system. To capture the ejected beam, two specially designed 'Header-tank quadrupoles', XHQ2 and XHQ3, are required, located inside the Nimrod vacuum header vessel. For the recent tests, only XHQ2 was installed and a further increase of efficiency (to 60 % or more) is anticipated when XHQ3 arrives later this year. It is hoped to try an improved version of the ejection magnet before the middle of 1970.

PLA closed down

The 50 MeV Proton Linear Accelerator, PLA, was closed down on 3 October 1969. In its lifetime (it came into operation for physics on 20 April 1960) it yielded 44 000 hours of useful beam for experiments out of 53 000 hours scheduled — an overall operating efficiency of 83 % (it was over 90 % in the last years of its life). The experimental programme concentrated on several topics in nuclear physics and involved about fifty research scientists, predominantly in teams from UK Universities, at any one time. Nearly forty Ph.D.s have been awarded for theses based on work at the PLA and several more theses are in preparation. About 140 papers appeared in the technical press from PLA research.

The machine had three linac tanks (taking protons to energies of 10, 30 and finally 50 MeV) of the Alvarez type with grid focusing in the first tank (which severely limited peak intensity) and quadrupole focusing in the others. The 50 MeV beam intensity reached 5 μA reliably with an energy spread of better than 50 keV and a pulse rate of 50 pulses per second. Two special facilities had a considerable impact on the fruitfulness of the experi-



One of the experiments drawing its particles from the new ejected proton beam, X3, is a search for charge symmetry violation in the electromagnetic interaction which hopes to settle definitively the controversy of the past few years. In 1966 a bubble chamber experiment at Brookhaven indicated a breakdown of charge symmetry in the decay of the eta meson into three pions on the basis of 1441 events observed. A CERN counter experiment with 10 600 events refuted this conclusion. A further experiment at Brookhaven with 40 000 events gave an asymmetry but not strongly enough to be convincing. The Rutherford experiment intends to amass 400 000 events and solve the question once and for all.

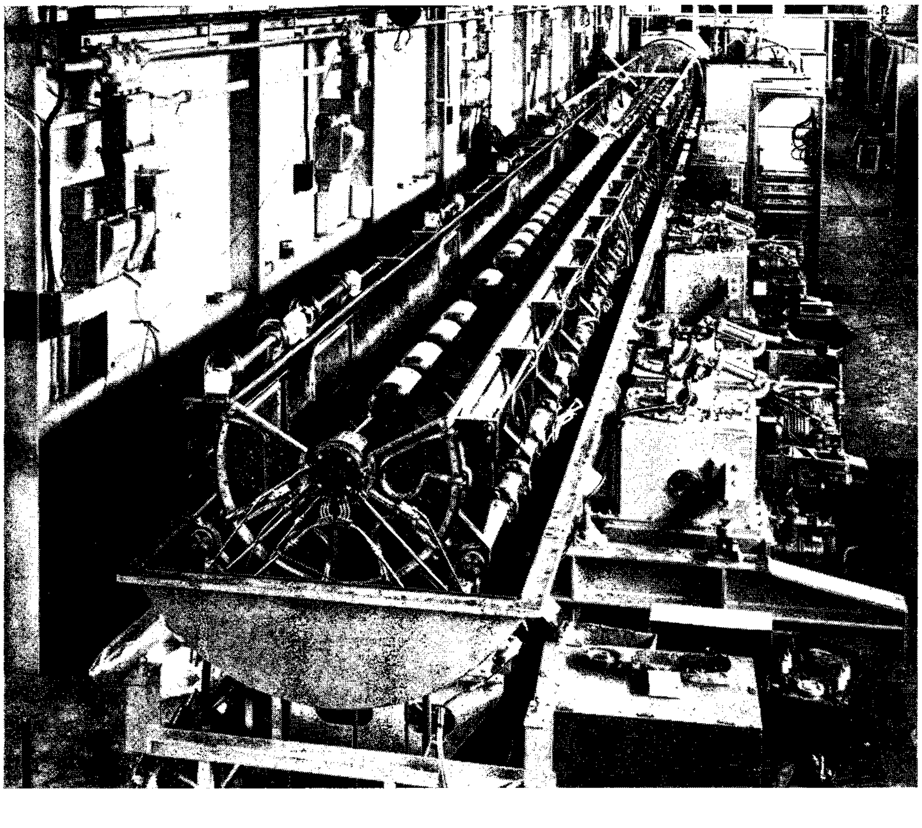
A schematic layout of their experiment is shown in the diagram. A negative pion beam is directed onto a hydrogen target surrounded by a spark chamber array in a magnetic field. Eta mesons will be identified by observing the neutron produced at the same time using a ring of counters. The eta spectrum has been clearly observed in preliminary runs. (An IBM 1130 is on-line to the experiment and final analysis is done on the Laboratory IBM 360/75.) A videcon system looks at the spark chambers where charged particles from the decay of the eta will be recorded. It is the observation of these charged particles which will be used to check charge symmetry.

mental programme. The first was a polarized proton source which could give proton beams with 60 % polarization and an intensity of about 2×10^9 protons per second (compared with 30 % and 10^7 when it first came into operation in 1961). This was one of the most powerful polarized beams available anywhere and it was used for about 40 % of the programme. The second was a time of flight technique which used the bunch structure of the beam within each pulse (proton bursts of 0.5 ns every 5 ns) to give very precise time fixes in the measurement of neutron energy and in particle identification.

A double-focusing spectrometer magnet was one of the major items of experimental equipment, being used for about 40 % of the experiments in the last years of the machine's life. The spectrometer measured particle energies with a resolution of 50 keV and was used to measure the spectra of protons (elastically and inelastically scattered) and deuterons, tritons and helium — 3 particles from nuclear reactions.

Some of the main topics of the research programme were the study of polarization phenomena in proton scattering and reactions, and the study of proton scattering by nuclei for analysis by the optical model. The PLA contributed much to the assembly of the consistent data on proton scattering, with several series of isotopes studied in great detail. It was this data which led to the recent refinement of the optical model.

Advances in the technology of other accelerators capable of intermediate energies appropriate for nuclear physics research, such as the tandem Van de Graaff and the cyclotron, put the proton linear accelerator at a disadvantage in terms of flexibility as a research tool. Some of the latest machines can give variable energy output, can accelerate many types of particle and can give beams with very small energy spread. The Rutherford PLA has therefore followed its twin from Minnesota into retirement. (The 68 MeV PLA closed down in January 1969 — see CERN COURIER vol. 9, page 15.)



A view from the output end of the 50 MeV proton linear accelerator, PLA, at the Rutherford Laboratory which has now been closed down. This photograph was taken in 1959 during construction and shows tanks 2 and 3 with the vacuum lids removed while installation of drift tubes in tank 3 was proceeding.

A new nuclear structure facility for the UK is now under study.

BERKELEY

Latest ERA research

The latest series of experiments on the Electron Ring Accelerator at Berkeley were reported by G. Lambertson visiting CERN early in February. (For the story so far, see CERN COURIER vol. 8, page 28, vol. 9, pages 40 and 261.) In a second run with Compressor 3 (the third of the series of units where the formation of electron rings has been studied) fed by the Astron electron accelerator at Livermore, electron rings were again produced but it was not possible, because of phenomena which are not yet well understood, to produce them with the parameters necessary for acceleration out of the compressor along a steadily decreasing magnetic field.

The minor radius of the electron rings was observed to change considerably with the intensity of the injected electron beam. This was much more marked than in the previous experiments and the number of electrons which could be captured in a ring was a factor of ten down on what had been achieved before. A variety of probes all revealed the same effect and it is not clear whether it was due to a growth of momentum spread or of the amplitude of the betatron oscillations of the orbiting electrons. It is likely that both phenomena were present — single particle effects leading to high betatron amplitudes, collective effects leading to longitudinal instability (bunching of the particles around the ring) occurring very early in the injection cycle. This could be the 'negative mass instability' which can occur in a beam with a momentum spread below several percent and it is known that the beam from the Astron injector has a spread of less than 0.1 %.

Attempts were made, nevertheless, to move the compressed rings out of the compressor down the solenoid field. The extraction cycle was successfully carried out and the rings moved as expected. They were not retained during acceleration which was no surprise since the compressed rings were known to have

Photographs taken using the Bonn Cherenkov counter during tests at CERN.
1. Light spots recorded from the passage of 100 pions through the chamber.
2. Light spots recorded from the passage of a single pion through the chamber (in between the two outermost circles — the circles are used for calibration, the diameter corresponds to a Cherenkov angle of 12.5 mrad).
3. Light spots recorded from all pions (about 10 000) passing through a collimator 1×1 cm² during a pulse of the proton synchrotron, the image intensifier being left open (not triggered) during the pulse.
(Photos Bonn)

parameters outside those needed to retain ring stability.

The next series of experiments awaits the completion of the new electron injector which will be exclusively for ERA research. (The previous experiments have been fitted into the programme of experiments on the Astron). Major parameters of the new injector are — injected beam current over 500 A, pulse repetition rate 1 to 10 Hz, pulse length 35 ns, emittance less than 0.2 cm rad. The energy is intended ultimately to reach 4 MeV but only nine of sixteen r.f. modules can be installed initially for lack of funds, which limits the energy to 2.25 MeV. Like all other programmes connected with high energy physics in the USA, the ERA research is suffering from budget restrictions in the present fiscal year. It shares, however, with the construction of the 200 GeV accelerator at Batavia — though on a much smaller scale — the distinction of being a project which has received additional money from the USA Atomic Energy Commission and much verbal encouragement.

Construction of the injector building is well advanced and it is hoped to have the injector assembled in March. When the experimental programme is no longer restricted on time of access to an injector, really thorough research on electron ring accelerators will open up at Berkeley.

BONN

High resolution Cherenkov counter

A Cherenkov counter capable of very high particle velocity resolution has been developed by R. Giese and G. Schuster at the Physikalisches Institut of the University of Bonn. It has been tested on a 16 GeV/c negative pion beam at CERN and has given a resolution, $\Delta\beta/\beta$, of 6×10^{-7}.

The Cherenkov counter measures charged particle velocity by observing the light emitted when the velocity of the particle in the chamber exceeds the local velocity of light. A 'bow wave' of light is emitted (similar to the shock waves emitted in air by an object travelling faster than sound) in the forward direction at an angle to the particle path which depends on the particle speed and the refractive index of the material in the chamber. This angle can be measured (and thus the particle velocity determined) by intercepting the cone of light usually with photomultiplier tubes.

The Bonn Cherenkov chamber uses a spherical mirror (of focal length 10 m) to focus the light to a ring image of about 100 mm diameter. A photographic lens forms an image of the ring on the photocathode of an image intensifier which provides very high amplification. There is enough amplification to record, with a camera, the light spots arising from single photoelectrons on its output phosphor. In this way the Cherenkov light from the passage of a single charged particle in a chamber has been observed for the first time.

In the tests at CERN a coincidence signal from scintillation counters placed in front of and behind the Cherenkov chamber was used to trigger the image intensifier (with a time resolution of 25 µs) when a charged particle passed through. High accuracy in determining the pion velocities was obtained using a small Cherenkov angle. The disadvantage of low light intensity can be compensated by the choice of a chamber of adequate length and a chamber length of 10 m gave a sufficient intensity in the tests. Helium was used in the chamber as the best medium with regard to dispersion and multiple scattering.

The photographs show the observations for three widely different conditions. About 5 % of the pictures arising from single pions passing through the chamber had four or more light spots with a suitable azimuthal distribution for measurement. The velocity resolution for 16 GeV/c pions was $\Delta\beta/\beta = 6\times10^{-7}$ as stated above and the technique could be extended to very high energy particles — in the hundreds of GeV range.

USA

Recommended future programme

Following on our report in the last issue (page 16) of the severe cut back at the Princeton Pennsylvania Accelerator Laboratory and the note on ERA budgets above, it is worth listing the major recommendations concerning the future programme for high energy physics in the USA put forward by HEPAP (the High Energy Physics Advisory Panel) chaired by Professor V.F. Weisskopf.

The recommendations began from a situation where the major established Laboratories (Argonne, Berkeley, Brookhaven, Cambridge, Princeton, Stanford) had been held at constant budgets for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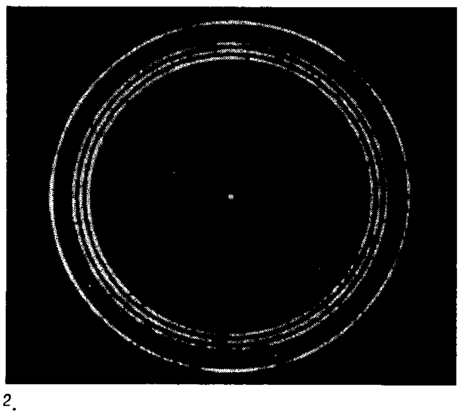
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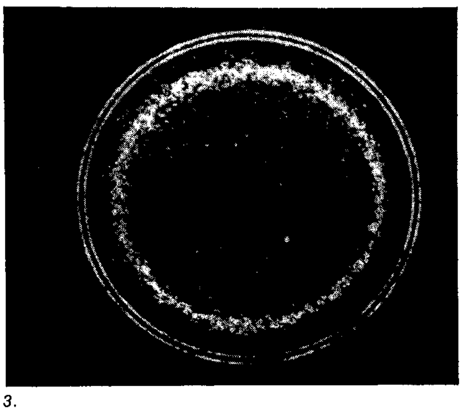

3.

several years, which has restricted development in a way that, it is felt, has been reflected in the contributions from the USA to high energy physics research. (In 1968, expenditure on high energy physics in Europe exceeded that in the USA for the first time.) Because of this, the first recommendation was that the annual budgets of the existing Laboratories and of research groups at Universities should be increased as soon as possible by 10 to 15 % per year for a period of a few years in order to avoid further deterioration in research capabilities and to extract a better return from investments already committed. The average recommended increase over ten years is 8 % per year. Emphasis was put on equipment budgets to meet the needs of existing experimental programmes, research facilities under construction and new devices, and on funding a greater number of new University groups.

For the immediate future it was recommended that construction of the 200 GeV accelerator at Batavia should not be constrained for lack of funding and that future projections should include provision to increase the accelerator's energy to its maximum capability (400 GeV or more) when it has operated successfully at 200 GeV and after some experience has been acquired in research at this energy.

The USA is particularly weak in storage ring facilities and vigorous support of the Cambridge 'by-pass' project for electron-positron colliding beam physics was urged, with construction of the Stanford electron-positron storage ring project (see CERN COURIER vol. 9, page 271) in addition at the earliest possible date.

Funds were recommended for the construction of a new, large cryogenic bubble chamber suitable for neutrino physics at Batavia (a 25 foot bubble chamber is under consideration as a Brookhaven-Batavia project). The 12 foot bubble chamber now being commissioned at Argonne was also regarded as a suitable candidate for moving to Batavia.

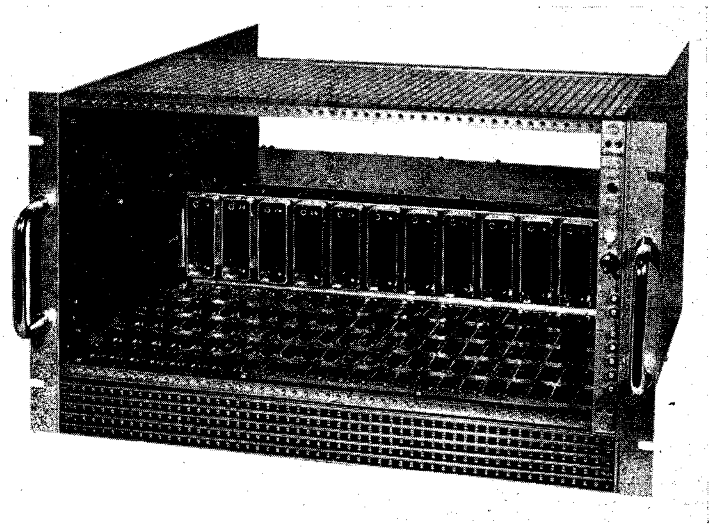
For cosmic ray physics, an increase of a factor of two in the budget was recommended, which would have a very small effect on the overall budget, though no pressing need was seen for a national cosmic ray Laboratory. International co-operation continued to be encouraged, high energy physics to be pursued as an international science with free communication among all nations. In particular, negotiations concerning participation in the research programme at the 76 GeV proton synchrotron at Serpukhov were singled out for special effort.

For the longer term future, a 2000 GeV accelerator was projected with the possibility of this being an international collaboration. In this direction, continued attention to new technologies such as the electron ring accelerator, superconducting or cryogenic synchrotrons, etc., was urged.

C7 ALN 13

CHÂSSIS ALIMENTATION NIM

- **Ce châssis pour tiroirs modulaires est destiné à l'alimentation des éléments fonctionnels normalisés NIM-TID 20 893.**
- **Permet le montage de 12 tiroirs**
- **Utilise l'alimentation P 7 ALN 10 délivrant:**
  + & — 24 V 3 A
  + & — 12 V 3 A
  + & — 6 V 6 A
  + 200 V 0,1 A
  117 V 50 Hz 0,5 A
  Puissance utile 200 watts
- **Trois ventilateurs pour le refroidissement des tiroirs**
- **Brochage du connecteur: 42 contacts.**



+ 200 V	+ 24 V	— 24 V	+ 12 V	— 12 V	+ 6 V	— 6 V	117 V alt.	0 V	Masse spéc.
8	28	29	16	17	10	11	33 et 41	34	42

CARACTÉRISTIQUES PROVISOIRES

Tension de sortie	± 24 V	± 12 V	± 6 V	+ 200 V
Plage de sortie	± 5 %	± 5 %	+5 % à —18 %	± 10 %
Régulation pour 100 % de variation de charge et les variations du réseau (+ 10 % à — 12 %)	$\pm 5.10^{-4}$	$\pm 5.10^{-4}$	$\pm 10^{-3}$	$\pm 5.10^{-2}$
Coefficient de température de 0 °C à +60 °C	2.10^{-4}/°C			
Dérive à long terme à charge constante après 24 h et sur 6 mois	$\pm 3.10^{-3}$			
Ondulation résiduelle et bruit crête à crête	⩽ 2 mV	⩽ 2 mV	⩽ 3 mV	5 mV
Réponse transitoire (overshoot et undershoot inférieurs à 10 %)	⩽ 20 µs			
Impédance de sortie dynamique jusqu'à 100 kHz	0,3 Ω	0,3 Ω	0,15 Ω	
Sécurité individuelle par limitation du courant réglé à	3,3 A	3,3 A	6,6 A	fusible
Plage de température	0 °C à +50 °C sans derating de +50 °C à +60 °C avec derating de 3 %/°C			
Protection thermique	2 vigithermes: > 50 °C Lampe orange > 60 °C Lampe rouge et coupure de l'Alimentation			
Visualisation d'une surcharge	un voyant par tension			
Réseau	220 V 50 Hz (possibilité 117 V)			
Dimensions	483 × 525 × 6u			

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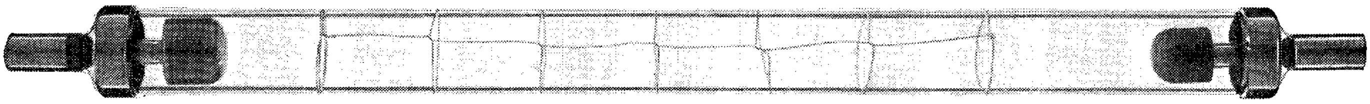

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XL615/9/4	1500	102	9.0	2.5	400	1 per 30 sec.	12–16
XL615/10/5.5	3500	140	10.0	2.5	400	1 per 30 sec.	16–20
XL615/10/6.5	5000	165	10.0	2.5	800	1 per 2 min.	20–25
XL615/13/6.5	10000	165	13.0	2.5	800	1 per 2 min.	25

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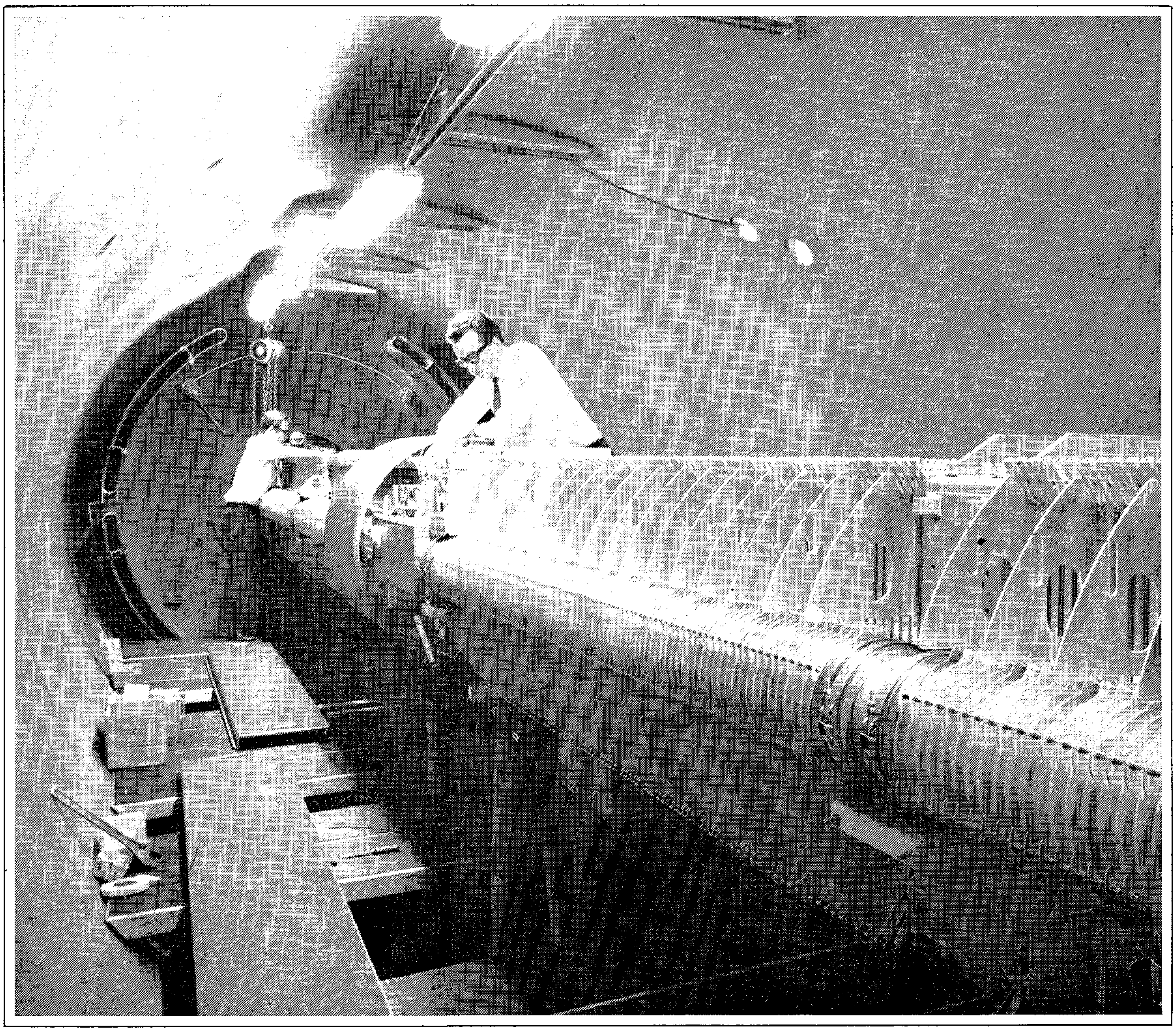

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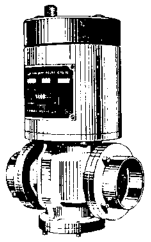
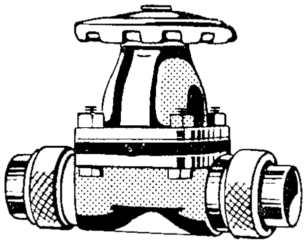
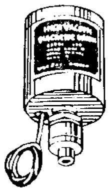


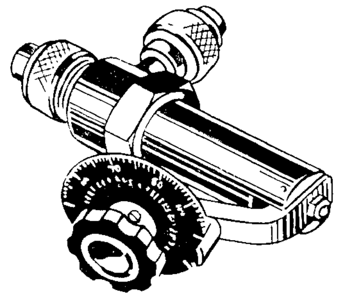
SOLENOID



MANUAL



SOLENOID AIR ADMITTANCE



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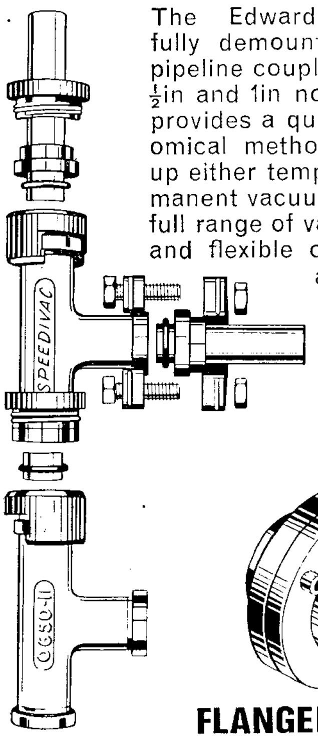
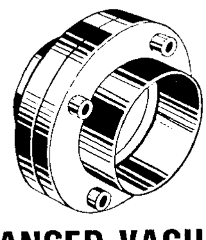


PIPELINE COUPLING SYSTEM



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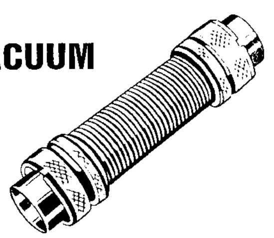

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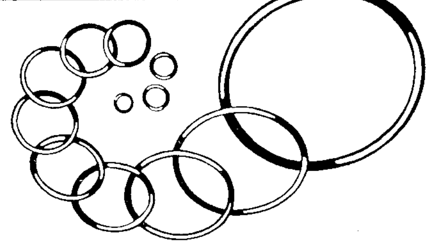

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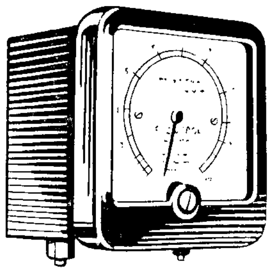

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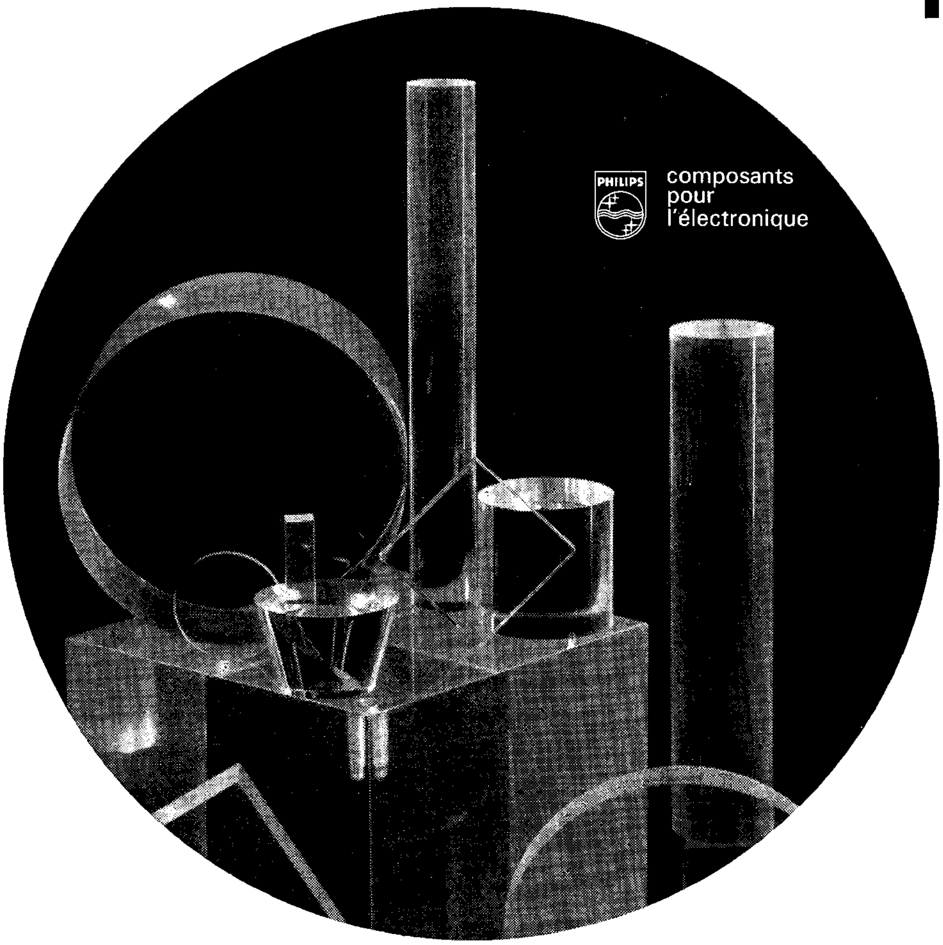

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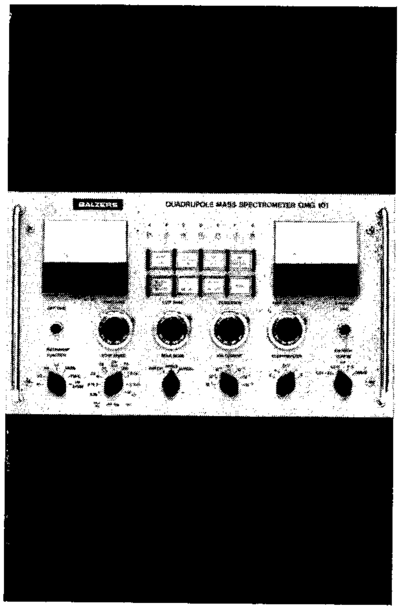

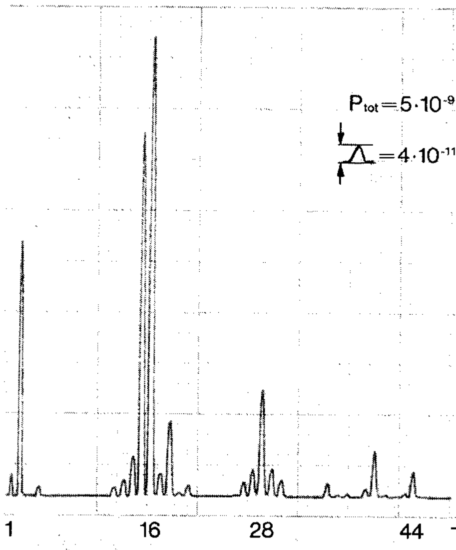

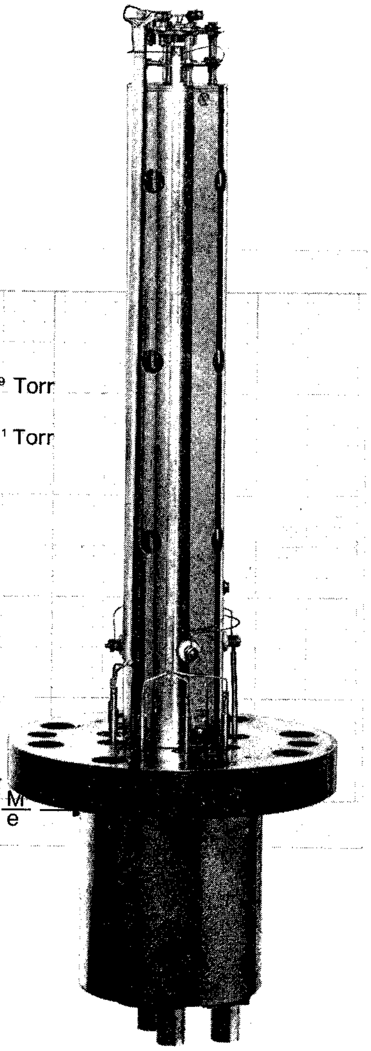

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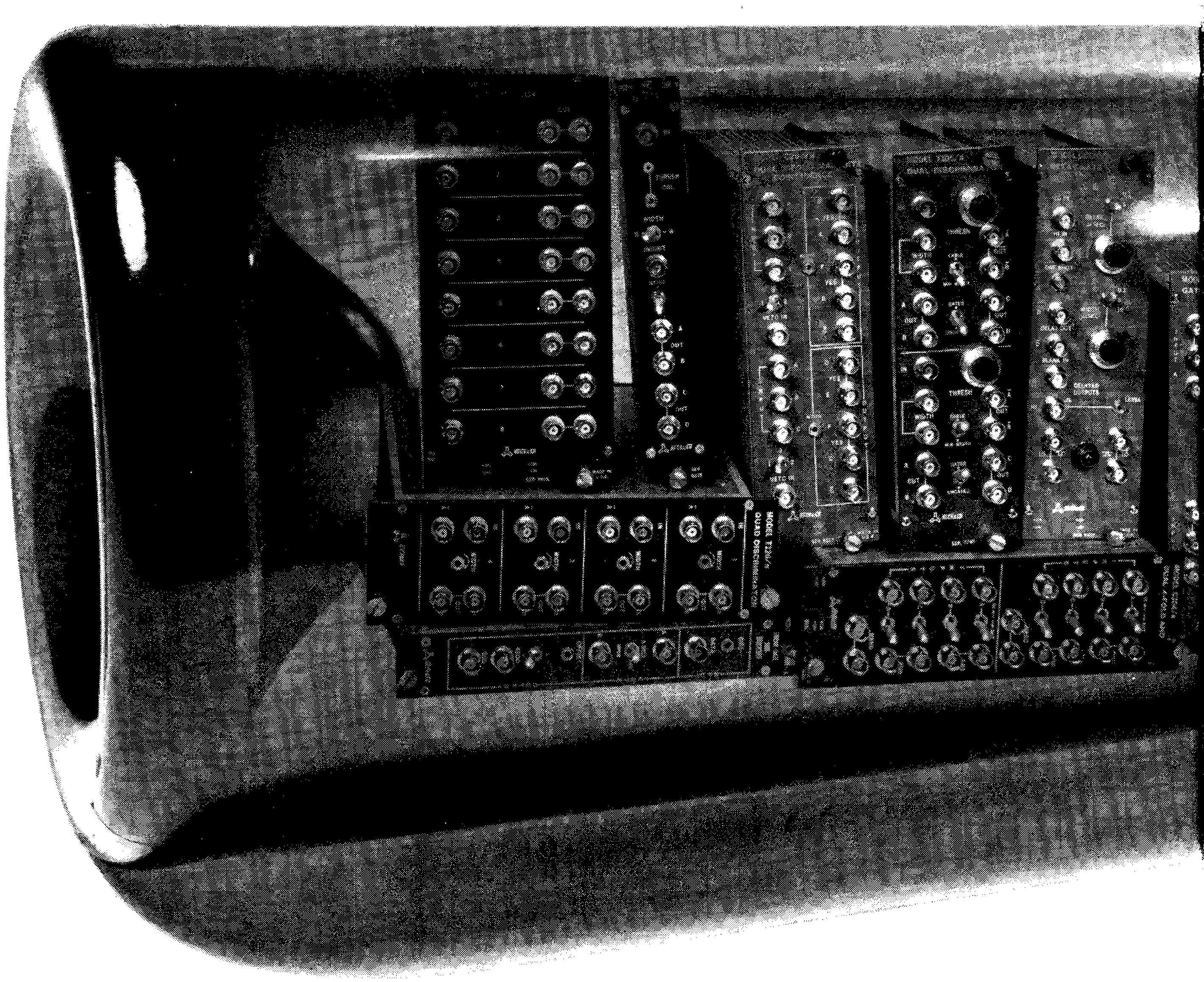

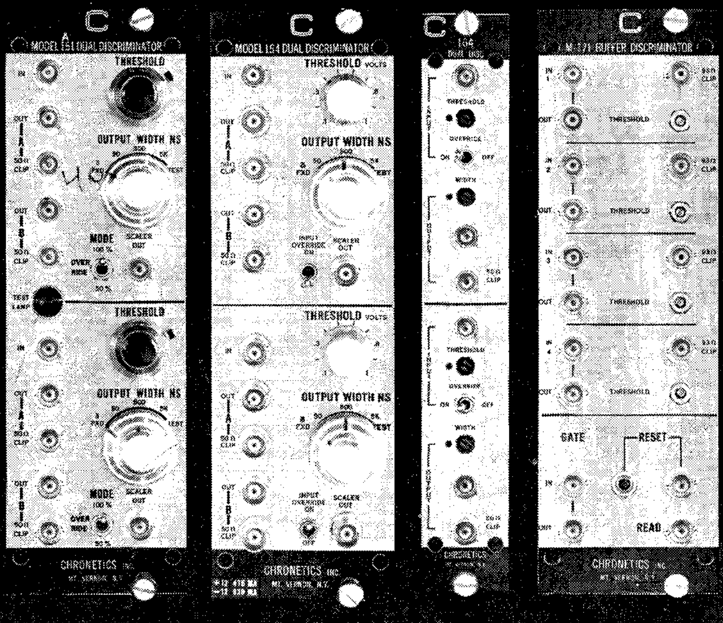

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