CERN COURIER

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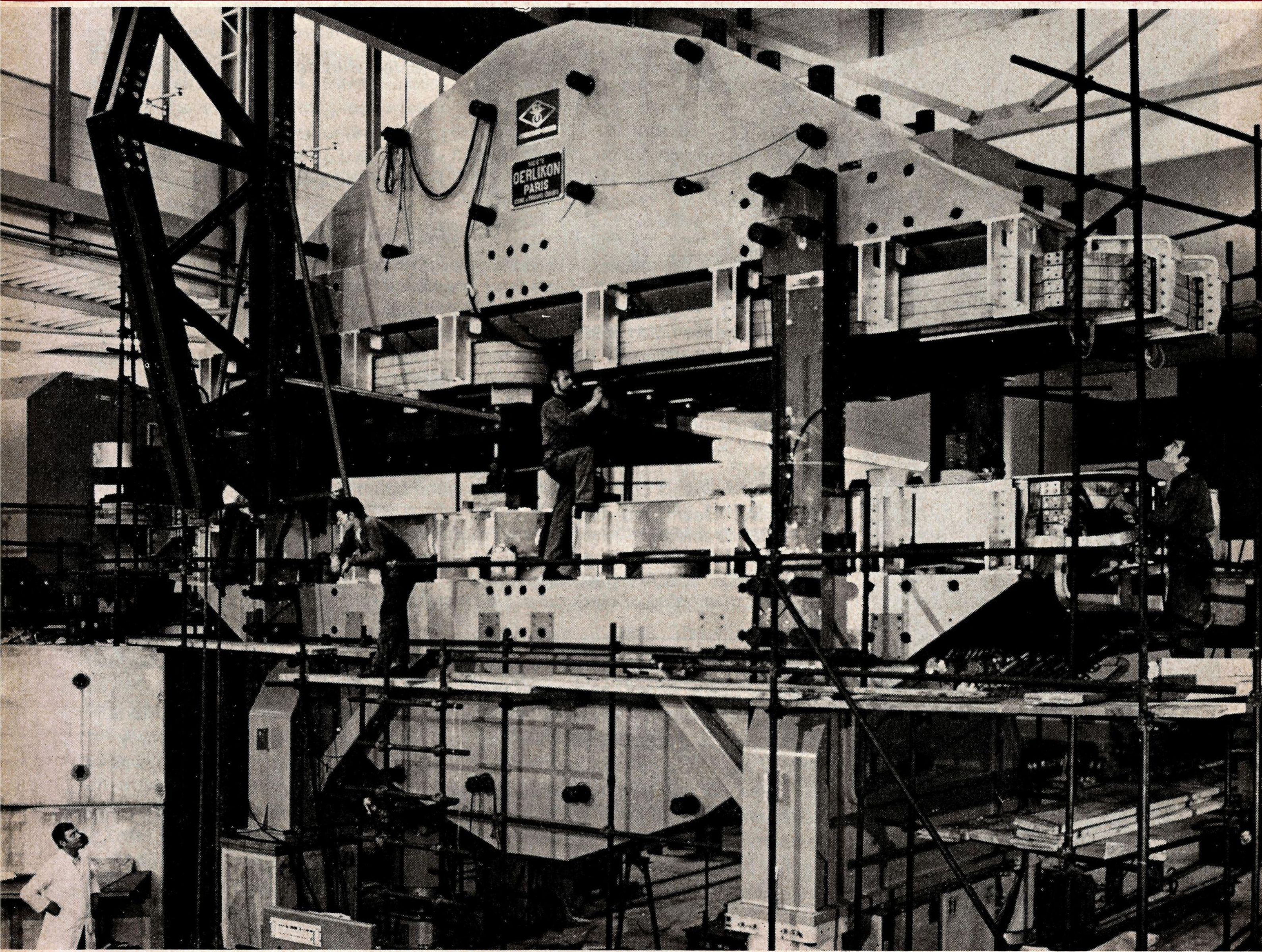
European Organization for Nuclear Research



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. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. 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 research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3000 people and, in addition, there are about 850 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 371.4 million Swiss francs in 1972.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of hundreds of GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1972 is 95 million Swiss francs and the staff will total about 300 people by the end of the year.

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Editor: Brian Southworth

Advertisements: Micheline Falciola

Photographs: PIO photographic section

Public Information Office
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 41 98 11 Telex 2 36 98

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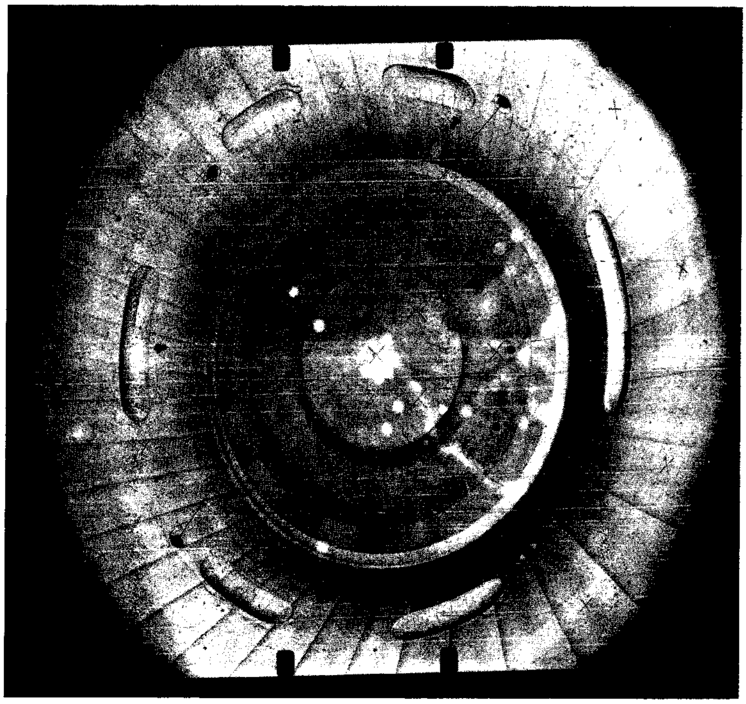
Cover photograph: Assembly of the Split Field Magnet nearing completion ready for power tests. The magnet is to be installed early next year in intersection region I-4 where, together with its system of multiwire proportional chambers, it will be a general purpose particle detection system for the study of very high energy proton-proton interactions. When the photograph was taken, the last coil winding was being put in place — the windings can be moved without disturbing the magnet yoke. On the left is one of the compensator magnets which will smooth out the effect of the Split Field Magnet on the circulating beams. About 50 m behind the magnet is its final destination — the I-4 intersection region. (CERN 186.7.72)

CERN News

One of the first photographs to be taken in the 3.7 m bubble chamber, BEBC. At the end of June most of the chamber components were in action and cameras photographed the expansions. A wire stretched across the chamber simulated a particle track. Photograph quality looked good with uniform background. The chamber is now receiving attention ready for further tests in the late autumn.



2000 GeV from ISR

At the end of June the Intersecting Storage Rings operated with beam momenta of 31.4 GeV/c in each ring. This means that proton-proton collisions were taking place in the interaction regions at energies equivalent to a conventional accelerator beam of just over 2000 GeV (or 2 TeV - T for 'tera') striking a stationary target.

The very high energy run began on 30 June at about 22.00 h and continued until noon the following day when a two-week shutdown began. The run was in addition to the normally scheduled physics runs but, nevertheless, most of the experimental groups were taking data with particular activity in interaction regions I-2 (particle production experiments) and I-6 (scattering experiments).

Normal r.f. acceleration was applied to the two beams which had been stacked at a momentum of 26.5 GeV/c. This involved rebunching of the beams and the peak current which can be subsequently accelerated is then limited to about 0.5 A. In fact 486 mA in Ring 1 and 235 mA in Ring 2 were taken to 31.4 GeV/c (debunching was not as efficiently handled in Ring 2). The luminosity was therefore very low but the accelerated beams were in good condition and the background was very low also so that several experiments were able to take data.

To achieve the magnetic fields required to hold the beams at these high energies the two main magnet power supplies were operating flat out. They survived the fourteen hour run through the night but it is not so sure that they would have held out on a hot afternoon since the cooling was being pushed hard.

Later this year acceleration by means of phase displacement is scheduled to be tried and this does not require rebunching of the beam which causes high loss of particles. Higher currents in the 30 GeV energy region would then become available.

BEBC first cool-down

Components of the 3.7 m bubble chamber BEBC have now virtually all come together and the cool-down of the superconducting magnet began on 12 June. After some initial trouble had been cleared, the large refrigeration plant operated satisfactorily during five weeks of tests. The temperature was taken down very gingerly in this first test (of the order of a degree Kelvin per hour for the magnet and three degrees Kelvin per hour for the chamber) to avoid causing mechanical stresses abruptly as components contracted and to check all safety devices en route.

For economy and because some work was not completed, all the systems were not brought into action to the extent they will be when the bubble chamber is in full operation. Thus, to avoid committing the full quantity of expensive liquid helium at this stage, the cooling of the magnet was done by gaseous helium so that its final temperature was only between 7 and 8 K. The magnet went superconducting for the first time on 25 June. Because of the relatively 'high' temperature only 500 A was passed through the windings establishing a 0.3 T field (higher currents would have sent the superconductor normal). The actual operating figures will be a temperature around 4 K, a current of 6 kA and a field of 3.5 T. Nevertheless, using 200 fixed probes, it was possible to obtain a first field map. It was not possible to look into one of the major concerns with regard to the magnet — the effect of 'frozen currents' inside the superconductor composite. As far as the magnet tests went, no problems are yet apparent.

A view of part of the large hall of the new computer centre which is now in regular use. The hall houses the CDC 7600 (seen in the upper left-hand corner), which is taking over as CERN's central computer, and a CDC 6400 which serves as a front-end machine channelling computing to and from the 7600. The empty area in front of the 7600 will be used for the CDC 6500 when it moves over.

The chamber was filled with 10 000 litres of liquid hydrogen (one third of the total volume) and held at 25 K. The safety systems and the major parts of the controls all operated as designed. No problems were encountered with the main chamber vacuum system.

Filling the chamber with hydrogen also made it possible to operate the servo-coupled expansion system together with the plastic piston at low temperature under dynamic conditions for the first time. The piston was pulsed for 3000 strokes with almost the design amplitude and cycle time. Some higher than anticipated friction was found on the piston and will be investigated. With the piston disconnected the expansion system did a further 100 000 cycles and is working well after some attention to the hydraulic pumps.

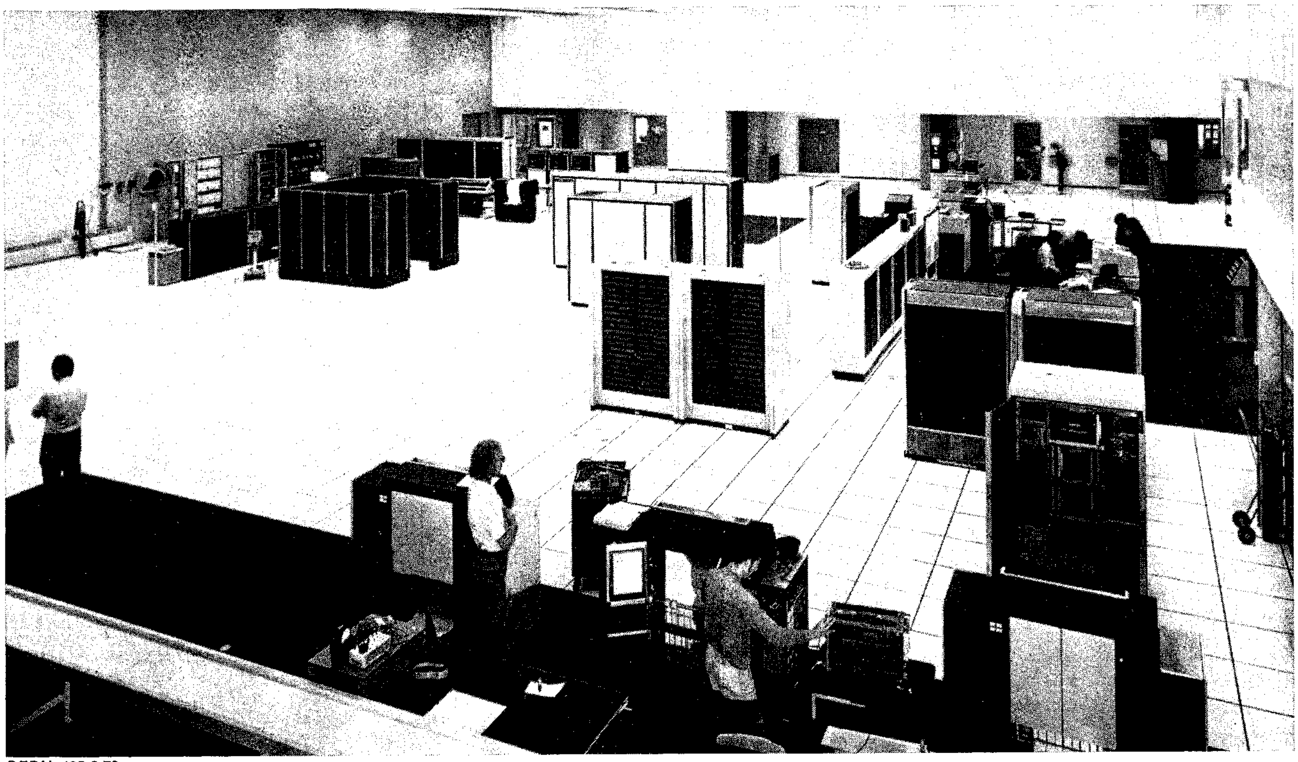
A first look was taken at the optical system. Two of the four cameras and their associated optics and electronics were in place and also, alternatively, the periscope. A wire was strung across the chamber simulating a particle track and the photographs look good with the scotchlite background quite homogeneous. There was some frosting of the inner fish-eye lenses but this can easily be cured. One other cause for satisfaction was that the large steel shield, which surrounds the whole chamber so as to hold in the high stray field, was made sufficiently leak proof despite the many penetration points. The interior of the shield is nitrogen filled as a further anti-explosion precaution around the large hydrogen volume.

On 3 July the magnet and chamber began to creep back up to room temperature which they reached on 14 July. The difficulties are now being tackled and a further series of tests is scheduled for the late autumn.

CDC 7600 passes acceptance tests

On 8 July CERN's new large computer, a CDC 7600, passed its acceptance tests. This required thirty consecutive days of operation on CERN's normal computing workload with an efficiency of 90 % or better. Over those thirty days the computer was 'down' due to faults for less than 10 % of the time and, with a few minor reservations, it was then accepted by CERN. Since then the performance has continued to improve.

The 7600 was described in the March issue (page 64). It has been purchased to cope with CERN's increasing computer needs and has about five times the computing capacity of its predecessor — the CDC 6600 which, aided by a 6500 in recent years, has been the central computer since 1965.



CERN 135.8.72

Prior to its delivery in February, the 7600 was successfully submitted to a variety of tests at the factory in Minneapolis and these tests were repeated when the computer came together again, beginning on 24 March. Initially, performance was very good but this was under small workload conditions and as the workload increased, some weaknesses in the software became clear. (Although the computer type is not new — CERN having bought the nineteenth 7600 to be built — the software, known as SCOPE 2, is new and hence the fact that some difficulties have appeared is not surprising.) During the month of May a couple of hardware problems appeared but they were cleared up during the month. At about the same time the worst software problems came under control. The operational efficiency achieved became good in June and has been sustained since.

Already the CDC 7600 is doing half as much computing as the 6600/6500 complex which remains in operation. It is in action for 1½ shifts six days a week handling about a quarter of the total number of CERN jobs. A number of selected users were helped to convert to the new computer system and the conversion has generally been smooth. The 7600 users gain from faster computing and from greater ease of access. On the other hand they have to convert their programs and have, at this stage, to tolerate slightly poorer reliability and some weaknesses in magnetic tape handling. Through to the end of the year the new computer is expected to shoulder more and more of the workload so that early next year the 6600/6500 complex can cease to act as a general central computing facility.

It is intended to move the 6500 alongside the 7600 in the new computer building. It will there be in parallel with a 6400 which acts as a 'front end' machine, channelling work to and from the 7600. It was originally planned to move the 6600 to the new building also but, in the light of the revision of the Laboratory's programme for 1973-75, it is now probable that the 6600 will remain in action for a limited period in its existing location, being used particularly for computing on-line to the HPD automatic measuring machines for bubble chamber film and for computing on-line, via the FOCUS system, to electronics experiments.

Five remote input/output stations (RIOS) are in action linked to the 7600 and from these stations users can feed the central computer themselves without necessarily involving a computer operator or travelling to the new computer centre. Initially operation of these RIOS proved slow and unreliable but this has been largely tidied up to now.

Overall, the 7600/6400 system has come into action smoothly and is already making its capacity felt on CERN's computing work.

Molecular Biology Laboratory comes nearer

On 28, 29 June the European Molecular Biology Conference met at CERN to continue its discussions concerning the setting up of a European Laboratory, on the CERN style, for molecular biology research. The aims of the Laboratory were described in vol. 10 page 117. A site, adjoining the Max-Planck-Institut für Kernphysik at Heidelberg, has been agreed and the government of the Federal Republic of Germany has offered a special grant of 12 million Deutsche Marks to help set up the centre.

Eight countries (Austria, Federal Republic of Germany, France, Israel, the Netherlands, Sweden, Switzerland and the United Kingdom) declared their readiness to participate in the financing of the project. Conditions regarding maximum contribution were however laid down by some countries and these conditions require that about 90 % of the percentage contributions, potentially coming from all the countries who have been discussing the Laboratory, be forthcoming.

Denmark (2.11 %) and Italy (13.46 %), while supporting the project, are not yet ready to join and Greece, Norway and Spain (totalling 7.66 %) have indicated that they will not be able to join in the beginning.

In addition to the central Laboratory at Heidelberg there will be two outstations where special aspects of molecular biology can be studied. One is at the DESY electron synchrotron Laboratory at Hamburg where a synchrotron radiation facility specifically for this research is already being built (as reported in the April issue page 131). The other is at the Institut Laue-Langevin at Grenoble where a high flux beam reactor will be used for irradiations.

The terms of the Agreement for the construction of the Laboratory were approved by the Conference. When they sign the Agreement, countries will commit themselves to participate in the project for a minimum of seven years. The estimated non-recurrent costs in this seven year period are given in Accounting Units (AU) each equal to about 4 Swiss francs. For the Laboratory the estimate is 9.6 million AU, for the DESY facility 1 million AU, for the Grenoble facility 0.27 AU and for the preliminary studies 0.13 AU (a total of 11 million AU). The participating countries will provide this amount less the grant of the German government.

A further meeting is planned for September when it is hoped that enough countries will be ready to sign the Agreement. Work on the

1. A vertical section through a DISC Cherenkov counter of which two are being built at CERN for use in the high energy beams at the National Accelerator Laboratory, Batavia.

2. The main body of one of the DISC counters. The particle beam will enter the detector from the right.

3. A view of the DISC counter as seen by the incident particle beam. The entrance window in the centre is surrounded by housings for eight high quality photomultipliers.

Laboratory could then start in 1973. It is anticipated that the Laboratory staff will grow to about 230 people (including some 60 scientists and engineers) plus up to 150 visiting scientists passing through in the course of a year. Operating costs are expected to reach 4.2 million AU in 1976.

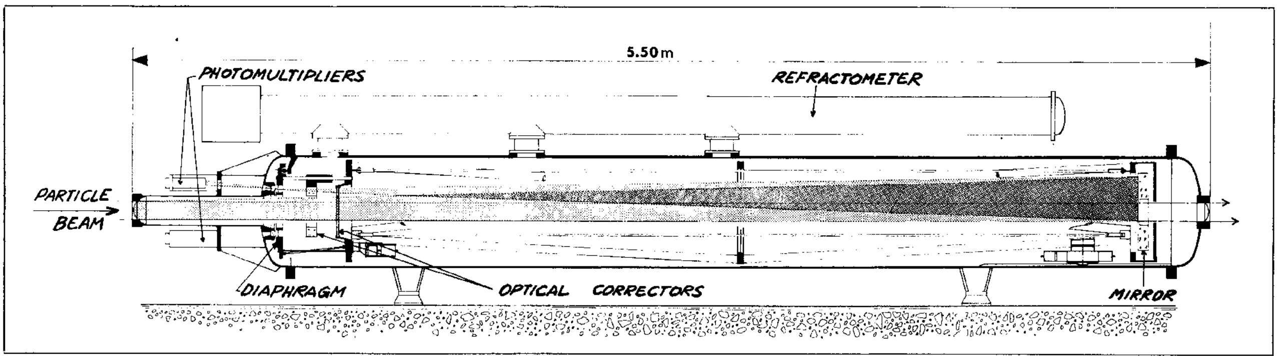
DISC counters for Batavia

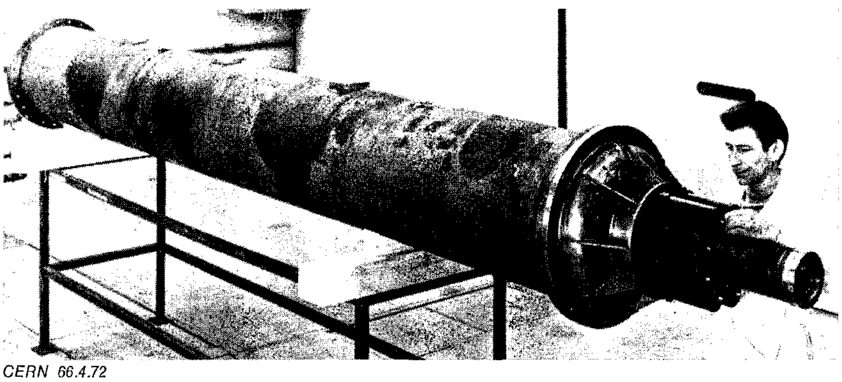
CERN is building two DISC (Differential Isochronous Self Collimating) Cherenkov counters to be used in the high energy beams at the National Accelerator Laboratory at Batavia. The principle of the DISC counter can be extended in a straightforward way to provide the design of detectors which can be used at very high energies such as are available at Batavia and will be available at CERN.

Construction of the counters for NAL is now well advanced as can be seen in the photographs. The two identical counters (previously mentioned in vol. 11, page 323) are 5.5 m long and filled with helium gas at pressures up to about 20 atmospheres. The Cherenkov light produced by the passage of a high energy charged particle through the counter is reflected by a mirror and the ring image is focused onto an annular diaphragm. The light which passes through the aperture of the diaphragm is detected by eight high quality photomultipliers which are equispaced around the ring. The counter contains a sophisticated internal optics made from fused silica and sodium chloride which corrects for certain aberrations in the system. The silica-salt combination of materials has the desired optical properties but is obviously unusual. Industry was not keen to manufacture lenses which can be damaged as easily as by breathing on them and these special optics are therefore being made at CERN. There is also a high precision refractometer associated with the detector which will provide a digital readout of the refractive index of the gas to an absolute accuracy of the order of 3×10^{-8}.

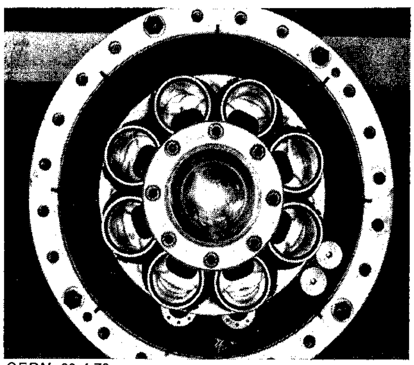
It is expected that these DISC counters will be capable of distinguishing between pions and kaons at momenta up to about 250 GeV/c, or between pions and protons up to about 500 GeV/c.

Construction of the counters, which is being carried out by a combined team from Nuclear Physics and Data Handling Divisions at CERN, is expected to be completed by the end of this year. It is planned to test the detectors at the CERN 28 GeV proton synchrotron early in 1973 following the annual machine shutdown and they will then be sent to Batavia.





CERN 66.4.72



CERN 63.4.72

One of the DISC counters will become part of a 200 GeV/c Focusing Spectrometer Facility which is to be constructed in the 2.5 mrad beam-line of the Meson Laboratory at NAL. A group of physicists from CERN is collaborating with physicists from eight other Laboratories and Universities in setting up this spectrometer and will be involved in the first year of the physics programme using the facility. The project is being coordinated by D. Ritson from Stanford University and is on the NAL schedule of approved experiments as Experiment 96.

The experience gained during the development of these two prototype DISC counters will help to optimize the details of their design, construction and operation. It is envisaged that detectors of this type will be used in the high energy beams of the CERN SPS. Also, there are ideas now being worked out which could take the Cherenkov detector technique a step further so that it could cope with multiparticle identification.

One million pictures from Gargamelle

The number of pictures taken in the heavy liquid bubble chamber, Gargamelle, passed the million mark in July. This achievement indicates how intensively the chamber has been used so early in its life. It first came into action for experiments in May 1971.

Five hundred thousand pictures were taken from May to November 1971 for the first set of experiments studying neutrino interactions. The period from November 1971 to April 1972 was spent preparing the chamber for operation with propane which was used in an experiment with an antiproton beam during which 400 000 pictures (at 1.6 GeV/c and 2.6 GeV/c) were taken. In July, 100 000 pictures were taken for an experiment with a proton beam (19 GeV/c).

Whilst the physics programme was being carried out, certain technical difficulties were overcome — notably, the mechanical resistance of the membranes in the expansion system was improved, as was the resistance of the fast pneumatic valves to fatigue. Other improvements have been the development of a continuous filtering system to keep the liquid clear and mastering the camera system to ensure the correct simultaneous operation of the eight cameras.

Other improvements may be made both to the quality of the pictures and to the reliability of the installation. However, Gargamelle has already proved itself a good instrument for neutrino physics (results have been presented to conferences at Brookhaven and Lake Balaton), and has now also shown its paces operating with propane.

And 20 million from the 2 m

In the course of an experiment running from 12-14 July, the 2 m bubble chamber clocked up its 20 millionth photograph. The experiment was being carried out by a Strasbourg/Tel Aviv collaboration studying neutron-proton interactions for direct comparison with antiproton-proton, antiproton-neutron and proton-proton interactions at the same momentum. The bubble chamber was filled with hydrogen and a beam of 11.8 GeV/c deuterons was fed in. The chamber was double pulsing and 70 000 good quality photographs were taken.

Operation of the 2 m bubble chamber continues to bear fruit. It came into service in 1965 but has had a number of modifications since then to keep it in the front line. From January to May of this year there was a major overhaul of the chamber when the vacuum tank was modified, a beam absorber was fitted, and a new flash unit cooling system was installed together with a system for measuring the luminosity of the flashes. In addition preparations were made to receive the superconducting field shield near the beam entry position to make experiments possible with low energy beams.

Following this wash and brush-up the 2 m bubble chamber is in good shape for the new series of experiments which have started and the chamber took the 20 millionth photograph in its stride.

Split Field Magnet ready for tests

The end of September will see the first power tests on the Split Field Magnet (SFM) which is to be installed as a general purpose experimental facility at the Intersecting Storage Rings. Together with a detection system, built up mainly of multiwire proportional chambers, the SFM will form a very powerful complex with which physicists will be able to study proton-proton collisions in one of the ISR intersection regions (I-4).

Such a facility has to take account of the special conditions prevailing in the ISR. The two stored beams travel in opposite directions, and cross at a small angle. The number of collisions which occur affects only a minute proportion of the protons per revolution ; the beams continue to circulate in the machine decreasing only very slowly in intensity. Because of this, the problems involved in the study of the collisions and their produce differ considerably from those encountered in conventional accelerator experiments. The physicist wants to get at the particles coming from the collisions and this means spotting them in detectors and bending them in magnetic fields to analyze their momenta. Ideally, the magnetic fields should cover the entire intersection region but, at the same time, he does not want to affect the protons still circulating in the machine and fields over the intersection region do just that. A solution had to be found which would provide the experimenter with the information on momenta that he required but, overall, would allow the circulating beams through the intersection region as if no magnetic fields were present.

Apart from the technical restrictions, certain practical considerations also came into play such as the space available for setting up the experiments, the cost of construction and operation and the construction timescale — the physicists wished to have a versatile detector in action at the ISR as quickly as possible. It was decided at the beginning of 1969 to go for a magnet system having a 'split field'. The Magnet Group of the ISR Department then set to work with computer programs and a fifth-scale model on the solution of the problems which this novel project involved. By January 1970, the characteristics of the system had been sufficiently well defined to allow a call for tenders for construction of the main magnet.

The fifth-scale model of the SFM was used to plot a complete field map, to measure the stresses on the most heavily loaded components of the structure, to decide on modifications to the shape of the yoke and above all to determine the parameters of magnetic screens which protect the circulating beams from focusing fields.

The structure of the magnet is complex because of the varied requirements it has to meet — as high a field level as possible (so as to have as good particle momentum measurements as possible) compatible with acceptable running costs, as large a volume in the high field as possible (so as to accommodate the maximum number of detectors) and, as emphasized before, no overall effect on the protons which continue to circulate in the rings.

This last requirement involves two factors — orbit deflections and focusing effects. To obtain a zero orbit deflection the magnet is designed so that its aperture is divided by a radial vertical plane into two symmetrical parts in which the field's vertical component is in opposite directions (hence the term 'split field'). Thus, a proton circulating in the machine is deflected first to the left until it reaches the magnet's radial plane of symmetry, then to the right (or vice versa for protons in the other beam) which brings it back towards the trajectory on which it was travelling in the absence of the field. To ensure that the proton returns its trajectory when it leaves the intersection region, its angle of flight is further corrected in a third magnetic field region provided by a 'compensator' magnet.

Two compensator magnets are added downstream and upstream from the Split Field Magnet. Large compensators, placed one on each beam downstream from the intersection region will be used also to analyze particles of large momentum produced at small angles which are not bent off by the field in the SFM itself. They have been designed with a wide aperture for this purpose. Small compensators located upstream are not used for momentum analysis and are therefore compact in design. Parameters are given in the Table. A magnetic screen in the form of a sleeve will be located around each beam in order to protect the protons from the highly asymmetric focusing fields occurring around the edges of the SFM. The screen is complex in design and includes remotely controlled flaps so that the field gradient can be modified within certain limits. It also compensates partially for the focusing effect to which the beam is subjected as it crosses the field inversion plane.

These unusual features made construction difficult. Nevertheless, assembly of the SFM, in an annex next to the intersection region I-4, is almost finished only a few weeks behind schedule. Some problems were encountered by the manufacturer in the machining of certain components. Also an accident occurred during the shipment of one of the poles to CERN. The pole, weighing 40 tons, fell from an articulated lorry and had to go back to the manufacturer to be re-machined. (The twin pole which had already been delivered was also returned to the factory so that it could be matched with the other.) The net result was the delay of a few weeks in the assembly.

The four compensator magnets have been delivered. The magnetic screens are also complete except for sextupole correction windings. The power supplies have been tested and some are already in operation. Field measuring

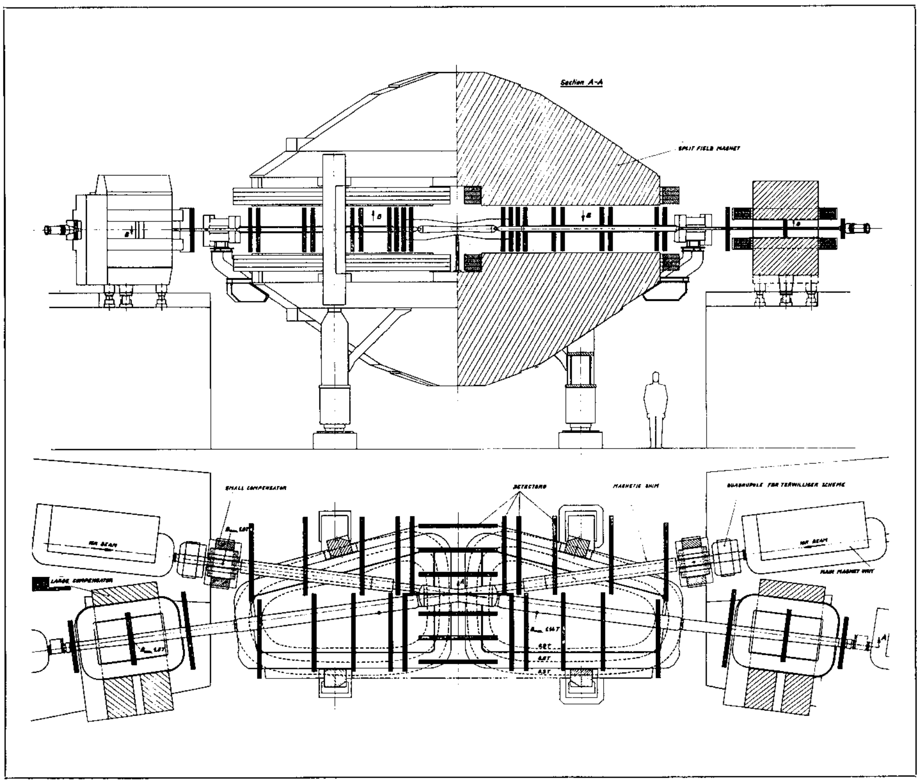
Split Field Magnet characteristics

	SFM itself	Large compensator	Small compensator
Length (m) . . .	10	2.5	0.75
Maximum width (m)	3.5	3	1.03
Gap height (m) . .	1.1	0.4	0.075
Weight (t)	850	68	2
Useful field volume (m^3)	28	1	—
Field in median plane (T) . . .	1.14	1.5	1.8
Power dissipation (MW)	4.1	0.38	0.06
Number	1	2	2

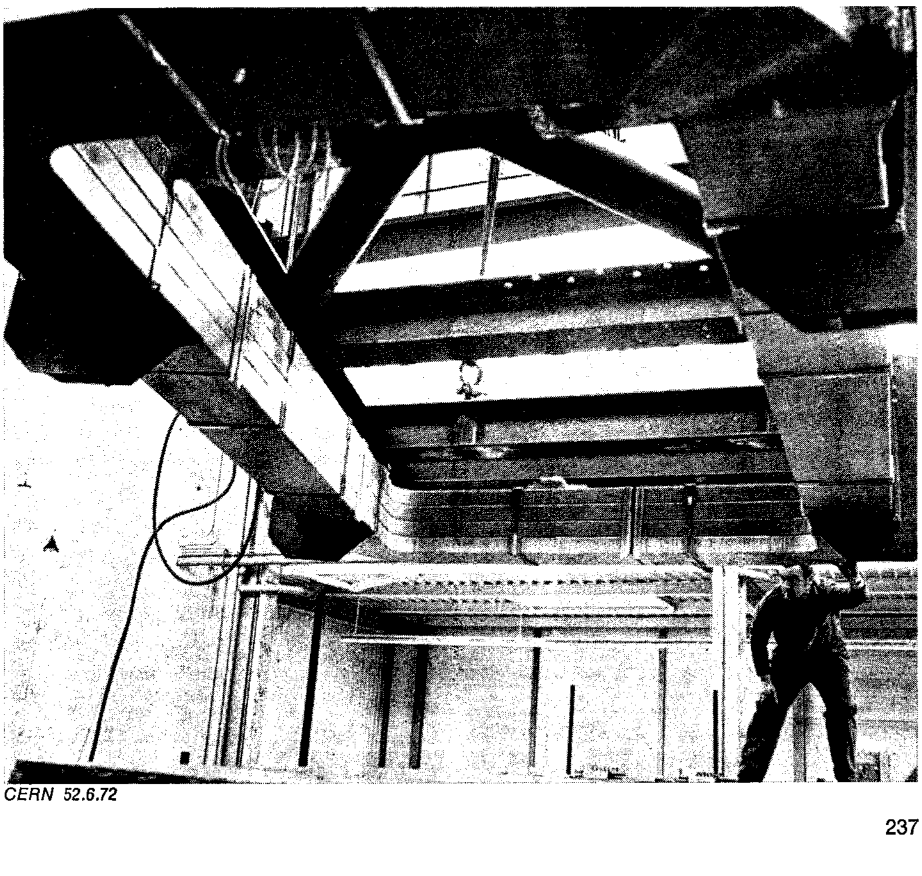
equipment for all the magnets is under test so that practically everything will soon be ready to power the full system of magnets and to measure their properties.

It is hoped to perform the first power tests at the end of September. The field map giving the bending and focusing properties of the SFM will be determined and the parameters of the correction elements will then be calculated in line with operating conditions which can prevail in the rings. The magnetic field will be accurately plotted at different levels throughout the useful volume of the SFM and of the large compensators and the results of these measurements, after processing by the appropriate computer programs, will be recorded on tape and made available to the experimenters. The experimenters will need to have this information, in addition to the readings of the detectors, in order to analyze the particle interactions which they observe.

The experiments will begin next year. The SFM will be rolled on rails by means of a special carriage from the annex into I-4 during a shutdown early in 1973. The special vacuum chamber is scheduled to be ready for installation in January. The multiwire proportional chambers will be put in place about a month after the SFM goes to I-4 (there has been some difficulty in the manufacture of the hybrid circuits which will pick up and amplify the signals from the wires but this should not delay the initial installation). The machine specialists will then need time to integrate the SFM into the storage rings — ensuring that the circulating beams behave as if the SFM were not there under the wide range of possible ISR operating conditions. The experimenters can then get to work with this new powerful addition to their armoury of detection systems.

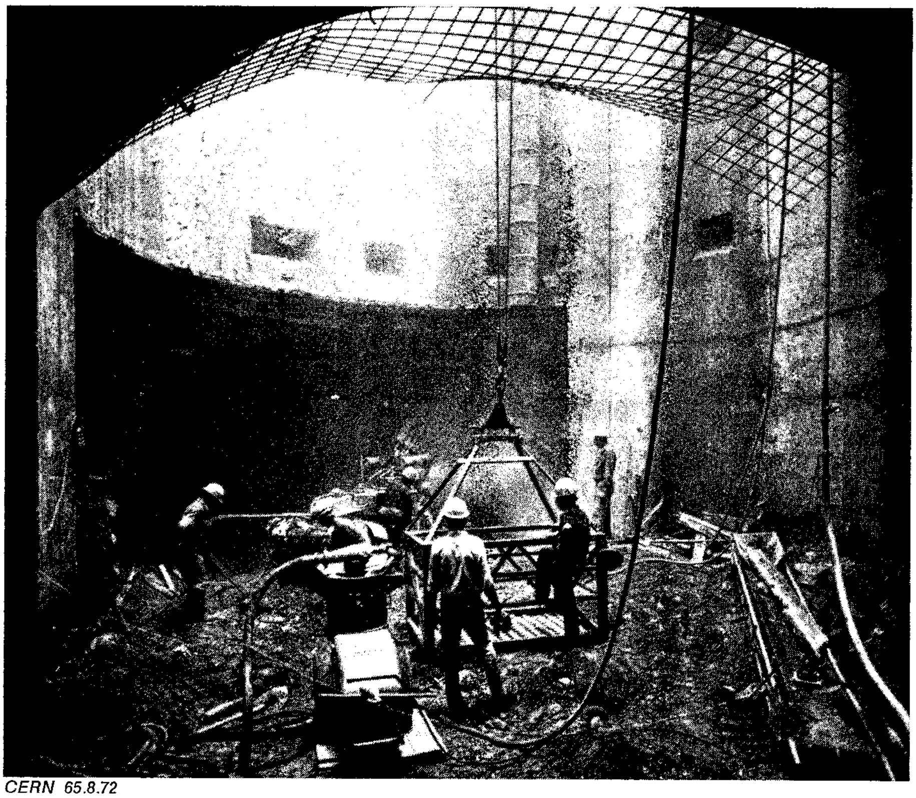


Drawing of the Split Field Magnet in position over intersection region I-4 at the Intersecting Storage Rings. The location of the large and small compensator magnets and of the multiwire proportional chambers is shown. The bottom half of the drawing is a bird's eye view indicating how the two rings cross within the SFM. The large compensator magnet downstream on each beam also serves as an analysing magnet for small angle high momentum particles and detectors are located in its large aperture.



The photograph shows a coil of the Split Field Magnet swinging into place. Like the photograph on the cover it gives an idea of the large size of the magnet. It is possible to install and remove the coils without dismantling the magnet yoke.

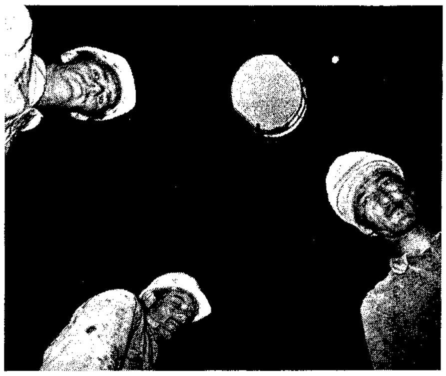
CERN 52.6.72



CERN 65.8.72

45 m deep in the ground, work begins on cutting a tunnel between two shafts (PGC and PPI) on the SPS site. It is in this tunnel that 'the Mole' and its train will be assembled to begin burrowing their way around the 7 km circumference of the machine.

Seeing the light. Construction workers watch the camera which is pointed to the top of the shaft, 45 m up.



CERN 60.8.72

Vacation students

The annual exodus from CERN to the beaches is partially compensated by the arrival each summer of over a hundred vacation students. They spend a few months in Geneva participating in the scientific and technical work of CERN.

Information on the Vacation Student Programme, which has now been operating for ten years, is circulated to Universities in the Member States towards the end of the year and interested University students of three years standing or more are invited to apply before 1 March of the following year. The application needs to be accompanied by two references from the student's Professors or tutors. For the past two years students of two years standing or more from technical colleges have also been welcomed.

The Fellows and Visitors Service in collaboration with the Divisions then has the difficult task of selecting from among the candidates, according to their interests, to arrive at a number of students which can be accommodated organizationally and financially (CERN meets travel and subsistence expenses). This year, from 457 applications, 123 University students and 21 Technical College students were invited to come to CERN. Three of the students, exceptionally, come from the USA rather than from the Member States. They have been invited following an initiative of the Equal Employment Opportunity Office at the National Accelerator Laboratory, Batavia, and are being financed by the Ford Foundation.

During their stay a course of lectures is organized for the students which extends over two months and covers scientific and technical topics related to particle physics and the advanced equipment it requires. In particular there are courses on elementary particle physics and on computing.

The students are allocated amongst the CERN Divisions ; about half of them join experimental physics teams and the other half work in applied physics, data handling or engineering. They join in the daily work of the group to which they are assigned and many of them make excellent contributions to the work. In return the students seem to gain a great deal from meeting and working with experienced scientists and most of them record their satisfaction as they leave CERN at the end of the summer.

Black holes at CERN

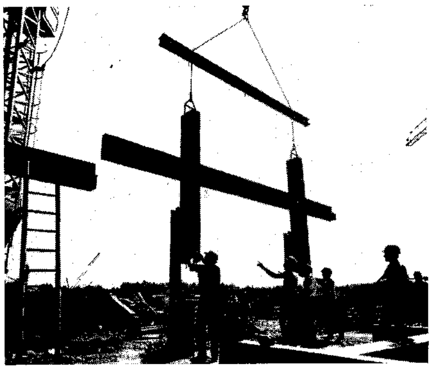
The world of astrophysics, which has been in a very healthy ferment for several years has recently rocked to the news of the possible identification of a 'black hole'. (Black hole in astrophysics context refers to a collapsed star where the gravitational pull is so strong that no signals can escape.) Not to be outdone, we have identified several black holes at CERN. There are seven of them and they have been given the designation PPG and PP1, 4 and 5, PA2, 3 and 6.

Though of less immediate physics interest, the CERN black holes are still very impressive. They are the shafts being dug deep in the ground on the site of the new accelerator, the SPS, which will produce energies of several hundred GeV. Several of the shafts are now so deep that the work under way at the bottom is lost in the gloom.

An important stage in the digging was reached early in August, when the shafts PGC (on the beam injection line) which is 9 m in diameter and PPI (near the injection straight section) which is 5 m in diameter, both reached their assigned depth of 45 m. A start was then made to link the two shafts underground. It is here at the end of November that 'the Mole' will be fed in. The Mole is the pet name for the machine which will bore round the 7 km circumference of the machine. It has associated with it a train which has equipment for lining the tunnel as boring proceeds, for disposing of the spoil from the working area and for bringing up the shoring and lining equipment. The train is about 40 m long — hence the need for the 'run-in' tunnel which is being dug out

The framework of the large assembly hall taking shape on the SPS site. The hall will provide 11 000 m² of floor space where the accelerator components will be assembled prior to being moved to the machine tunnel.

Girder sections for the assembly hall swing into place. The hall is scheduled to be ready for use early next year.



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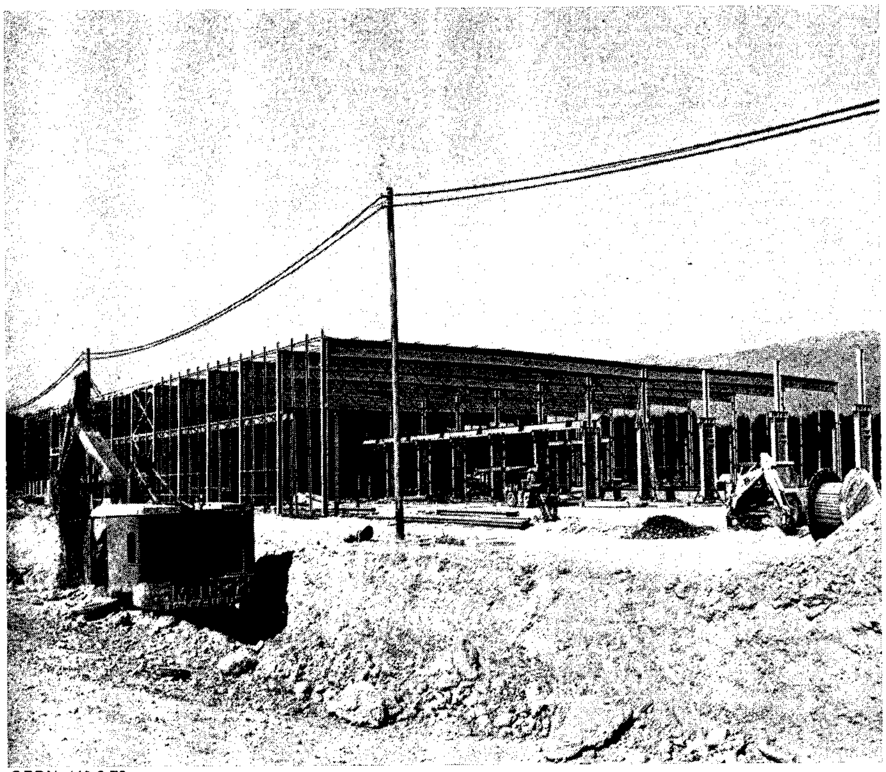

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between PGC and PP1. Appropriately, the Mole will enter at the injection straight section.

More tunnelling is under way to the North where the ejected proton beam will emerge en route to the North experimental area. In this case the tunnel is being cut into the ground from the surface down to machine level and the work is well advanced.

Nor is all of the activity going on in the ground. The laboratory and office buildings and particularly the large hall, which will be used for the assembly of the machine components, are going ahead fast, aided by some fine summer weather. Most of the framework of the hall is in place. It is intended to have the hall and a laboratory and office building ready for use early in 1973.

Some like it hot

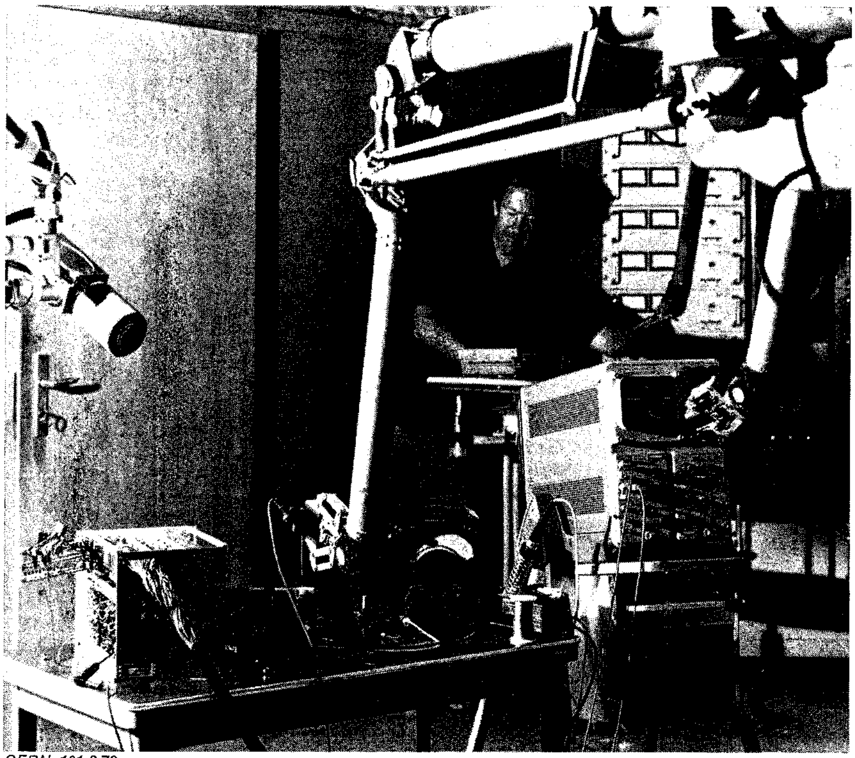
Further experience in remote handling techniques is being gathered in the Proton Synchrotron Division with a new advanced type of 'teleoperator' known as Mascot. The interest in remote handling techniques at CERN and other high energy physics Laboratories is in order to develop expertise should it prove necessary to use teleoperators (or telemanipulators or remotely controlled robots) to work in 'hot' regions around the accelerators where radiation levels can prevent human intervention, or make it extremely difficult.

Progress in accelerator design in recent years has meant higher energies and higher intensities both potential sources of higher induced radioactivity in the accelerator components. Fortunately, skill in monitoring and controlling the accelerated beam has also improved so that the beam losses which cause the radioactivity have been held down. Nevertheless with beam intensities climbing to 10^{13} protons per pulse, even a high ejection efficiency like 95 % corresponds to the loss of 5×10^{11} protons per pulse in the accelerator. There are regions where components inevitably get hot, such as at target stations and ejection components.

Already at the CERN proton synchrotron there have been occasions when work on components in and around the vacuum chamber had to be done in relay so that no single person absorbed more than the maximum permitted dose. This problem will become much worse as the intensity goes up a factor of five using the Booster and new measures of one kind or another will be needed to master it. One possibility is the use of a teleoperator and in 1968 a Model 300 electric manipulator was installed in the PS ring to study the capabilities of such devices.

Remote handling is a fascinating subject. Robots have been fertile material for science fiction writers for a very long time but it is only in the past 25 years that their development has really got off the ground (leaving aside the 'pre-programmed' type such as the famous Jaquet-Droz automata). Much of the stimulus came from the nuclear industry, precisely because of the problems associated with hot materials, such as nuclear reactor fuel elements, and the Argonne Laboratory was the scene of a great deal of the pioneering work. Space programmes are another obvious user with the possibilities of doing things like sending teleoperators to dig up bits of Mars. Another user, pushing development hardest at the moment, is the oil industry where the interest centres on sending teleoperators down to the bottom of the sea to exploit oil fields at great depths off the continental shelf.

These examples indicate where the teleoperator is mainly being used up to now, namely to extend man's normal handling abilities into hostile environments. However in addition to this advantage there is the obvious potential of greater power or of greater finesse and of transmitting exceptional manipulative skills over great distances. Advocates of teleoperators speak of the possibility of a heart surgeon in South Africa (where the more voluble seem to reside), by the end of the century, being able to carry out refined surgery on a patient in Canada by operating a miniature



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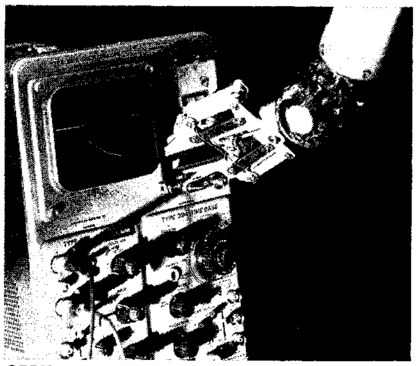
The teleoperator, Mascot, in action checking one of its own pulses; the movements of the operator are followed by the slave unit. CERN is keeping an eye on remote handling devices, such as teleoperators, in case growing induced radioactivity problems call for their use in working on the accelerators.

The close-up shows the unemotional hand of Mascot adjusting the scale illumination on the oscilloscope.



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slave manipulator via a satellite telemetry link, of teleoperators clumping around sea beds attending to oil field installations... and so on. Just as the computer has extended man's brain power, the teleoperator could extend man's physical power.

Many of the more exotic ideas currently being developed around the world are not however applicable to teleoperators at accelerators. Plastic components and miniaturized solid state components are not happy in high radiation environments. Also the master/slave mechanically linked telemanipulators which have reached a high state of perfection in the nuclear industry are not appropriate. (Probably most people are familiar with this type — working in pairs in hot cells with direct vision through lead glass windows they are capable of quite intricate work such as transferring hot liquids in test-tubes, etc...) But they are used in fixed positions covering limited volumes and the scale of accelerators can demand mobility over large volumes. Devices of restricted mobility and capability are already in use — for example, a unit which works on the focusing horn in the neutrino beam-line at CERN. A variant to full mobility has been developed for Los Alamos. Known as Merrimac, it is effectively a hot cell on wheels which can move along and sit over a section of beam-line and be remotely manipulated in this position.

Another device in hot labs is a switch-operated unilateral electric manipulator which can move on overhead rails and do fetching and carrying for fixed master/slave manipulators. It was an adoption of this type of device with which the first tests at the PS, mentioned above, were carried out. The device was unsatisfactory being slow and difficult to use but it did provide very valuable experience and served to pin-point the problems in this new field very well.

In the absence of radio control, cable links had to be used plugged in to a point on the PS tunnel wall. This limited the range to about 40 m from the plug and was mechanically messy. However it proved a problem which could be handled and the 40 m limit, with the new device Mascot, has been overcome by having a self-plug-in capability. Mascot can roll round a tunnel on rails fixed to the wall and plug itself in at a new position so that its component parts become alive again in a new work zone.

Other factors which became clear with the previous device included the necessity of efficient manoeuvrable television so that the operator sitting in the control room could see very cleanly what he was working on. The use of just one arm was very inefficient — which ties up with evolution's decision in the design of man himself. It became even more obvious that quick release and self-aligning techniques on the accelerator components ease the task of the teleoperator enormously.

The Mascot electronic servo master/slave combines the best characteristics of previous types. It has two arms and has even greater touch and dexterity than the fixed mechanically linked types used in the hot cells. In 'no-load' conditions the bandwidth is 20 Hz and rapid hand movements by the operator are followed by the slave immediately. The operator hundreds of metres away can literally feel what the teleoperator is doing. Sensations of weight, mechanical resistance, etc... are all transmitted to the master arms which the operator is holding. Television arms, resembling compact manipulator arms themselves, carry the visual signals efficiently.

Mascot has been assembled on test rails simulating the PS tunnel rails in Hall 169 and will be tested on a variety of tasks — dismantling accelerator components and so on — so as to increase experience in the use of teleoperators. The region of straight section 16 in the PS has been designed with the possible use of Mascot in mind. This is a crucial region of the machine which could also become one of the hottest regions since it is the ejection point for beams to the Intersecting Storage Rings and to the new very high energy accelerator.

Around the Laboratories

Photograph taken in the 85 cm chamber at DESY when studies of the effect of tritium in the chamber liquid were carried out. The bubbles coming from radioactive decay of the tritium fog the picture, and the study of particle interactions in the chamber would be very difficult under these conditions. These were however the worst conditions to be tried — an atomic concentration of 10^{-11} tritium. The chamber operating temperature was 25 K and the minimum pressure 1.33 kp/cm^2. The photograph was taken 6 ms after passing the pressure limit of sensitivity, and this is 3 ms after the beam particle injection.

DESY
Studies on tritium contamination

The common fillings for cryogenic bubble chambers are 'light liquids' such as hydrogen or deuterium. Hydrogen provides an excellent and very simple proton target whereas deuterium, which has a proton and neutron clinging together in the nucleus, is the nearest we can have to a free neutron target.

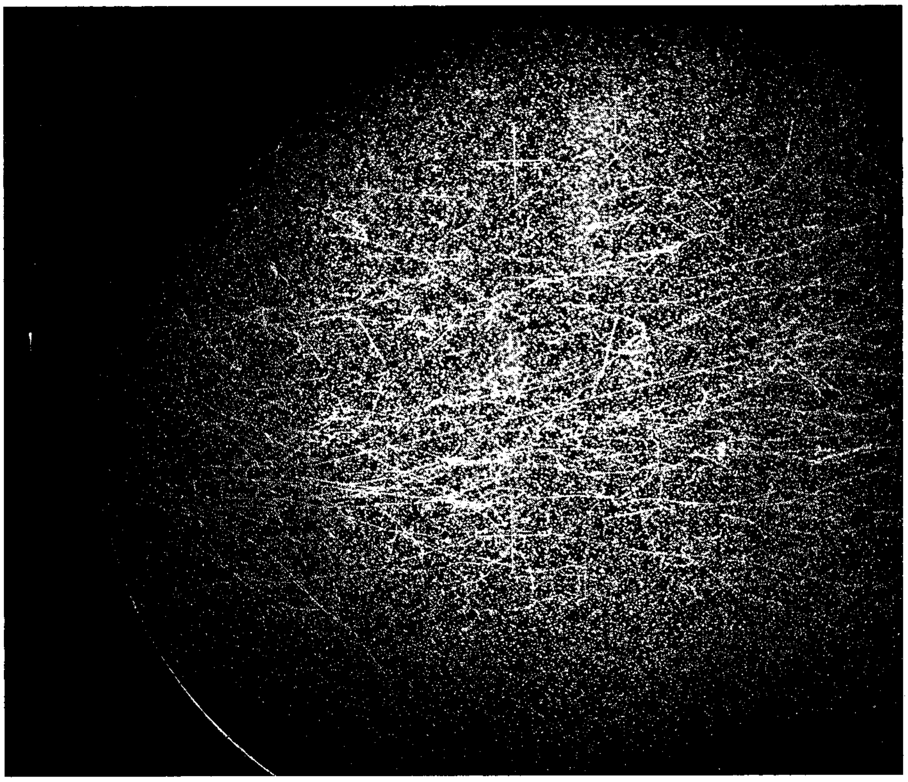
Bubble chamber operating conditions for deuterium are almost identical with those for hydrogen so one chamber does for both. However a hydrogen chamber usually needs to be tidied up even more than usual when it is to be used with deuterium so as to reduce the leak rate to an absolute minimum. This is because deuterium is an expensive liquid to produce — to fill the 3.7 m chamber, BEBC, with deuterium would cost not far short of 10 million Swiss francs. All the more reason to be very confident that experiments with deuterium can be carried through successfully. One worry on this topic has recently been investigated at DESY.

In the production process for deuterium a certain amount of tritium will inevitably find its way into the deuterium. This is a worry because tritium is radioactive with a half-life of 12.26 years ; the one proton two neutron nucleus of tritium transforms to helium 3 (two protons one neutron) with the emission of an electron. The maximum electron energy is 18.5 keV. In a bubble chamber, these electrons will be a source of unwanted bubbles (or background) and the number of tritium decays occurring during the sensitive time of the chamber could be so high that the wanted particle tracks are fogged over.

Fogging from this source has been experienced in small Brookhaven and Saclay chambers. However, until comparatively recently, the tritium contamination in the available deuterium has generally been sufficiently small not to hamper experiments. The situation has changed because the nuclear bomb programmes of the past few decades have sent up the tritium concentrations by about two orders of magnitude. The contaminations are now sufficiently high to demand a careful look at precisely what the experimental conditions will be before acquiring a large quantity of deuterium. It seems that the only large stock in the world which is certainly of sufficient purity for particle physics needs is in the USA — and they have large chambers of their own (see report from Argonne in the June issue).

The 85 cm chamber at DESY was filled with hydrogen (rather than expensive deuterium since the filling had to be rejected after deliberate contamination) and controlled quantities of tritium were introduced. The chamber was operated at two different temperatures, 25 K and 26 K, and with different pressure conditions. Both bright field and dark field illumination were used. The number of bubbles resulting from the presence of the tritium depends on the degree of contamination, the length of time for which the liquid is sensitive for the production of tracks and on the probability that an electron initiates bubbles.

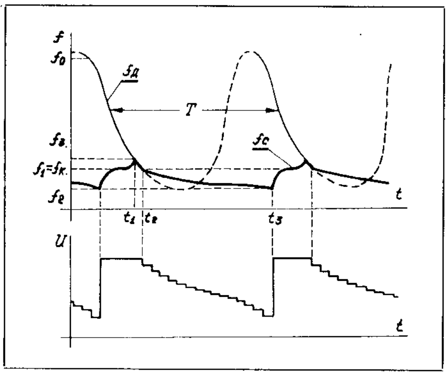
The ratio of tritium atoms to hydrogen atoms ranged from about 10^{-16} to 10^{-11}. For each chamber condition the number of bubbles per cubic centimetre emanating from tritium decays was counted. The results cannot be expressed as a simple 'yes' or 'no' for different tritium contaminations since the particular chamber conditions are also relevant. The DESY

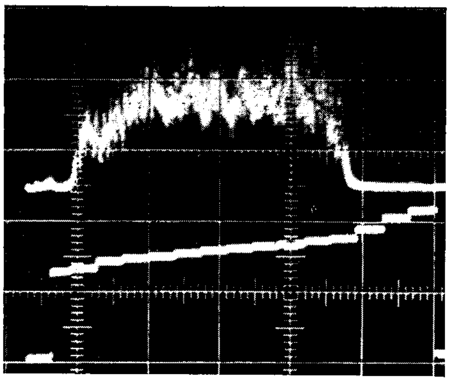


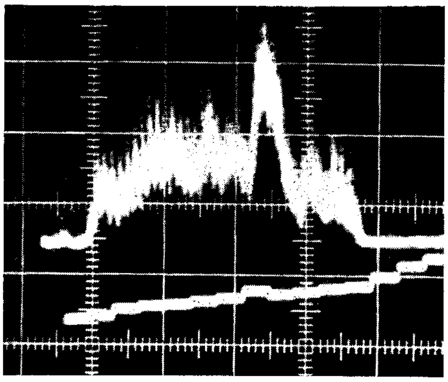
1. The beam stretching system at the Gatchina synchro-cyclotron uses Cee and Dee electrodes. The variation of their frequencies with time is shown in the figure — the Cee frequency being represented by the thick line at the bottom and the Dee frequency by the thin line. From t_1 to t_2 (100 μs) they are in phase. The Dee then returns to accelerate more protons while the Cee continues to eject beam from t_2 to t_3. The Cee frequency then moves back to line up with the Dee frequency.

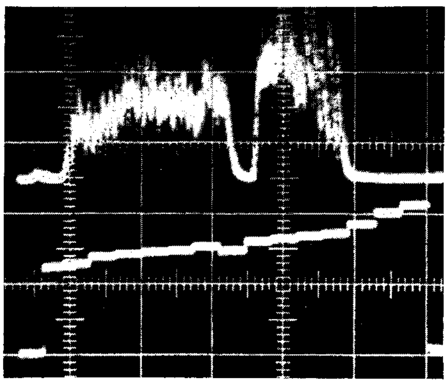
2. The upper trace on this scope picture is of the extracted beam intensity while using the beam stretcher (one division is 2 ms). Below is a signal corresponding to the voltage applied to the Cee electrode.

3. and 4. These are similar pictures to figure 2 but show how tricks can be played with the extracted intensity at any time by varying the voltage on the Cee electrode.









work has given graphs which will help in taking important decisions. As a rough indication, the studies have shown that with a concentration of 10^{-13} or above no-one should go for a deuterium bubble chamber experiment without both eyes open.

GATCHINA 1 GeV synchro-cyclotron

The 1 GeV synchro-cyclotron at the Joffe Physico-technical Institute at Gatchina near Leningrad accelerated its first beams in November 1967. Regular operation for a full experimental programme with beams up to the peak energy of 1 GeV (the highest energy achieved so far by any synchro-cyclotron) began in 1970. The machine schedule now has two weeks of operation followed by a one week shutdown and, during operational periods, only 5 % of the time is lost through faults.

Internal accelerated beam intensity is 0.4 to 0.5 μA and the machine repetition rate is 48 Hz. Extracted intensities are 0.1 to 0.15 μA and secondary particle beams are drawn from external targets so as to minimize induced radioactivity problems inside the accelerator itself.

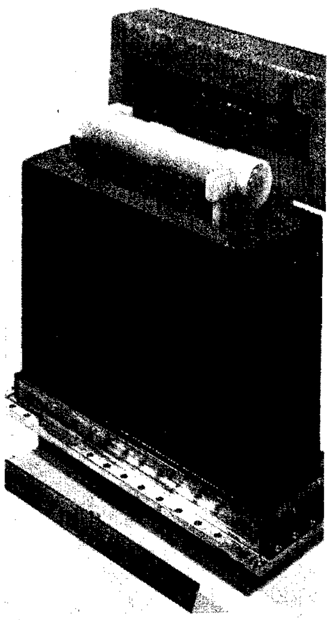
A 'beam stretching' system similar to those in use with other synchro-cyclotrons makes it possible to extract protons over the greater part of the machine cycle. This is done by powering a Cee electrode in addition to the normal Dee accelerating electrode. During 100 μs the Cee is in phase with the Dee during which time it gets hold of the particles accelerated by the Dee. Then, while the Dee system returns to start a new acceleration cycle, the Cee is powered with a separate frequency programme which serves to eject the beam slowly. By adjusting the voltage on the Cee the ejected intensity can be temporarily raised or lowered during the ejection as indicated in the photographs. As a new acceleration cycle is accomplished by the Dee the Cee frequency is again brought in line with the Dee and the process recommences.

An unusual feature of the Gatchina synchro-cyclotron is that the Cee electrodes can also be used to give a vertical deflection of the beam by applying a fast pulse to one of the two plates. This enables the beam to be kicked onto an internal target situated off the median plane where it produces a 70 μs burst of neutrons. The neutrons are used in time of flight measurements. A similar kicker system operates in the synchro-cyclotron at Harwell but not using the same pair of electrodes for the two modes of operation.

Typical beam intensities for the experiments are 8×10^{11} protons per second, yielding secondary fluxes of 10^6 positive pions and 10^5 negative pions per second. There is a polarized proton beam and other experimental facilities include a heavy liquid bubble chamber (fed by a proton beam) and a hydrogen bubble chamber (fed by the polarized proton beam).

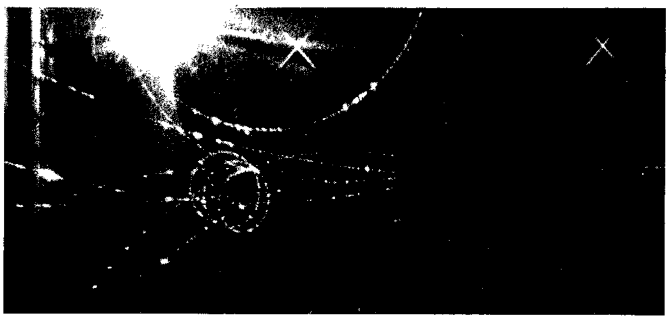
The experimental programme covers the usual topics of study at synchro-cyclotron energies — particle physics (particularly proton-proton scattering and pion-proton interaction), nuclear physics (scattering off nuclei, production of light nuclei), fission, radio-chemistry (off-line at present) and medical research (proton therapy).

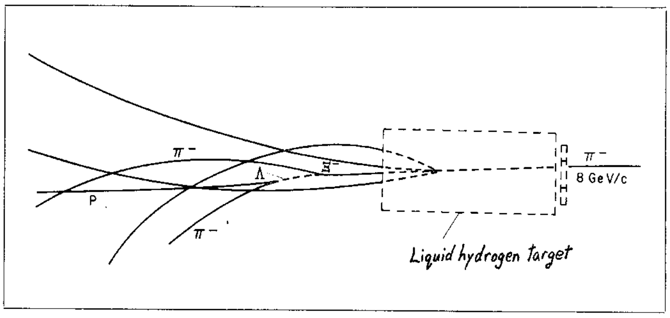
Foreseen improvements at the machine include the installation of a new rotary condenser which is now under construction. This is designed to increase the accelerating voltage and the repetition rate of the accelerator and should increase the intensity by a factor of two or three. Much higher intensities than that could not in fact be tolerated because of the radio-



The foam insulated liquid hydrogen target used in the streamer chamber at Argonne. The target is seen here before the foam end-cap was put in place. The nylon support structure and feed line for the Mylar flask are visible on top of the polyvinylchloride foam block. This target design seems to have eliminated the flare and voltage problems encountered previously.

(Photo Argonne)





An interesting event recorded in the Argonne streamer chamber. The interpretation is that a Ξ⁻ has been produced in the hydrogen target and subsequently decayed to give a lambda which itself decayed to give a high momentum proton which leaves the chamber and is the trigger for photographing the event. About five candidates for this type of event have been observed in the 1 % of film from the experiment which has been scanned so far. The possibility of studying Ξ production in this way is now under discussion.

activity problem. By 1974 it is hoped to have a muon channel installed. There is also discussion about an ISOLDE-type facility — an on-line isotope separator to extend the radio-chemistry research.

ARGONNE First streamer chamber experiments

The first experiments have begun in the streamer chamber facility built by an Argonne — University of Illinois collaboration at the Zero Gradient Synchrotron. The chamber has a volume of 1.5 × 1.0 × 0.6 m³ and is located in a 1.45 T magnetic field. The experiments are using an 8 GeV/c negative pion beam to study baryon exchange mechanisms by observing the backward production of bosons with masses up to 2.5 GeV. The trigger requires a high momentum proton to emerge downstream of the chamber. The initial exposures consisted of 113 000 pictures with a liquid hydrogen target and 52 000 pictures with a liquid deuterium target.

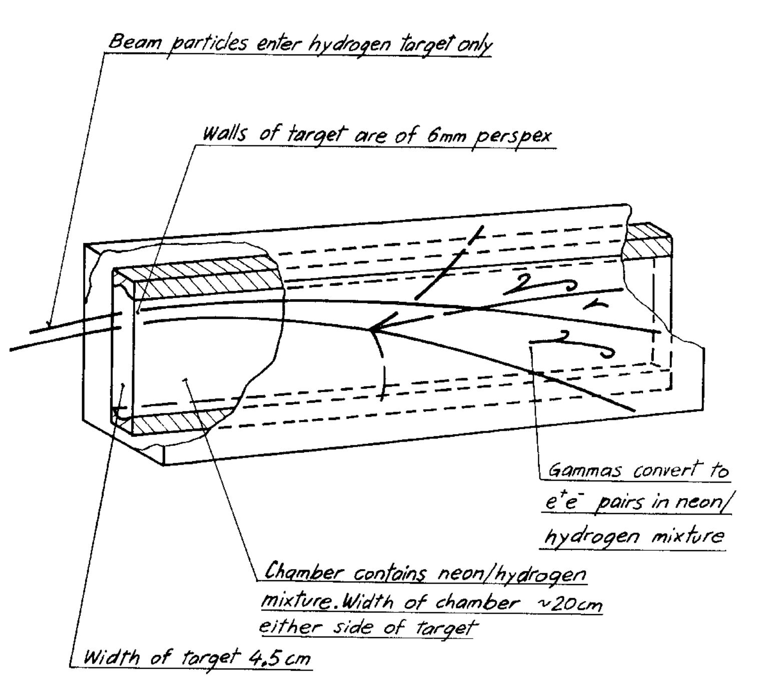
A new feature of the chamber was the successful operation of a foam-insulated liquid hydrogen target within the sensitive volume of the chamber next to the high voltage electrode. Previous designs which used evacuated plastic boxes around a Mylar flask have led to flaring problems in the chambers and occasional destructive high voltage breakdowns. None of these high voltage problems was encountered with the foam-insulated design.

Analysis of the film taken in the experiments is now proceeding. The automatic measuring system at the University of Illinois, DOLLY, will process most of the data.

Another streamer chamber recently to have begun physics is a UCLA-Berkeley chamber in operation at the Bevatron. This chamber is 1.28 m long. The first experiment began in the Spring looking at the pion decay of the X° meson. The distributions of the positive pions and negative pions emerging from the decays should be identical if charge conjugation in the electromagnetic interaction is valid (see vol. 6, page 171). The data taking is now complete with about 150 000 pictures. Performance of the chamber has been very good.

STANFORD Experiments with ultra-high fields

The synchrotron radiation phenomenon, the emission of radiation as an electron follows a curved trajectory, *Schematic diagram of the track sensitive target facility at the Rutherford Laboratory. The 1.5 m bubble chamber has been converted to operate with a hydrogen volume contained within a hydrogen/neon mixture both liquids being sensitive to the passage of charged particles simultaneously.*



is being put to use in many electron Laboratories (see the review in the April issue, page 130). For electron synchrotron energies and magnetic field levels, the radiation energy distribution can be theoretically calculated on a semi-classical basis and lines up well with observation. At much higher energies and fields, however, more sophisticated quantum electrodynamic concepts become important. A Stanford/Illinois Institute of Technology team have used high energies and fields to push the study of the radiation reaction into a new range.

Megagauss fields (100 T) were created in small volumes using several techniques. Such high fields involve tremendous forces on the field-producing components so that they are one-shot, self-destructive systems. One system used in the experiment was the discharge of a low inductance capacitor bank through a single turn coil. A special one-shot switch passed current from the bank to the coil and field rose to over a megagauss in just over 2 μs and lasted for about 0.5 μs before the coil blew apart under the forces. Coil internal diameters were typically about 0.5 cm. Another system involved the rapid compression of thin aluminium cylinders by powering a surrounding copper coil thus trapping and compressing magnetic flux. Again megagauss fields were achieved, the field rising over 10 μs and sustaining peak values for about 0.1 μs.

Electron beams from the Stanford linear accelerator (usually operating at 19 GeV for the experiment) were lined up and timed so that electrons entered the few millimetres of field volume during the brief intervals when peak fields were reached — quite a tricky exercise in synchronization. The magnetic bremsstrahlung, or synchrotron radiation, produced as the electron trajectories were curved in the high fields, was detected by nuclear emulsions. Emulsions were used in order to catch the brief high intensity bursts — about 5×10^6 photons were produced in 0.1 μs and a fraction (about 4×10^3), converted to electron-positron pairs in the emulsions. Measuring the pair energy distribution leads back to the original radiation spectrum.

Results from these experiments at Stanford are to be published soon. They have taken the study of synchrotron radiation from 6 GeV, 6 kG levels to 19 GeV, 2 MG levels. The people involved were T. Erber, R. Gearhart, H. Heckman, F. Herlack, M. Mashkour, R. McBroom and J.J. Murray. At present a similar experiment is being planned for the electron facility at Batavia (see volume 11, page 328). The facility is designed to provide electrons of 100 GeV and over.

RUTHERFORD Target experiment

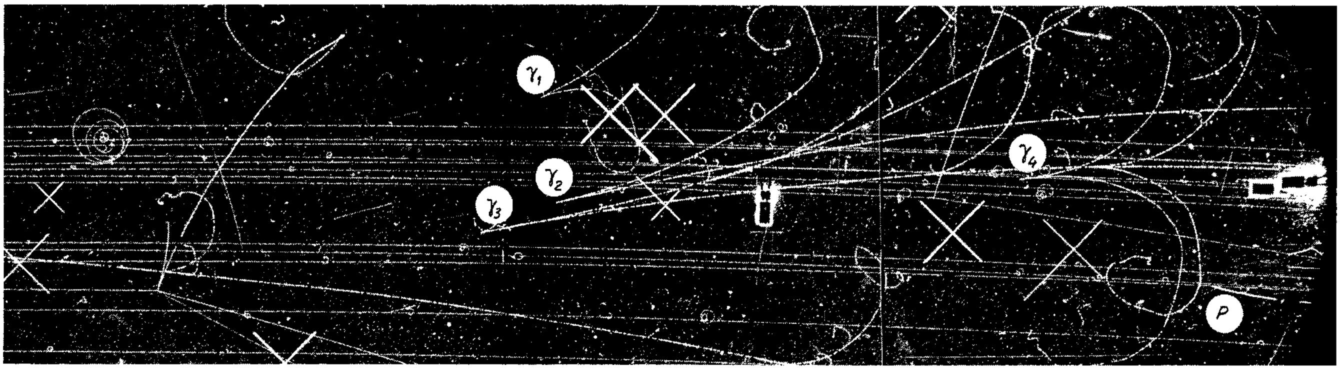
The first physics experiment is now under way at the Rutherford Laboratory using the 'track sensitive target' facility in the 1.5 m bubble chamber. This facility was described in vol. 11, p. 356. It consists of a region of pure hydrogen contained in a perspex bag inside the bubble chamber which is filled with a neon-hydrogen mixture. (The set-up is illustrated schematically in the drawing.) The advantages of having interactions occurring on free protons in hydrogen are thus combined with efficient gamma detection in the short radiation length heavy liquid mixture.

A significant advance has been achieved this year with the successful operation of the system using a mixture with a high concentration of neon (70 mole % neon in hydrogen ; radiation length 44 cm). Operation of the facility depends on being able to make the two liquids, hydrogen and neon-hydrogen, simultaneously track sensitive with essentially the same conditions of pressure and temperature.

A picture taken using the 70 mole % mixture with a 4 GeV/c positive pion beam from the 7 GeV proton synchrotron, Nimrod, is shown. Track quality both inside and outside the target is excellent. The tracks in the hydrogen show the typical effects of 'running hot' (small bubbles at high density), whilst the neon-hydrogen mixture is 'running cold' (the tracks having large bubbles with lower density). It is obvious which media the tracks are in and the position at which they penetrate the perspex can be seen.

The track quality is quite satisfactory for physics and useful bubble density information can be obtained in the hydrogen — see for example the proton track from the elastic scatter at the downstream end of the photograph. Preliminary results on track reconstruction through two additional

A photograph taken in the track sensitive target facility demonstrating its ability to spot gammas. Can you spot where the tracks pass through the perspex wall of the target ?



perspex layers show no particular difficulties.

By the end of the Nimrod cycle which finished on 8 August, 220 000 pictures to study the positive pion-proton interaction had been taken using the 70 mole % mixture. The primary interest in the experiment is the study of the $\pi^0\pi^0$ system through the $\Delta^{++}\pi^0\pi^0$ final state — hence the advantage in being able to spot the gamma rays, arising from the pion decays, as the gamma rays convert to electron-positron pairs in the mixture. The experiment is a collaboration between the Rutherford group, the Lawrence Berkeley Laboratory, Turin and CERN.

The track sensitive target technique is now well proven and further experiments are planned for the Rutherford facility (see the January issue page 15). There is also considerable interest in the technique at other Laboratories.

Hearings on USA high energy physics budget

The printed record of the 'Hearings' held earlier this year before the Joint Committee on Atomic Energy was made available on 14 July. The main subject discussed was the budget for the USA high energy physics programme for fiscal year 1973 (beginning 1 July) — its justification and implications. In the course of Hearings of this type many aspects of the high energy physics programme are probed by the Committee who keep a watching brief over this field on behalf of the US Congress. We select just a few topics here, slightly doctored for consumption by a wider audience.

Laboratory budgets for 1973

The Atomic Energy Commission put forward for authorization a total high energy physics budget of $126.4 million for operating expenses, compared with the $116.4 million estimate for 1972. This is broken down between the Laboratories as follows, with last year's figures in brackets (figures in millions of dollars) :

CEA, Cambridge Electron Accelerator	2.20	(2.25)
AGS, Brookhaven proton synchrotron	24.70	(22.65)
ZGS, Argonne proton synchrotron	15.35	(15.65)
Bevatron, Berkeley proton synchrotron	15.20	(15.50)
SLAC, Stanford electron linac	25.20	(23.95)
200 GeV, NAL (Batavia) proton synchrotron	19.20	(12.65)

plus 24.55 (23.85) for general research and development. Note that the 12 GeV electron synchrotron at Cornell is funded by the National Science Foundation and therefore does not appear in this list.

In addition to the operating funds there are $45.8 million for construction projects, of which $42.8 million is to complete construction of the Batavia machine (where $250 million was authorized for construction at the beginning of the project but has not yet all been allocated), and $27.5 million for capital equipment.

Overall, these figures represent a small increase on those for 1972 but no more than will be eaten up by cost of living increases. If they are allocated in full however, they would halt the downward trend which has prevailed in the USA since 1968 and which has driven the Princeton accelerator to the wall, cut Cambridge to the bone and resulted in Argonne, Berkeley, Brookhaven and Stanford working well below full potential.

AEC report

In the context of diminishing budgets the Joint Committee had asked the AEC to examine the minimum level of support necessary to keep the high energy physics Laboratories viable and to develop a priority listing of which accelerators should be kept operating should future funding be less than the minimum necessary to effectively support each of the six Laboratories. The AEC presented to the Joint Committee for the Hearings a report entitled 'Considerations for a Viable and Productive High Energy Physics Programme'.

The AEC gave as their best estimate at this time of the relative priorities of the accelerator facilities — 1) NAL, 2) AGS and SLAC, 3) ZGS and Bevatron, 4) CEA. (Again note that Cornell is not under consideration.) They stressed however that if a decision to cut was forced on the AEC it could prove better in terms of programme balance not to axe the lowest priority facility. (The problem was expressed as 'somewhat like the task of determining which has greater priority, the right leg or the left arm' !)

The high energies of 200 GeV and above at NAL are recognized as providing the greatest potential for new discoveries. The 21 GeV electron linac at SLAC provides electron beams of unique energy and intensity and is being supplemented by an electron-positron colliding beam facility SPEAR (see May issue page 167). The 33 GeV Brookhaven AGS is nearing the end of a major improvement programme and is surrounded by a versatile range of beams and detectors. The Argonne 12 GeV ZGS has unique advantages for accelerating polarized protons and feeds the 12 foot hydrogen chamber. The 6 GeV Bevatron has new capabilities for the acceleration of heavy ions (see vol. 11, page 252). The CEA accelerator is currently specializing in electron-positron colliding beam physics in the Bypass scheme.

A sketch of minimum budgets for the next five years (through to fiscal year 1977) which would keep all the accelerators in operation shows the operating budget of NAL growing considerably as the experimental programme gets well under way (from $19.2 million projected for 1973 to $43.0 million in 1977 — which would still only support operation at about 70 % of potential). Brookhaven and SLAC would increase a little to make use of the new capabilities provided by the improvement programme and SPEAR respectively. The other Laboratories would remain on constant budgets.

Long-term, new construction projects will need support to keep the facilities in the front line of research and several candidates are mentioned in the report — SLAC recirculator scheme, 25 foot bubble chamber for NAL, Electron Ring Accelerator, NAL energy doubler, high energy colliding beam rings.

Justification of research

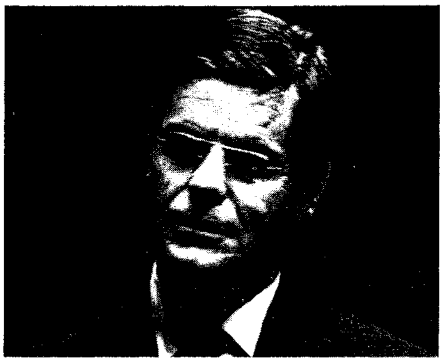
To conclude these few paragraphs, which are drawn from Hearings reported in a volume of 2300 pages, on a more lively and optimistic note, it seems worth presenting the replies of three of the spokesmen for high energy physics in which they promote the value of research.

Despite the recognition that the USA Laboratories are capable of much more and in some cases are being pushed to the brink of viability, it should be appreciated that a very large sum, close on $ 200 million, is being requested for high energy physics. The ultimate value of such expenditure for a branch of pure research is difficult to define clearly. This was recognized at the Hearings by V.F. Weisskopf, Chairman of the High Energy Physics Advisory Panel, and one of the foremost advocates of support for pure research. Representative C. Hosmer was in an appropriate mood to be Devil's Advocate at the Hearings having, as he put it, flown in to Washington from the West Coast the previous night on the 'Red Eye' flight. He pressed Professor Weisskopf saying 'You are never satisfied'. The reply was 'Fundamentally, I am deeply satisfied and appreciate that this kind of science is getting the support it gets. It is great. It shows how much idealism and foresight is still around. Of course we feel that this programme could be and should be supported more than it is but I think that it is great that we get these hundreds of millions for the increase of fundamental knowledge.'

Elsewhere in the Hearings Professor Weisskopf justified expenditure on high energy physics saying 'I think the significance of fundamental science is usually underestimated because one is only looking at the direct, immediate results. A vigorous scientific programme at the frontier of science establishes an intellectual climate in the scientific and technical community. This frontier offers new kinds of challenges. It produces technical and scientific experts — people who are steeped in an atmosphere of challenge, facing great unknown problems. A vigorous fundamental science creates a certain intellectual level to which all scientific and technological activities must, and do, adjust. This is often forgotten. It is no accident that a country is a leader not only in practical and technological developments, but also in fundamental science. If it is neglected there are bad long-term effects.'

Representative Hosmer asked Professor W.K.H. Panofsky, Director of the Stanford Linear Accelerator Centre, whether he thought the high energy physics pleas seemed 'anachronistic in relation to the public mood.' Professor Panofsky replied 'Many of the social problems which we are facing, the environmental and other problems, ultimately amount to the question as to how man can live in harmony with nature. I fundamentally believe, as a matter of faith, that the decision making on how to live with nature will be taken more intelligently on the average if we understand nature in its deepest aspects than if we don't... In the past, material advances have resulted from such work and will again

Spokesmen for high energy physics at the Hearings of the USA Joint Committee on Atomic Energy — left to right, V.F. Weisskopf, W.K.H. Panofsky, R.R. Wilson.



in the future. I cannot point a clear path from the discoveries which are made today in this field to specific material gains, but science has never failed to work that way in the past. To take a humble example — if at the time of Faraday people had asked to develop better sources of light, then, at the time, a possible solution might have been to propose improvement projects for the efficiency of candles. The other way was to invent the generation of electricity. It was the invention of the generation of electricity which led to the possibility of better light, not the improvement of candles, but nobody knew that at the time.'

Professor R.R. Wilson, Director of NAL, also touched on a similar theme to Professor Weisskopf in response to Senator S. Symington who asked whether the research provided 'just additional knowledge without any practical interpretation in applied research, let alone development ?' Professor Wilson replied 'There is an aggressive attitude that I think people must have. If you sit and do not do advanced research, then you will, before long, use up the capital of present knowledge. If applications cannot be guaranteed to flow from this kind of research, what can be guaranteed is that there will be no applications at all if there is no such research.'

Professor Wilson also leaned on his favourite theme in promoting pure research, 'The first thing that one gets out of it is a cultural value, the pride and satisfaction of understanding and of discovery, making a fundamental contribution to the dignity and stature of men... The immediate value of this research is the same as the other values of a great Nation which has a literature, has theatre, has poets and painters and sculptors, composers and musicians ; those cultural things that make life richer. Scientific understanding too has inherent cultural value, it has great beauty ; it adds to the satisfaction of our lives... I am proud to have played even a small part in an activity that will become an important part in the culture of future generations.'

ARGONNE
The muon is the message

Using a muon beam produced at the 12.5 GeV Zero Gradient Synchrotron at Argonne, R.C. Arnold has passed coded messages over distances of nearly 150 m. With the high penetrating power of muons the signals could be sent along a line which passed through 2 m of concrete, a trailer containing computers and a metal building.

The experiment used a high energy muon beam obtained from the decay of pions produced at the accelerator. The muon flux was modulated into pulses by means of a chopper and the pulse modulation was done with Morse code rhythm. Counters picked up the signal 150 m away.

The muon can travel a considerable distance before interacting with other particles since it does not feel the strong interaction. With muon beam energies in the few GeV region, such as are available from the Argonne machine muon lifetimes of a few tens of microseconds are achieved and the range in air would be a few tens of kilometres. Good beam control at the emission station could give a beam which does not diverge greatly so that an array of scintillation counters about 10 m square could catch the signal at the receiving station.

The amount of information which could be transmitted would depend on the intensity of the muon beam. Up to 1000 megabits per second could be feasible with 10^9 muons per second. The pulse modulation would need to be applied with an accuracy of about a nanosecond.

Obviously other communication systems are so highly developed that no-one is going to be putting scintillation counters on his roof to receive television pictures in the foreseeable future. Accelerator costs, radiation problems, the fact that signals travel only between two points, etc., etc... all would need many years of work to make particle beam communication systems feasible. Nevertheless the principle has been shown to work and there may be applications in the future. Arnold speculates about 50 GeV muon beams sent just above the atmosphere curving in the earth's magnetic field to pass signals 1000 km. And, to add a final dash of imagination, he also speculates about communicating with neutrino beams fired straight through the earth.

BATAVIA
Beams to 300 GeV

On 16 July beams were accelerated to an energy of 300 GeV in the proton synchrotron at the National Accelerator Laboratory, Batavia. Peak energy from the NAL machine was initially set at 200 GeV but the accelerator was designed so that higher energies became possible. 200 GeV corresponds to a field of 0.9 T in the main ring magnets and up to 500 GeV might be possible if a field of 2.25 T in the magnets can be reliably achieved (though at much reduced repetition rate particularly because of the restricted cooling capacity installed).

The power supplies are capable of the higher energy operation but during the July 300 GeV run engineers from Commonwealth Edison were standing by to monitor the effect on the grid system in the region. The main magnet power supply is of the static compensator type where power flows from and to the grid and rotating plant is not used as a buffer. Operation at 300 GeV caused no problems on the grid.

When the run started the power supplies had to be tidied up following severe storms in the Chicago region two days previously which knocked out the Laboratory power several times. However, within a couple of hours of the start of operation 300 GeV beams were achieved and attention switched to feeding the beam out to the experiments.

Ten experiments have been setting up or gathering data during the past few months. They include observation of the first 200 GeV events in the 30 inch hydrogen bubble chamber (see photograph in last issue page 209). The first physics run from 21-26 June collected 37 000 pictures. The average charged multiplicity (the average number of charged particles emerging from a collision at 200 GeV/c laboratory momentum) is about 7.6 which lines up well with cosmic ray and ISR findings.

Another experiment involves a collaboration with scientists from the USSR to study elastic proton-proton scattering. It uses an internal target which was initially a thin film — 12×10^6 events at 80 GeV were collected on mylar and polyethylene and 23×10^6 events at 200 GeV on polyethylene. Now a hydrogen jet target, developed at Dubna and used at Serpukhov (see vol. 10, page 190), has been installed.

The accelerator itself is performing more reliably and beam intensity and ejection efficiency are being steadily improved. The latest news is of accelerated beams of up to 6×10^{10} protons per pulse using only one injected pulse from the 8 GeV Booster. (When the Booster is multi-pulsed it should multiply the accelerated intensity figure by thirteen without difficulty.) There is still high loss — up to 50 % — between injection and peak energy and more precise magnet alignment is under way helping to bring this down. Fast ejection efficiency has been improved up to 90 % and equipment for slow ejection should be ready in about a month's time.

From 6-13 September the Laboratory is host, together with the University of Chicago, to the 16th International Conference on High Energy Physics. We hope to carry a report in the October issue on this Conference (one of the 'Rochester Conferences' held every two years — the major conferences in the field of high energy physics).

STANFORD
SPEAR gets sharper

Performance of the electron-positron storage ring SPEAR, fed by the electron linear accelerator at Stanford, was polished considerably in the course of its second running cycle which ended in June. A luminosity as high as 10^{30} per cm^2 per s was reached.

SPEAR gave its first colliding beams at the end of April (see May issue, page 167) very soon after injection tests began. The rapid rate of commissioning continued in the second run. The peak luminosity, recorded above, was reached with 17 mA stored in both positron and electron beams and a beam lifetime of 1 ¼ hours.

Filling rates of 60 mA per minute for electrons and 40 mA per minute for positrons were achieved, which are close to the anticipated figures. At low current the beams survived for three hours. Orbit distortions were reduced to less than 10 mm peak to peak in the horizontal plane and less than 6 mm in the vertical plane.

Electron-positron rings have proved rather recalcitrant objects in the past. All the more credit to the Stanford team who, on a low budget and with a rapid construction schedule, seem to be bringing SPEAR smoothly under control.

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Video cables are manufactured as coaxial cables with a characteristic impedance of 75 Ω (in exceptional cases 60 Ω with solid insulation and are used, for instance, to connect the camera amplifier to the monitor, intermediate amplifier, radio or television transmitter.
Video cables must have very low attenuation and be homogeneous. As they are often used in lengths which, in relation to the individual frequency of the broad video band, are comparable with a unit of a quarter wave length or its multiples, it may be expected that some mismatches are present in the cable run when lengths of a different characteristic impedance are connected. This can lead to a disturbing second reflection component in the transmitted picture, so that with the video cables any deviation of the characteristic impedance must not exceed ± 1 %.
F&G manufacture these cables in many different sizes with an outer diameter from 4.8 mm to 22 mm, whereby the outer sheaths have the standardized colour coding for colour television studio operation. These cables are also manufactured as multicore or multi-purpose cables.

Camera Cables

Camera cables are used for the transmission of all pulses, video and sound signals, operating voltages, connecting and pilot functions between the camera and camera control unit required during operation.
As the biggest manufacturers of camera cables F&G, in collaboration with the German broadcasting stations and the camera manufacturers have developed colour television camera cables incorporating 3 or 6 coaxials.
The elements are twisted in units according to their function and are largely symmetrical. This construction provides the cable with the necessary flexibility and stability for studio and outdoor operation.
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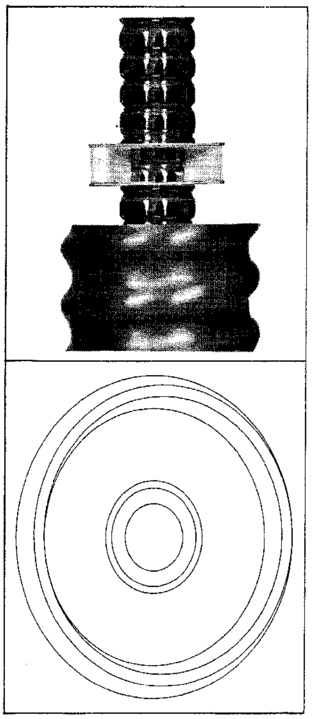

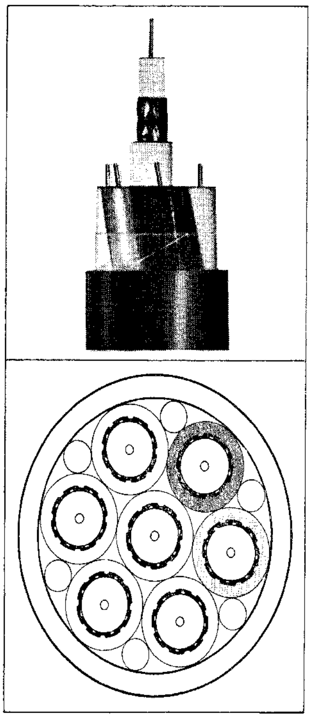

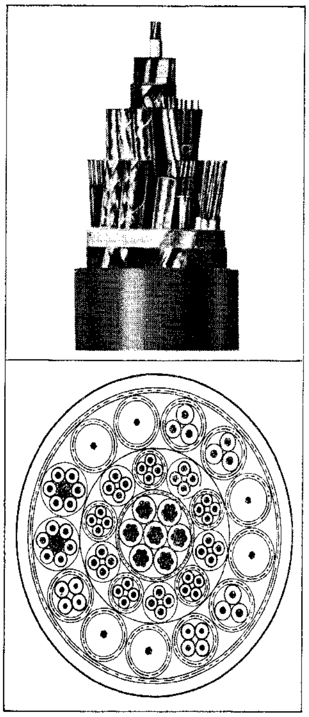

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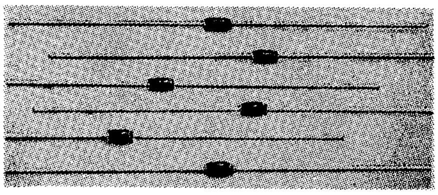

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	Vdc	V (pk)	A	25°C	100°C	Vdc (Max)	A (pk)	I_F (Surge)	Max
R1	100	100	1.0	1.0	25	1	5	25	.300
R2	200	200	1.0	1.0	25	1	5	25	.300
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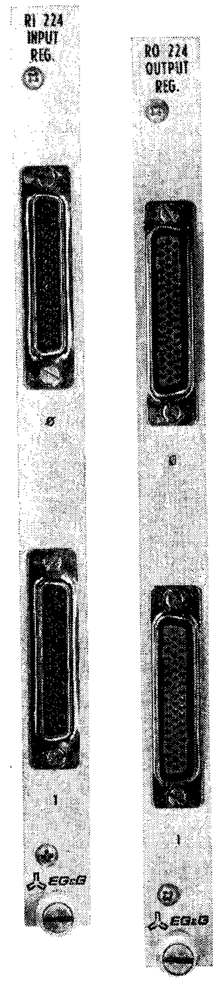

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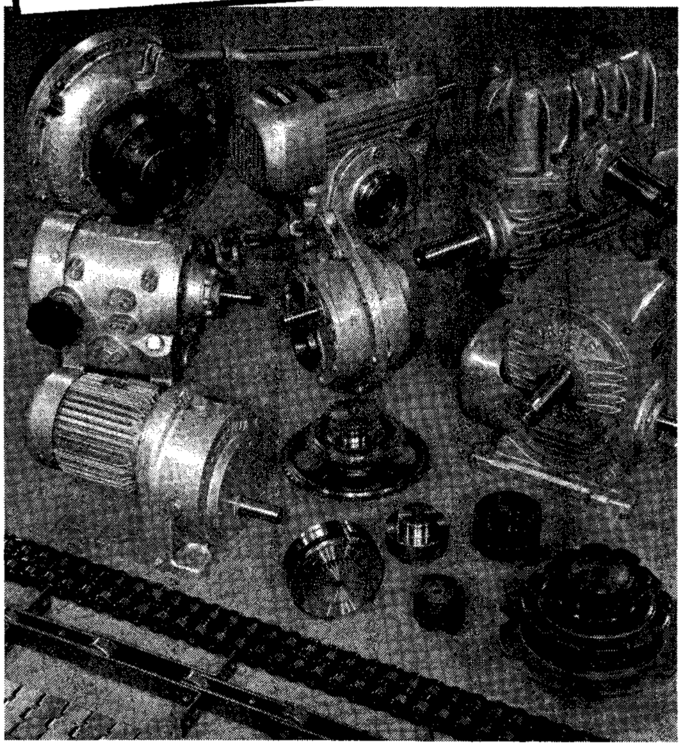

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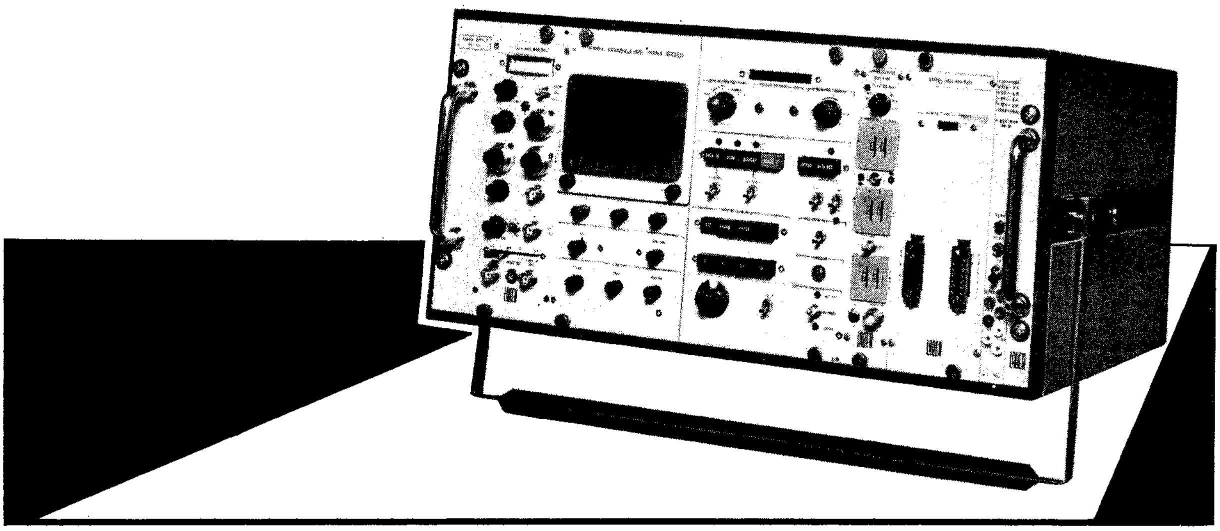

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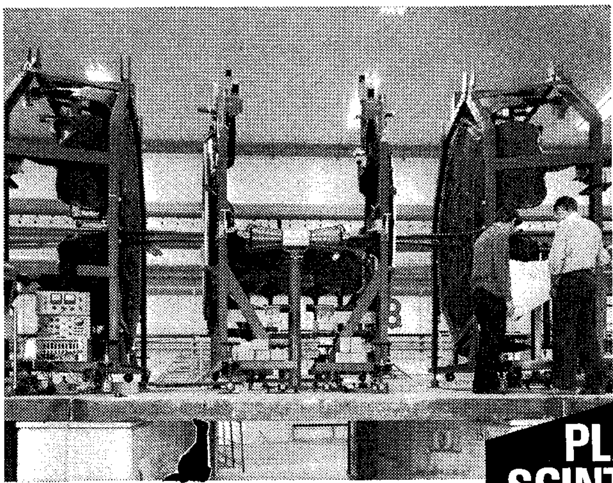
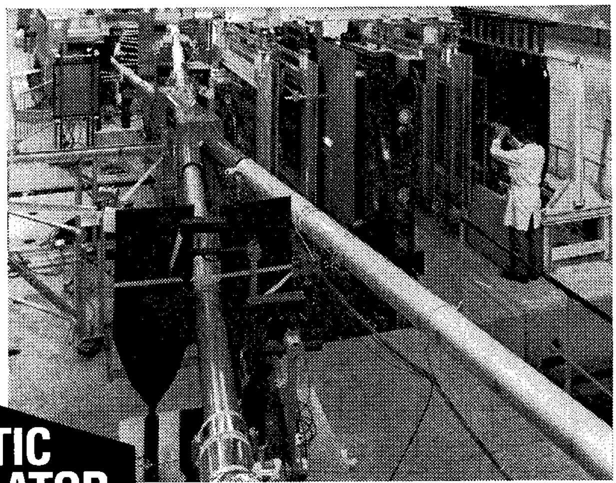
Intersection region I-8 of the ISR where the Pisa—Stony Brook collaboration system measures the total cross-section of the proton-proton interaction. Large arrays of NE 110 counters appear as large black discs around the beam-pipes. (Photo CERN)

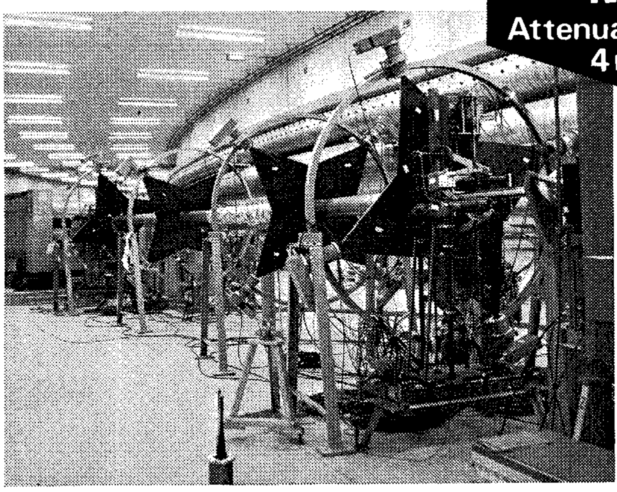


SACLAY/STRASBOURG

The detection system of the Saclay-Strasbourg collaboration in intersection region I-1 includes NE 110 scintillator. Gammas and electrons produced in the decay of particles which emerge from the collisions are recorded. (Photo CERN)

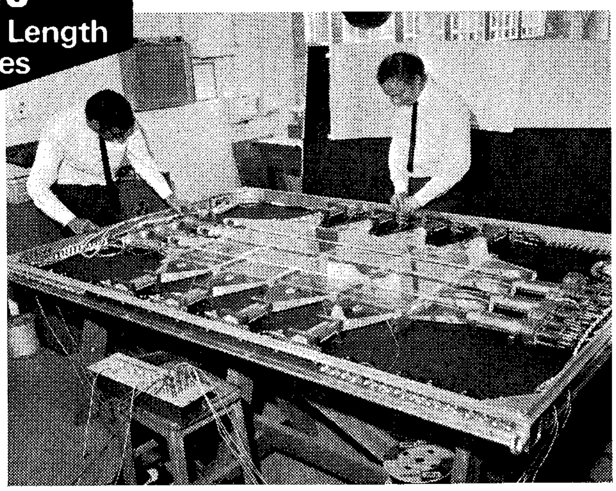


PLASTIC SCINTILLATOR NE 110
Attenuation Length
4 metres



CERN/ROME

The stars around the ISR beam pipes are NE 110 scintillation trigger counters used for a total cross-section measurement by the CERN-Rome collaboration. (Photo CERN)



RUTHERFORD/CERN

NE 110 was specified for all the plastic scintillators used in counter arrays for the Muon Experiment at the Intersecting Rings CERN, by U.K. scientists. Picture shows three counter arrays being assembled at Rutherford Laboratory, Chilton. (Courtesy Science Research Council)

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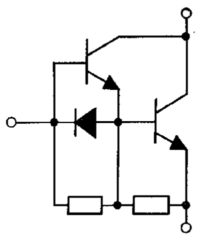

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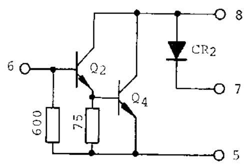

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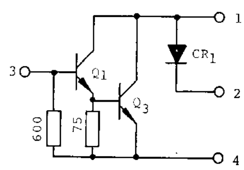

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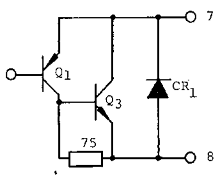

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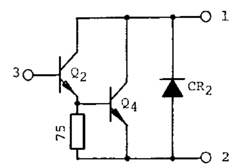

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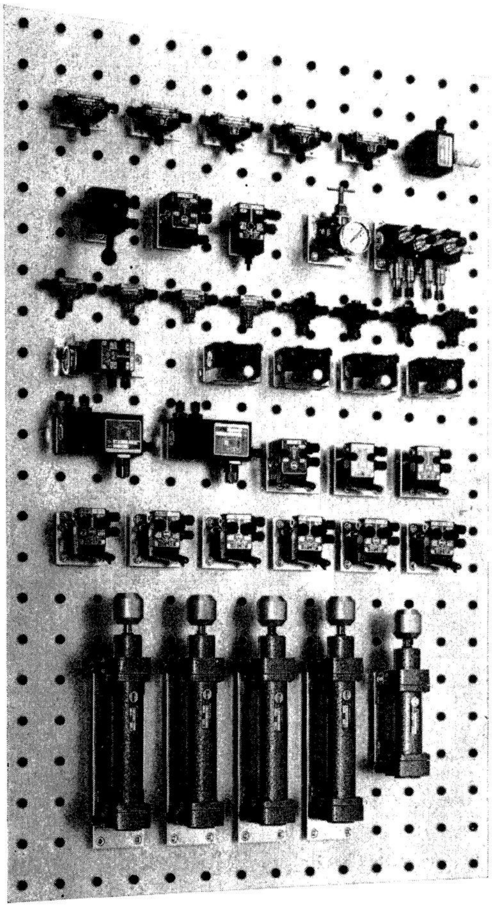

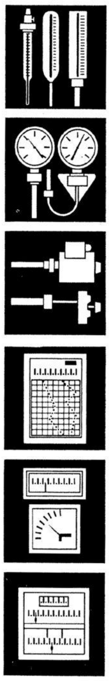

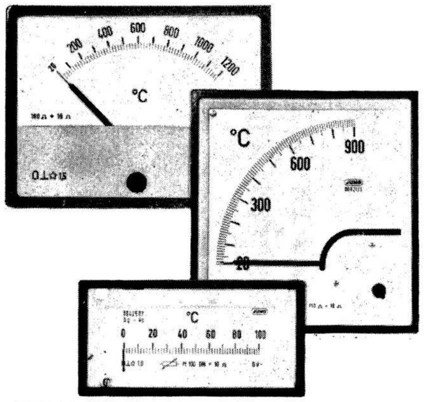

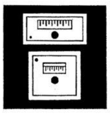

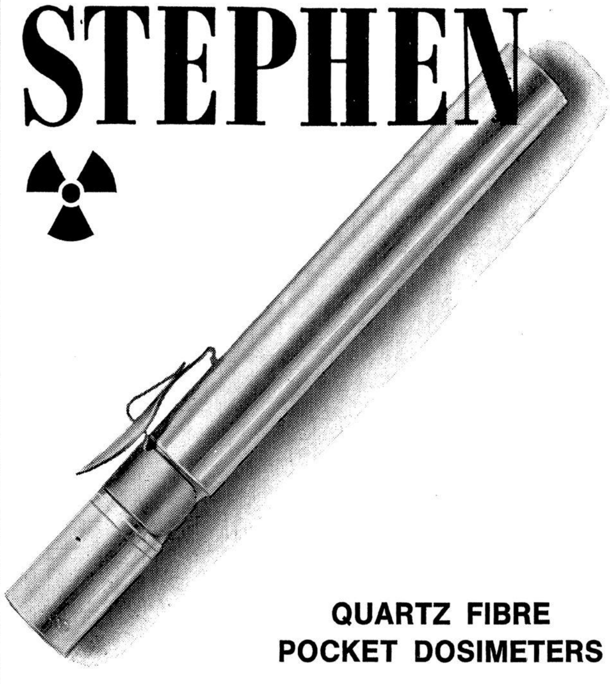

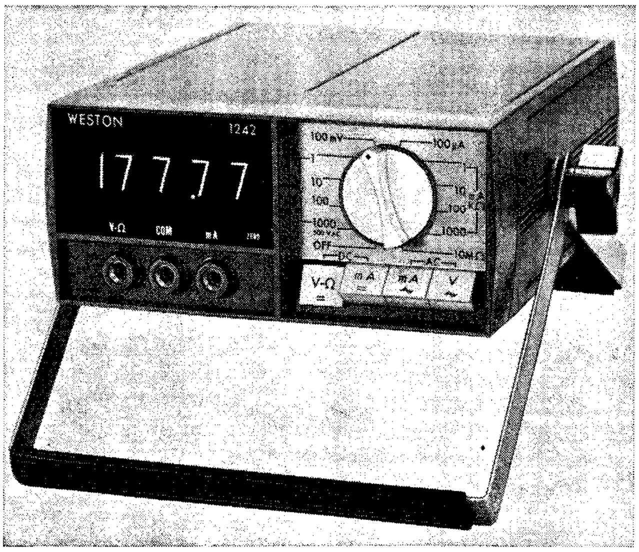

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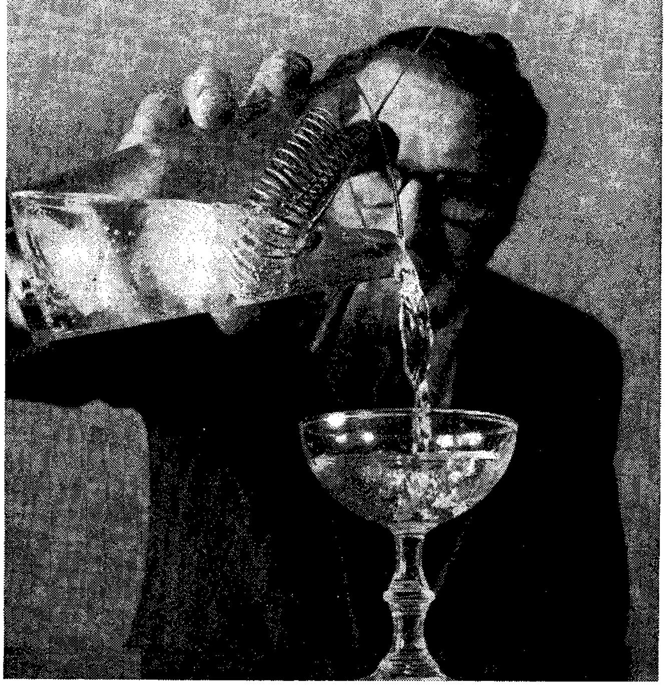
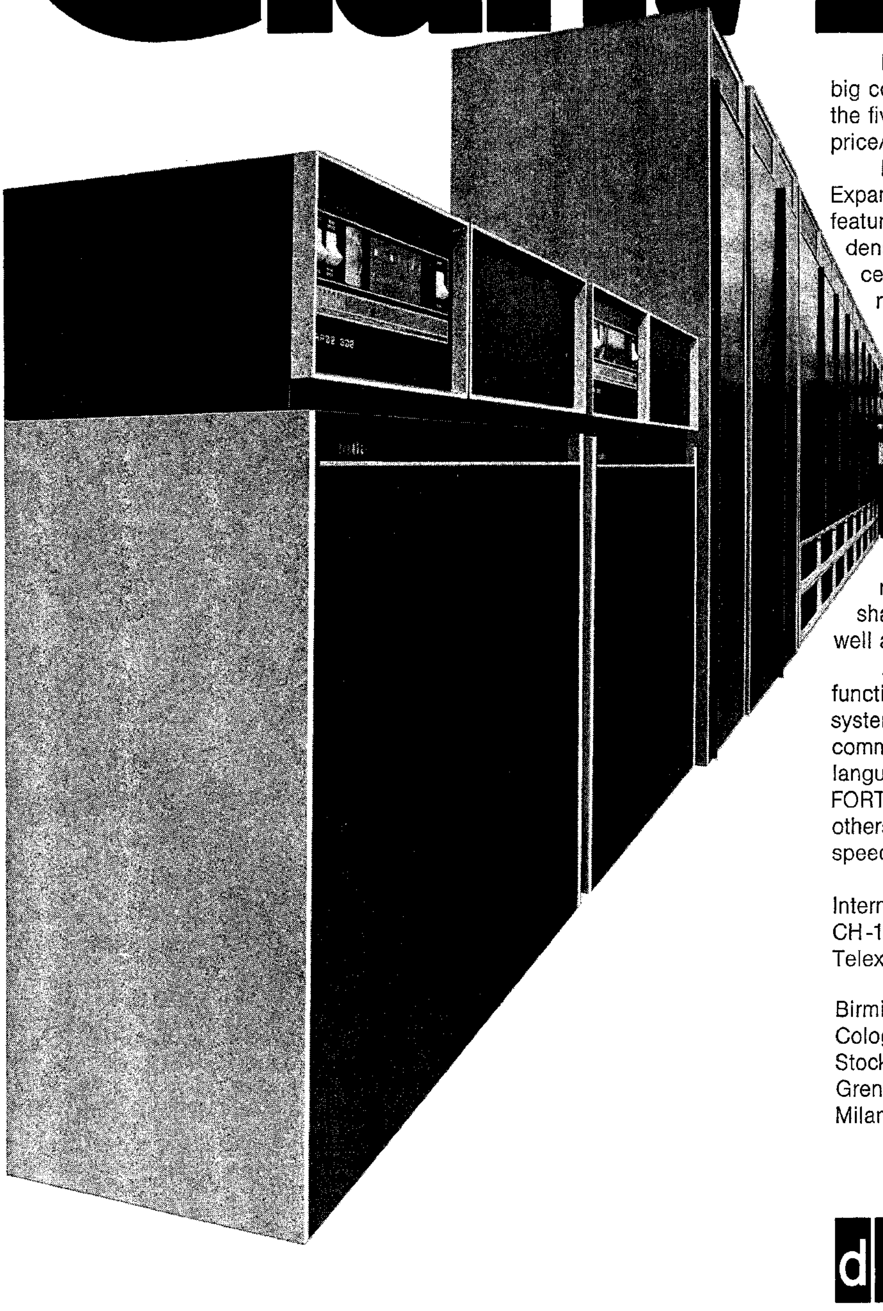


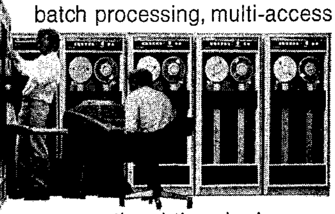
The Giant Ten



Digital Equipment's new family of big computers, DECsystem-10. Each of the five systems (2nd shown) is a price/performance giant.

New faster, bigger processor. Expanded core memories. More COBOL features. New high performance dual density disk packs. Super multiprocessor systems. Improved card readers. New magtapes. And more.

DECsystem-10 runs four functions: batch processing, multi-access



conversational timesharing, remote job entry (batch and timesharing), and real-time equally well and simultaneously.

All five systems run all four functions using the same operating system with the same job control commands. All are serviced by the same language processors COBOL, ALGOL, FORTRAN, BASIC, MACRO, and many others. The only thing that changes is speed and capacity.

Digital Equipment Corporation International-Europe, 81, Route de l'Aire, CH-1211 Geneva 26. Tel. 022/42 79 50, Telex 22683.

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digital

AIM DAC-100

10 BIT D/A CONVERTER

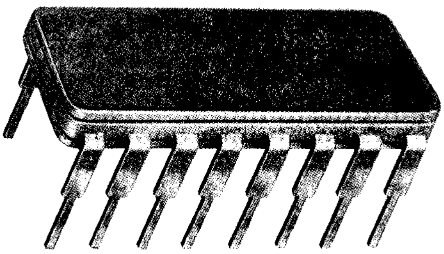
MINIATURE SIZE :
16 pin DIP or 24 lead flat pack including internal reference and resistor network

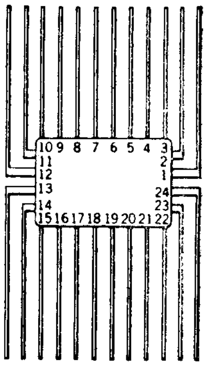
COMPATIBLE LOGIC : DTL or TTL

HIGH SPEED :
225 ns for 8 bits, 375 ns for 10 bits

WIDE VOUT CHOICE : +5V, +10V, ±2.5V, ±5V

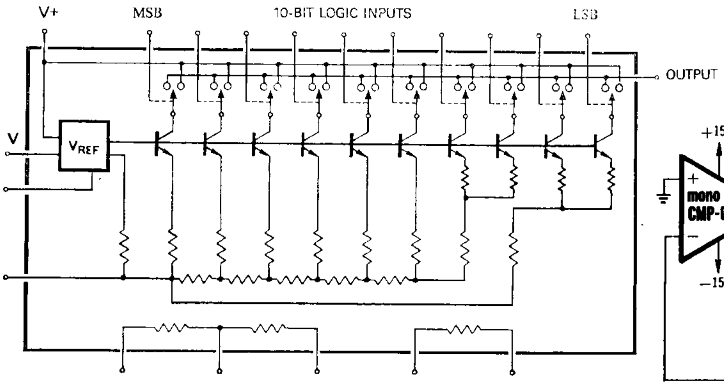
LOW COST :
Choice of 14 cost/performance tradeoffs



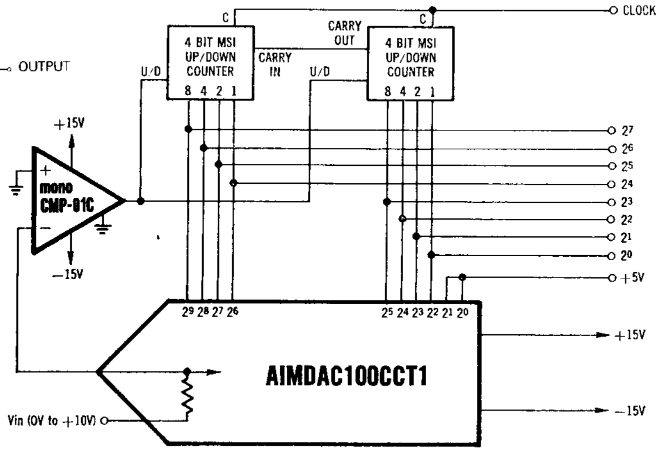


DESCRIPTION: The aim DAC-100 is a complete Digital to Analog converter packaged in a single 16 pin DIP or 24 lead flat pack. A standard digital I.C. logic level input code is accepted, providing an analog current output that is readily converted to an analog voltage with a single external op amp shunted by an internal feedback resistor. The package contains two monolithic chips. One chip provides the internal precision voltage reference plus ten weighted current sources and switches. The second chip provides a precision thin film ladder network, tracking feedback resistor, and bipolar source resistor.

Simplified schematic



8 bit A/D Conversion approach



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2. MONO CMP - 02 — Low Input Current Precision Comparator
3. MONO OP - 01CJ — Low Cost, Fast Slewing/Settling Op. Amp.
4. SSS 725CJ — Low-Noise, Low Drift Instrumentation Op. Amp.
5. SSS 741CJ — Improved Performance 741 Op. Amp.

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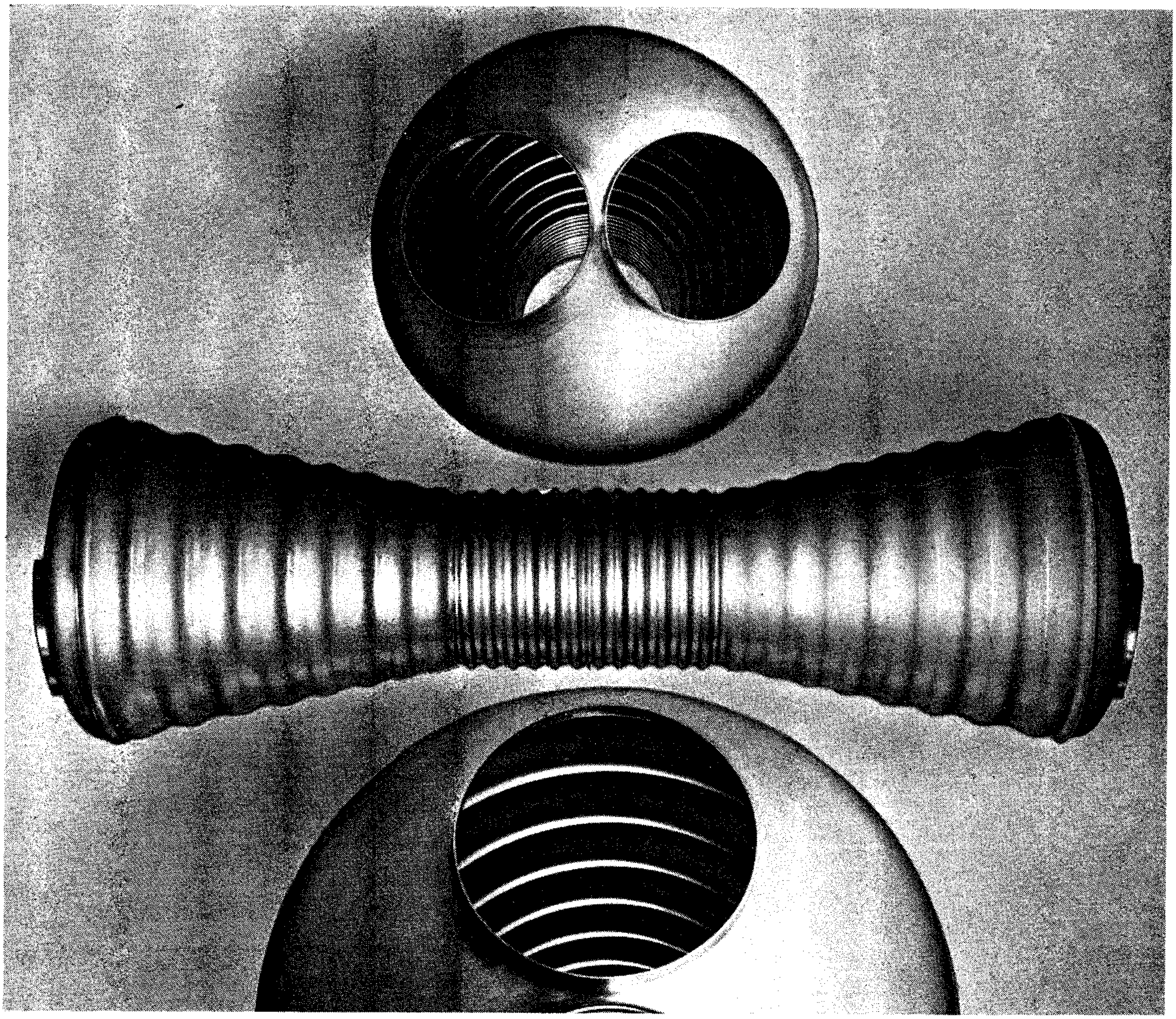

WHAT'S

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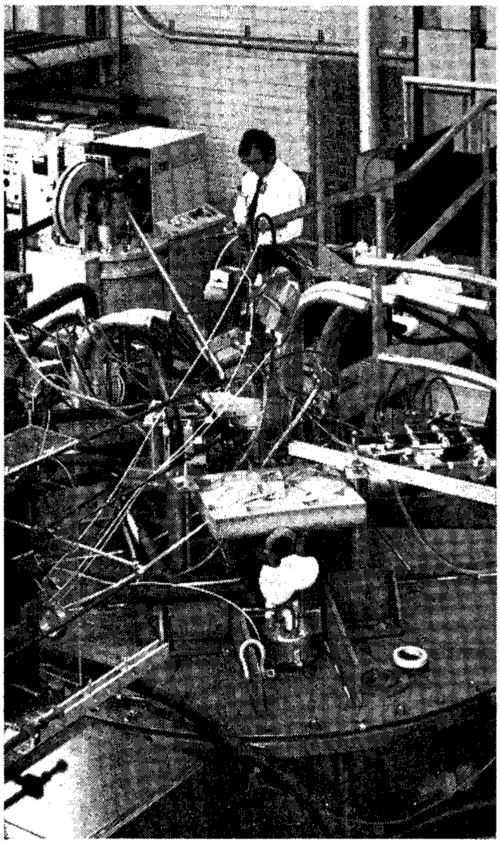
DOING AT

OAK RIDGE?

The use of thermonuclear reactions in boilers of future electric power plants is being investigated world-wide.

Scientists at Oak Ridge National Laboratory* are now engaged in a controlled fusion experiment, using a CTi Model 1400 Helium Liquefier as an important tool. An ORNL-designed superconducting mirror quadrupole magnet (10-20 kilogauss center field; 85 kilogauss maximum field at the superconductor) provides the containing field for plasma confinement.

At present, plasmas produced by electron cyclotron resonant heating reach 10^{12} particles per square centimeter at energies from 50 kev to 1 Mev.



*Operated by Union Carbide Nuclear Division for the U.S. Atomic Energy Commission.

CTi's Model 1400 provides around-the-clock capability to keep the 300-liter magnet dewar full. It handles with ease the 10 liter-per-hour heat leak into the liquid helium.

The Model 1400 was designed with superconducting systems in mind, and will run continuously for weeks between simple, routine maintenance periods. It can produce from 5 to 40 liters per hour of liquid helium, 20 to 100 watts of refrigeration at 4.5°K, 100 to 350 watts of cooling at 20°K, and can be modified for hydrogen or neon liquefaction.

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