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 scientifice and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 700 physicists outside CERN are provided with their research material in this way.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2350 people and, in addition, there are over 400 Fellows and Visiting Scientists.

Thirteen European countries participate in the work of CERN, contributing to the cost of the basic programme, 197.5 million Swiss francs in 1968, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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Comment

This issue (pages 103-109) contains accounts of some of the work of the Rutherford and Daresbury Laboratories in the UK. These are the Laboratories referred to by Professor B.H. Flowers at the CERN Council Meeting in December 1967, when he said that the UK was very ready to consider how its national centres could be used on a European basis.

Their particular interest in such a scheme stems from the priorities clearly laid down by the UK delegation at recent Council Meetings (1) 300 GeV, (2) CERN Meyrin, (3) National Laboratories. Confronted with a ceiling on expenditure for sub-nuclear physics, the attitude seems to be that the international projects, where the real frontier work is going on, must have first claim, because without them the other work has little meaning in the long term. Most existing national Laboratories would in any case change their character in the shadow of a 300 GeV machine, and it seems an appropriate time to confront the ideal of full integration of such Laboratories in a single pool of European facilities.

The European Committee for Future Accelerators has twice had a broad look at the European programme in the course of evaluating the cornerstone of this programme for the future — the 300 GeV project. ECFA suggested some desirable machines for national projects (though it was outside the Committee's terms of reference to recommend particular projects to particular countries) and recommended that 'each particle accelerator should, as far as possible, be exploited on an international basis, even when the accelerator has been built by a national organization'. ECFA also intends to discuss national accelerators at a future meeting.

Close collaboration has, of course, always existed. There is regular exchange of scientists, free access to information and representation on committees of other Laboratories, and there have been some major operations such at the shuffling of bubble chambers from one Laboratory to another.

Nevertheless, national Laboratories are national Laboratories. Obviously, selection of the type of machine for such a Labo-

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Cover photograph: Inside the ring tunnel of the intersecting storage rings. This impressive structure is advancing around its circumference at the rate of about 15 m per week. So far about one octant (120 m) has been assembled since 1 March. The tunnel has a radius of 150 m and is 15 m wide and 7 m high. It is constructed mainly of prefabricated blocks, weighing about 50 tons each, lifted into place by a giant crane standing astride the tunnel. The scaffolding which can be seen in the photograph is used in positioning the blocks and moves around in step with the construction work. The main contractor for the civil engineering of the ISR is Sogene, Italy. (CERN/PI 163.4.68) ratory and the selection of experiments for the research programmes take account of what is happening elsewhere and a fairly logical list of complementary machines and programmes have been established. But, as costs and manpower requirements rise, and as machines and their related instrumentation become more and more sophisticated, the time seems ripe for fuller integration.

The practical difficulties are considerable. The research programmes of national machines are at present almost entirely filled from the local Universities — would the national Universities suffer from internationalization of the Laboratories? How would the financing of a Laboratory be organized, if one country were encouraged to build a particular machine there, while other countries made extensive use of it? How would Laboratories cope with large teams of foreign scientists in terms of language, education of children, accommodation etc., without being geared to meet these problems almost to the extent of CERN itself? What body would recommend a particular machine for a particular country? Would that body ever be able to tell a country that it ought to shut a machine down? Who would control the research programmes in such Laboratories?....

But to confront these problems may prove to be very important. Faced with limited resources, some overall plan should ideally operate. Let us hope that when the sun of the 300 GeV machine finally rises it will be surrounded by an orderly array of satellites.

Gargamelle

CERN's new heavy liquid bubble chamber

In the April issue of CERN COURIER we reproduced a photograph of the arrival of the first piece of the new heavy liquid bubble chamber 'Gargamelle'. The 140 ton base-plate for the magnet was towed onto the site by two tractors in a 48-wheel convoy on 31 March. It seems an appropriate time to say something about this significant addition to CERN's research equipment.

Its use

Gargamelle has been conceived principally as an instrument for research on neutrinos. The fascination of these elusive particles has been brought out in several previous articles in CERN COURIER (see particularly the article by C.A. Ramm, vol. 6, p. 211). They are the most abundant particles in the universe and their study will tell us much about the weak interaction, the only one in which they take part. Their interactions are so rare that ten years ago, our present ability to observe neutrinos was unimaginable. By 1963, it had become possible at high-energy accelerators, where large, refined detection equipment was already in use, to 'see' about one neutrino an hour from the millions that the accelerator produced. This will have increased by the early 1970s to something like 10 000 per day and the study of neutrinos will be on the same footing as that of most other particles. At CERN, Gargamelle will be one of the important contributors to this advance.

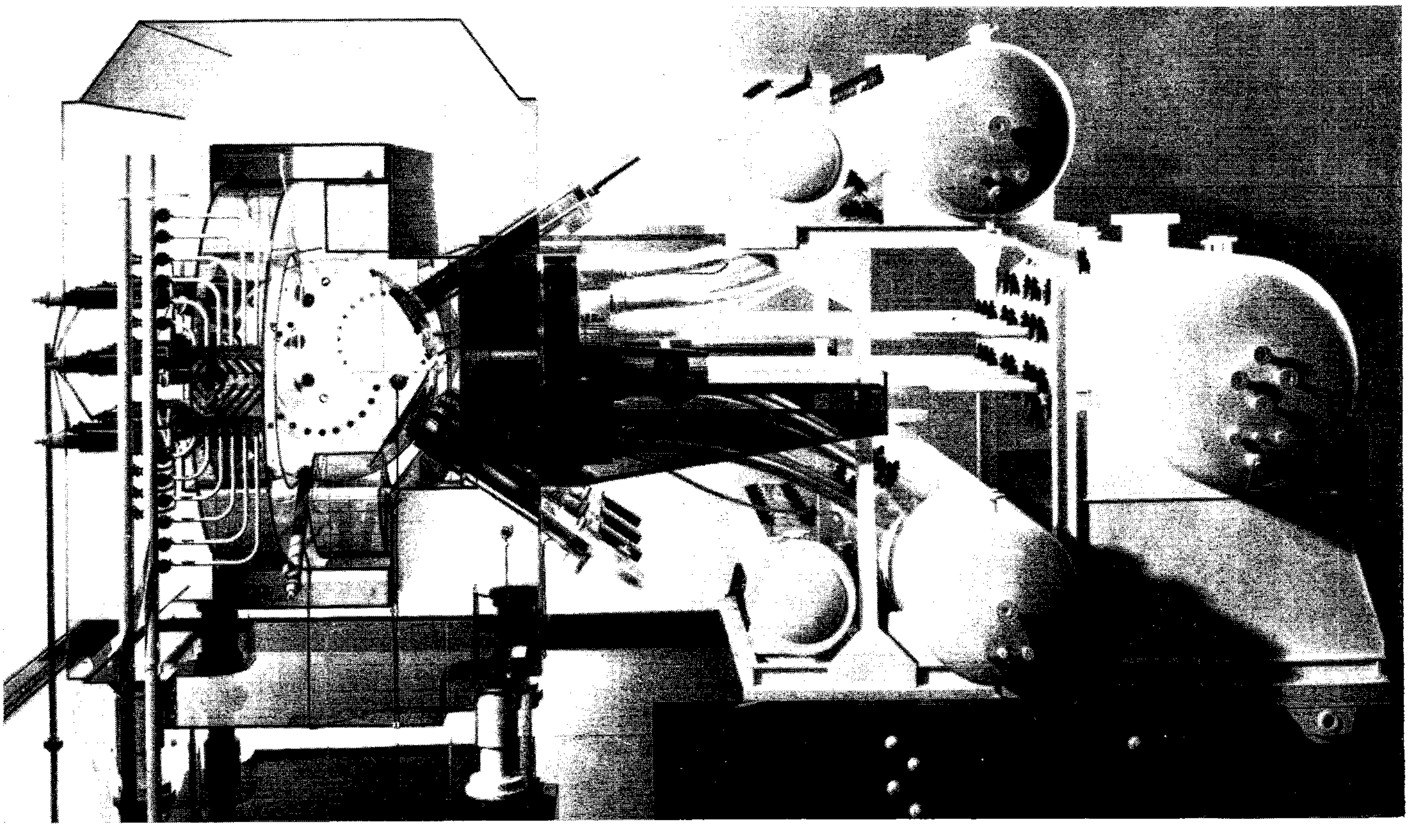
For neutrino experiments, a heavy liquid bubble chamber has two advantages over a hydrogen bubble chamber:

i) It presents a more dense target so that there are more particles with which the neutrino can interact;

ii) The distance a neutral particle travels in the liquid before producing charged particles (which leave tracks giving information about the parent neutral particle) is shorter. Many important neutrino interactions — such as the elastic scattering of an antineutrino and a proton producing a neutron — yield neutral particles, and the ability of the heavy liquid chamber to give information on them is therefore invaluable.

CERN/PI 166.5.68

An aerial view of part of the CERN site. The wheel shape of the proton synchrotron itself is fairly obvious and, pointing from it towards the bottom of the picture, is the tunnel housing the neutrino beam-line. The large new building (bottom centre of the picture) is the one which will house Gargamelle.
In the background top left can be seen some of the excavation work for the Booster (the new higher-energy synchrotron injector) and for the Intersecting Storage Rings.



A heavy liquid chamber is less favourable than the hydrogen chamber in the complexity of the target it presents to the incoming beam and in the accuracy with which the particle tracks can be measured. Also, it is worth adding here that modified hydrogen chambers are now coming into vogue containing hydrogen/neon mixtures or a hydrogen target surrounded by a hydrogen/neon mixture, which compromise between the advantages and disadvantages of pure hydrogen and heavy liquid.

The main detector in the neutrino experiments previously carried out at CERN has been the CERN heavy liquid bubble chamber, which has a volume of 1180 litres. Gargamelle is much bigger with 10 000 litres of useful volume. In a uniform neutrino beam the event rate would be proportional to the volume for the same liquid. In fact, Gargamelle will contribute about a factor of seven to the rate at which neutrino interactions can be observed.

The new chamber is being designed and built at the Saclay Laboratory in France, with help from Ecole Polytechnique, Orsay and industry and is being given to CERN who are providing its buildings and supplies. As mentioned above, the first piece arrived recently and the other components will arrive during the course of the next year. The magnet is coming directly to be assembled at CERN. The other components will be first assembled and tested at Saclay. It is hoped to have the chamber in operation at the end of 1969.

Description of the chamber

The main features of the chamber are as follows: the body (which is almost ready for delivery) is a welded cylinder with dished ends, 1.85 m in diameter and 4.5 m long, with the axis of the cylinder in the direction of the beam. It is constructed of low carbon steel, 60 mm thick increasing to 150 mm in the region of the ports. Its total volume is 12 m^3 of which 10 m^3 is 'useful volume', i.e. can be seen by two cameras. Two diaphragms, made of polyurethane elastromer 4 m by 1 m, running in the direction of the axis on one side of the chamber are used to vary the pressure on the liquid. The liquid can be pure propane (when the chamber would contain 5 tons of liquid) to freon (15 tons) or any intermediate mixture. Four fish-eye lenses, with an angle of view of 110° are set in apertures in each diaphragm; each set of four have their images recorded on a single film. There are 21 xenon flash tubes distributed over the chamber behind diaphragms to give 'dark field' illumination (see CERN COURIER vol. 7, p. 144).

The chamber is surrounded by a magnet designed to produce a field of 19 kG. The magnet yoke, weighing 800 tons, serves as support for the chamber, the expansion system and the coils. The two sets of coils weigh 80 tons each and are mounted vertically; the field direction is horizontal.

The name Gargamelle is taken from the satirical novel 'Gargantua' by Rabelais (1534) in which Gargamelle was the mother of the giant Gargantua. She gave birth to Gargantua through her ear. The association of headaches with Gargamelle is appropriate even in modern times. The construction of the new chamber has created many problems for its makers. Bringing forth the data from Gargamelle will also cause some headaches. The direct interpretation of the events recorded on the two films will be much more complicated than with smaller bubble chambers. New scanning and measuring techniques will be essential and already, under the auspices of the Gargamelle Users' Committee, much development is in progress.

Gargamelle, in combination with the increases in repetition rate and intensity per pulse of the proton synchrotron and the refinements incorporated in the new neutrino beam-line, should make the coming years of neutrino research at CERN very fruitful ones.

A 1/8 scale model of Gargamelle has been constructed of transparent coloured plexiglas so that the way in which the different components fit together can be seen. On the right are the units of the pressure system culminating in the diaphragms in the chamber (they look like two pistons pointing in directions almost along the diagonals of the photograph).
The optical system views the chamber through fish-eyes lenses set in the diaphragms. The chamber, magnet and coils can be picked out and on the left is the illumination system.

PS Shut down

A description of the major items of work which will be done on and around the 28 GeV proton synchrotron during the long shut down which has just begun. The Editor wishes to thank U. Jacob for considerable help in preparing this information.

The proton synchrotron began a shut down on 27 May which will last until the end of September. The exceptionally long duration of this shut down is determined by three important civil engineering projects:

i) The increase in the beam intensity of the machine coming from the improvement programme (higher repetition rate and, eventually, higher intensity per pulse) makes it necessary to add extra shielding to guard against increased radiation levels. During the shut down, a series of pre-stressed concrete beams will be constructed over the target area for the South Hall. These beams will make it possible to pile more earth shielding on the roof.

ii) An exit has to be cut through the synchrotron ring building where the proton beam is to be taken out towards the intersecting storage rings. The junction of the ISR transfer tunnel at the PS includes a passage through the linear injector building (see Figure).

iii) Further holes in the synchrotron ring building are needed for connecting the new higher energy injector. Openings in the PS outer wall are being made for injection into the booster and for transfer from the booster to the synchrotron, together with cabling and access points (Figure).

New power supply

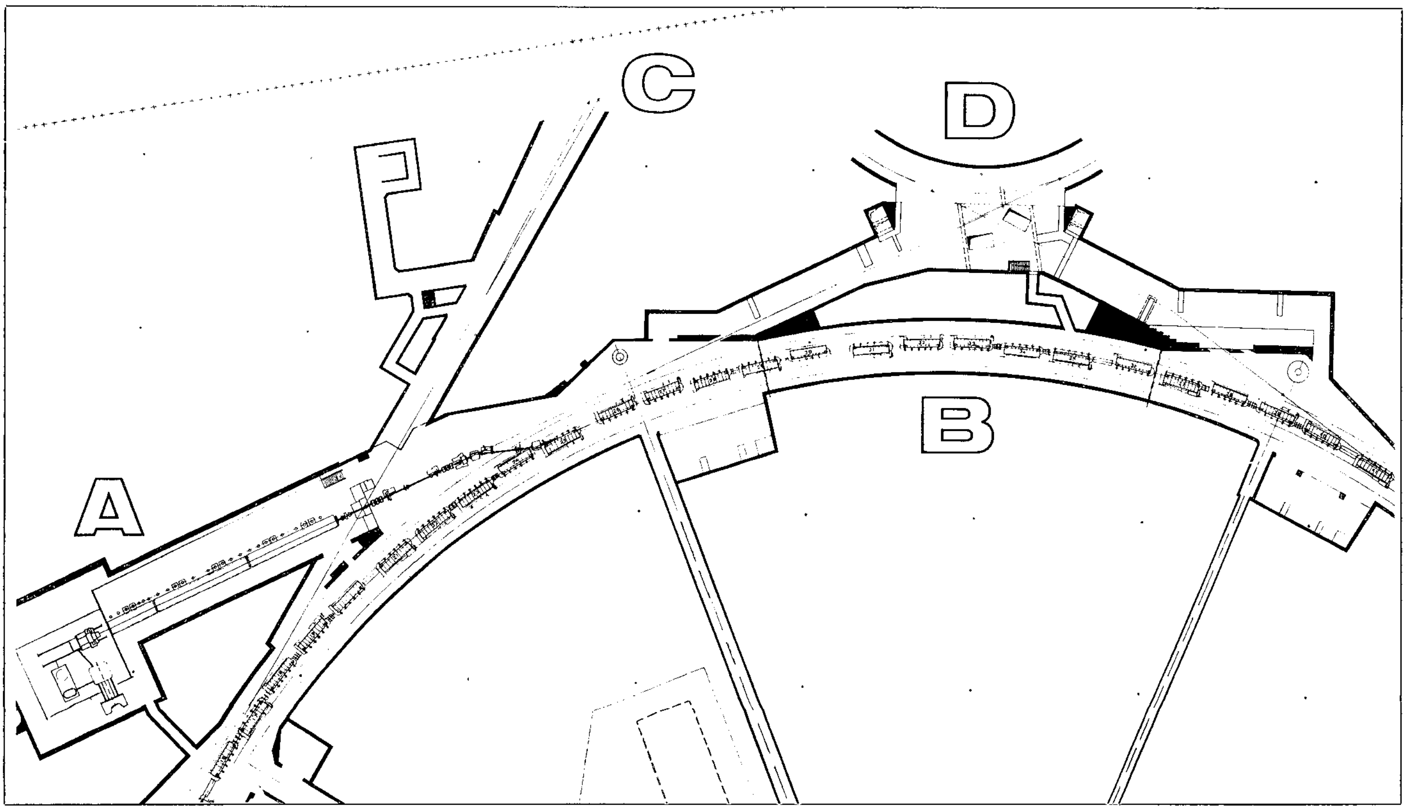
The new power supply for the PS magnet, which is the major item in the first stage of the PS improvement programme, will be connected and commissioned with the magnet as load during the shut down. From October onwards, the PS should then be in operation with an increased repetition rate.

The new supply has a 1000 rev/min alternator driven by a 6 MW asynchronous motor. The total weight is about 216 tons including an 88 ton rotor. Its mean power is 46 MVA with a peak power of 95 MVA supplying up to 6400 A at 11 kV to the magnet.

It will make it possible to operate at approximately twice the previous repetition rate depending upon the machine cycle called for by the experiments. Commissioning with the magnet is planned for June and August operating during the late afternoon and night so as not to interfere too much with other work which will be going on in the ring.

Various other units of the PS have to be modified to cope with the increase in repetition rate and in flexibility of the machine cycle (it will be possible to have several 'flat-tops' at different energies during one cycle). These include:

- replacing the cables, which connect some of the magnets, by busbars which can tolerate the increased power dissipation
- modification to the B-pulse generator and the B— and M—timing distribution in the main control room (these are units which synchronize the operation of the machine to the magnetic field and to the power supply cycle respectively)
- improvements to the controls of the pole-face-windings generator to handle more frequent operation at higher energy



A drawing of the injection region of the proton synchrotron showing the complex arrangements of access points into the main magnet ring tunnel. Several of these are being cut into the tunnel during the shut down, as described in the article. The existing linear accelerator is at position A; B is the ring itself; C is the beam transfer tunnel to the intersecting storage rings; D is the position of the Booster synchrotron.

— installation of a new set of septum magnets and a septum lens for the slow ejection system, which will operate at the faster repetition rate and with longer flat-tops

— installation of a new power supply for the bump coils used in the fast ejection system emerging from straight section 74, and of a new fast ejection septum magnet in straight section 58.

General modifications

Every group connected with the machine is taking advantage of the long shut down to do thorough overhauls, to carry out modifications and to install new equipment. The list of jobs to be done covers about fifty pages and only a few have been selected for mention here.

On the Linac:

The beam transport for the 500 keV beam will be improved. The radio-frequency system for the accelerating cavities will be modified in preparation for injection into the Booster in the second stage of the improvement programme. This requires longer, more intense pulses at a higher repetition rate. A major overhaul will be carried out on the refrigerators for the vacuum pumps.

On the PS ring:

Vacuum chambers in three of the magnet units will be changed for improved versions and new vacuum tanks or special vacuum chambers will be installed in six of the straight sections. Additional back-leg windings will be installed on all 100 magnets to increase the flexibility of closed-orbit correction at injection. This control of closed orbit position may eventually be done by the control room computer.

The new full-aperture kicker (see CERN COURIER vol. 8, page 26) will be installed in straight section 66 and the pulse generator of fast kicker magnet 97 will be improved so that

— the pulse duration (hence the number of ejected bunches) can be adjusted without restriction

— several bursts of protons can be ejected in the same cycle

— the energy can be varied from burst to burst and from cycle to cycle.

The fast ejection septum magnet in straight section 1 and its hydraulic actuator will be removed. Two water-cooled sextupole lenses will be installed in straight sections 35 and 95. It will be possible to operate three ejection systems (from straights 58, 62 and 74) with more flexibility.

A pipe-line for demineralized water will be installed around the ring for general use — for example, for the ejection magnet in straight section 16 and for the new dipole magnets.

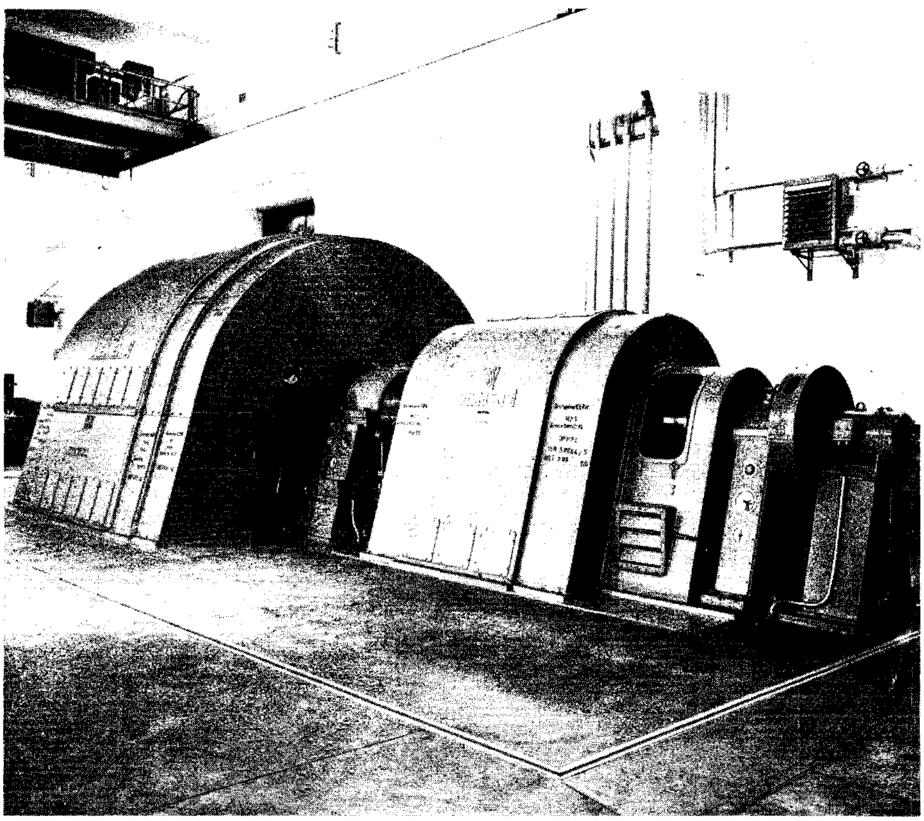
In the experimental halls:

The ejected proton beam which fed the muon storage ring in the South Hall will be removed (the experiment has finished taking data). Two new beams will come from straight section 8 — a low-energy beam and a medium energy beam for electronics experiments in the South Hall. All the other beams will remain basically the same but improvements to be made will nevertheless require their complete rebuilding. The thermal capacity of the cooling towers and heat exchangers for the beam transport cooling system will be increased by 30 %.

In the control room:

Improvements will be made to the instrumentation, and the controls for the ejection system will be regrouped to integrate the modified controls of the fast kicker 97 and those of the full-aperture kicker 66. The computer will receive an additional 8 K memory and the programming system will be adopted to make use of it.

When the proton synchrotron comes back into operation in the Autumn it will be a thoroughly 'serviced' machine, capable of more versatile operation at higher repetition rates, and already partly prepared for its further improvement in a few years time.



CERN/PI 16.3.68

The new magnet power supply which will increase the pulse repetition rate of the proton synchrotron. During the present shut down of the PS, the power supply will be connected up to the magnet and tested.

CERN News

The Godet Workshop

In the last issue of CERN COURIER we reported the sad death of R. Godet, head of the surface treatment workshop. Under his guidance this workshop tackled many unusual and challenging problems. As a further tribute to Godet's work we select three of the achievements of the workshop which merit particular mention.

Oxidation of aluminium strip

The surface treatment workshop was called upon to oxidize an aluminium strip to be used in a magnet coil where there was need for near-perfect linearity in the magnetic field. It was necessary to produce a continuous strip, 2500 m long, covered with a fine coating of aluminium oxide which would serve as insulator between the different layers of the coil. This deposit of aluminium oxide was maintained within a thickness of 1 to 1.5 microns.

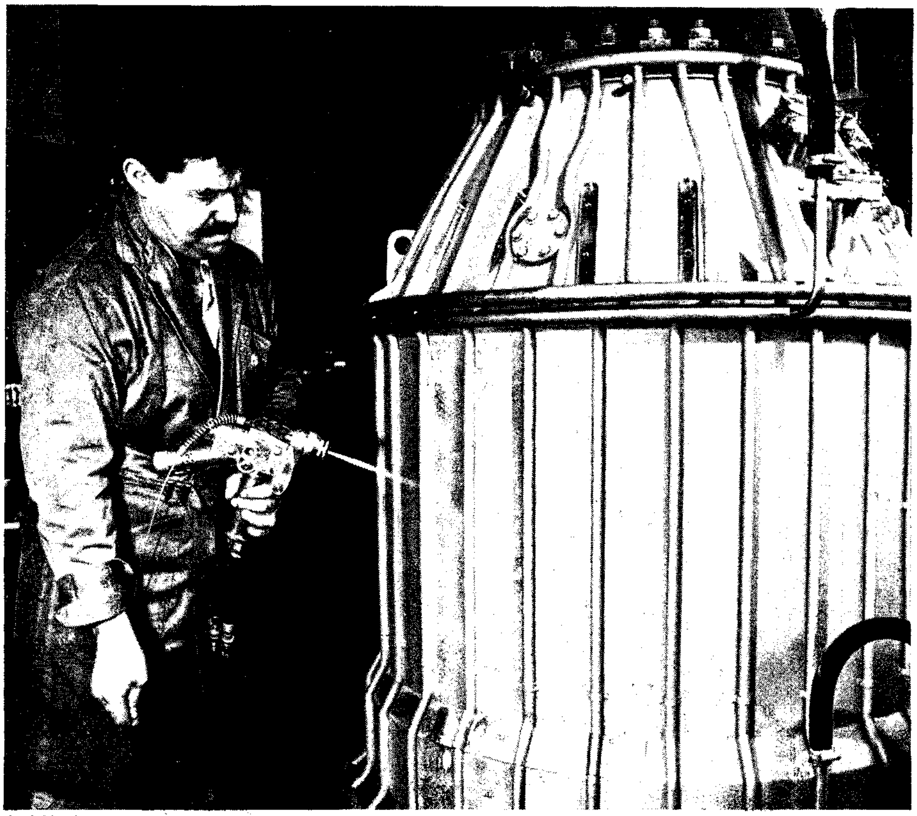
After a series of tests, the workshop applied three special techniques to master the problem

i) The oxide layer was dyed blue and the thickness of the deposited layer was then controlled by monitoring the colour intensity.

ii) The oxidation process itself was standard but by the simple manœuvre of raising the temperature of the oxidation bath from 20 to 30° C, a much more flexible oxide layer was achieved. This flexibility was maintained when the layer cooled and meant that the strip could be wound into a coil with much less likelihood of fissures appearing in the insulator which could have resulted in electrical breakdown.

iii) It was important that the very long strip did not fracture during the deposition of the oxide layer and a system with the stip passing through several stages like a chain was set up. Two strips, in parallel, were wound from a single spool drawn by a motor. They passed through the different treatment baths, feeding through rubber rollers, and were finally wound on to a drum.

When the oxidation was taking place, R. Godet was at the workshop day and night to ensure that everything was work-



CERN/PI 9.3.68

Fixing the heat-exchangers onto the body of the 1 metre model of the large European hydrogen bubble chamber by metalizing with copper. This technique was developed in the West workshop and is being used for the first time on the model. It ensures a good mechanical bond and excellent heat conductivity.
The model is to be used for a thorough investigation of the thermo-dynamic problems connected with the new chamber. It will also serve to study the behaviour at low temperatures of the plastic materials intended for the expansion system. The large European chamber is unusual in having its expansion system operating at the bottom of the chamber. The model will also be used to study the chamber optics.
The first cool-down of the model is scheduled for the beginning of June.

ing to plan. The result met the stringent specification laid down.

Copper plating for the kicker magnet

As reported in CERN COURIER vol. 8, page 26, a full-aperture kicker magnet has been successfully commissioned for use on the proton synchrotron. The magnet makes it possible to select various combinations of bunches from the twenty bunches orbiting the machine to be ejected down a fast-ejection beam-line. This full-aperture kicker avoids the problems of hydraulically plunging the small, more conventional kickers into the synchrotron vacuum vessel. It introduces however various technical difficulties of its own, most of which were covered in the above article. One, which was not mentioned, confronted the west workshop and the surface treatment workshop.

In order to pick out individual bunches for ejection, the magnet has to be capable of reaching the required field strenght and of returning again to zero field each in times of the order of 100 ns. This made it necessary to use ferrite as the magnet core. Then came the problem of coating the ferrite first with silver-loaded araldite (done in the west workshop) and then with copper, to form the conductors of the magnet.

The copper-plating was done in the surface treatment workshop. The handling of the brittle ferrite cylinders was in itself difficult — there were two of them each 2 m long, 30 cm in diameter weighing about a ton. The coating of copper had to be evenly distributed over this large surface area with good adhesion and with good bonds to metal fittings.

After many tests, Godet developed a rapid method of plating the inside and outside of the cylinder at the same time. It involved very careful setting up of the electro-plating units including the construction of a specially shaped anode. The result was a perfectly even deposit of copper over the whole cylinder which met all the requirements asked of it.

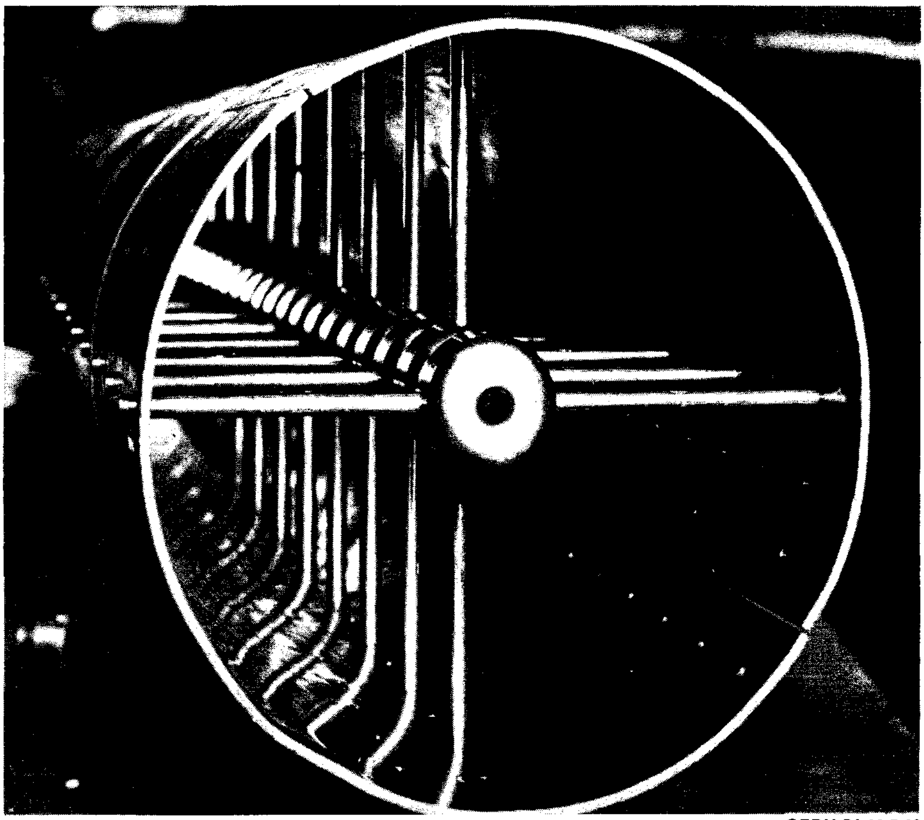
Producing a septum

One type of magnet used in ejecting the accelerated beam from the proton synchrotron is known as a septum magnet. (See, for example, CERN COURIER vol. 6, page 176.) The septum itself is a thin plate of current-carrying metal which serves to prevent the field in the magnet from influencing the beam except when the beam is deflected into the septum magnet. It shuts off the gap between the top and bottom of the C-shaped magnet so that magnetic field outside the gap is eliminated.

The septum needs to be as thin as possible so as to reduce the number of particles which are lost by collision with the septum when the beam is deflected into the magnet. This need for a very thin septum is complicated by several factors -

i) It has to cope with current densities of the order of 250 A/mm²
ii) The heating that this current produces (several tens of degrees) causes a thermal expansion each time the magnet is pulsed and the septum and its attachments have to cope with millions of pulses without fracture due to metal fatigue
iii) To keep the temperature effects as low as possible the septum has to be built in such a way that it can be cooled. For example, water cooling can be applied using water under pressure, typically 25 kg/cm². Finally, the whole system has to operate in vacuum.

The surface treatment workshop was asked to examine the problem of establishing water cooling channels in a copper septum 3 mm thick and 1 m long. Obviously, the solution of drilling holes through such a long thin strip of metal was not feasible. R. Godet tried many different approaches and finally settled on an electroforming technique, at a time when the tech-



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A scale model linac cavity (15 cm in diameter) which is being used in the linac section of the ISR Department to optimize cavity design for future linacs. This model has a 'cross-bar' structure — the stems supporting alternate drift-tubes are at right angles (for the first drift-tube in the photograph they are horizontal, for the second vertical and so on).
Several structures of this type are now being investigated. By changing the orientation and the size of the stems it is possible to achieve conditions which considerably improve the cavity performance compared with the conventional Alvarez structure. The advantages include making it easier to cope with beam loading, more uniform accelerating fields (dispensing with the need for field flatteners) and less stringent mechanical tolerances.

A display console in use with a CDC 3100 computer. On the left are two examples of graphical display of functions generated by the computer, and, on the right, the console is being used with a 'light-pen' to examine particle track configurations such as could be produced in a new bubble chamber.

nique was far from being well-established.

The idea was simple — instead of attempting to tunnel through the metal, why not cut out the channels and then cover them over. Taking a copper strip about 2 mm thick, channels of square cross-section were cut into the top side. These channels were then filled with indium and the top surface polished flat. Over this flat indium/copper surface a further millimetre of copper was electrolitically deposited. To ensure a good bond which would not fracture during the pulsed operation of the magnet, the copper of the base and of the deposit had to be as close in characteristics as it was possible to achieve. The indium, which has a low melting point, could then be removed by heating and the channels given a final chemical cleaning to ensure that their walls were perfectly smooth.

The septums produced in this way have given entire satisfaction in their performance under their stringent operational conditions in the proton synchrotron, and the method of production has been taken up at other accelerator Laboratories.

On display

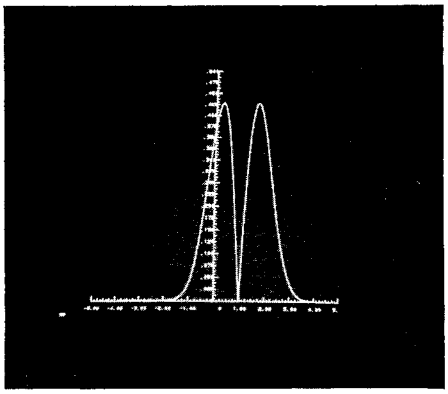
Computers usually yield the results of their efforts in the form of thousands of numbers printed on endless sheets of paper. CERN's computer output, for example, covers some fifteen million sheets of paper a year. In general, the computer has not, up to now, been used either to yield or to receive its information in a more digestible way. Mechanical plotters are being used to give data in graphical form but are too slow for large quantities of output.

One of the ways in which this digestion problem is being tackled is to have the computer present its information as a graphical display on a cathode ray tube. A user may then sit in front of this display and, with the aid of a typewriter keyboard and light pen, direct the computer in its processing.

Since the beginning of this year, facilities have been developed at CERN to investigate the usefulness of such a display. A display console has been attached to the CDC 3100 computer in the Data Handling Division.

There are some applications which could prove valuable. One is to help rescue 'events' that the automatic measuring systems (such as the HPD, see CERN COURIER vol. 8, page 79) have rejected. For example, in measuring photographs of particle tracks taken in spark chambers, the automatic systems will reject say 5 to 10 % of good events because of the complexity of the event or the quality of the picture. There has to be human intervention if these events are to be absorbed into the results. The measurements of the events are recorded on magnetic tape and from there, via the 3100, displayed on the cathode ray tube. The operator can then see what additional information is required by the computer for the analysis and can feed this information in using a keyboard on the display console.

In the large photograph, the display is being used for a related activity. When developing the design of a new bubble chamber, it is important to know what the photographs of typical events taken in the



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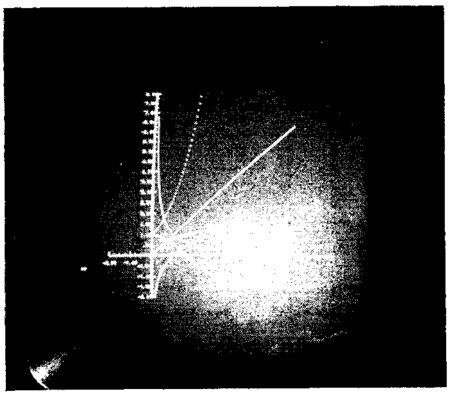

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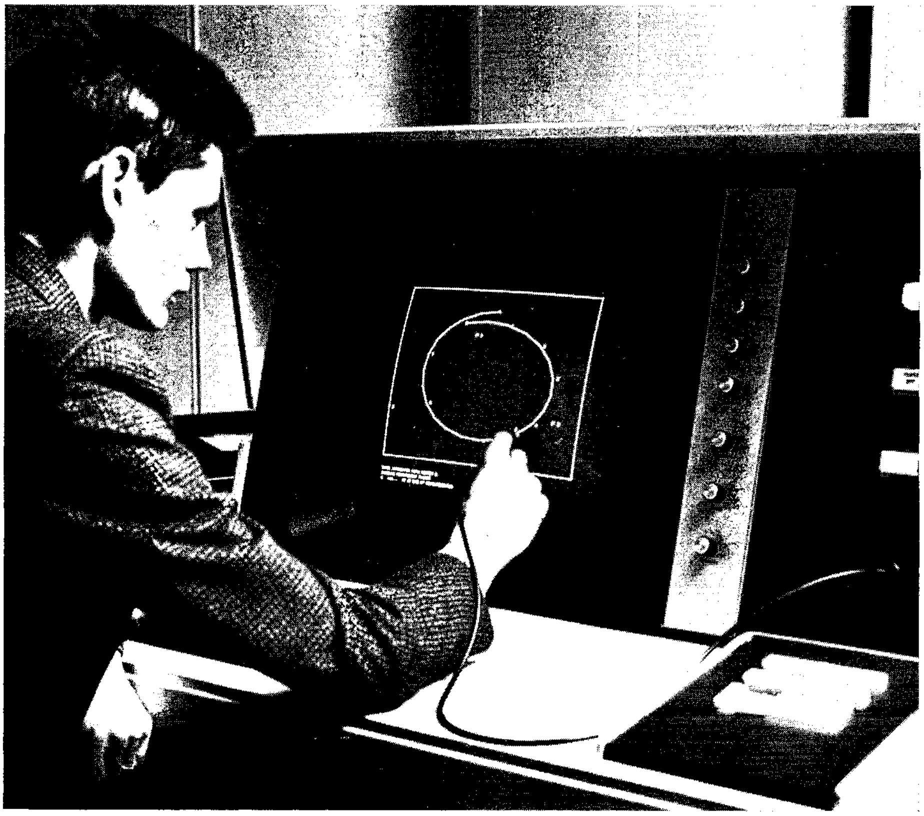

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chamber will look like (to ensure that they will be amenable to scanning and measurement) and to select the best arrangement of camera positions and optics, checking how the appearance of the tracks varies as the cameras are moved around. It is possible to generate artificial events using the computer and these can be projected on the display console as they would appear in the bubble chamber. The photograph shows a programmer using a 'light-pen' to indicate measurement points on the track. The measured points are later used for testing the geometry programmes for the new bubble chambers. The name light-pen is a slight misnomer as the light-pen is a device which is sensitive to the light generated by the CRT spot and is not really a drawing device. However, it can tell the computer the position of the spot, sensed by the light-pen, and hence the position of the light-pen.

Another application of the display was suggested by Professor L. Van Hove who saw this application at the University of Santa-Barbara in the USA. It is known as the Culler-Fried on-line computing system. The combination of the display, the computer and the keyboard serves as a very sophisticated keyboard calculator at which it is possible not only to perform all the operations of a standard desk calculator but also to perform operations on functions and so explore solutions of mathematical equations, with the great advantage of being able to see immediately the form of the function presented on the display. The two small photographs are examples of what the display can present when being used in this way.

It is hoped that by the end of this year sufficient experience will have been gained in these areas of application to be able to decide whether graphical displays should be introduced as additional facilities of the CERN central computing installation.

The crane·bridge cometh

At the beginning of May, sections of the crane-bridges for the new experimental hall (West Hall) being built alongside the intersecting storage rings, arrived at the site. CERN already has experience of large cranes, such as the two serving the East hall of the proton synchrotron which span a width of 40.7 m and lift 20 and 40 tons. But the newcomers are even more impressive.

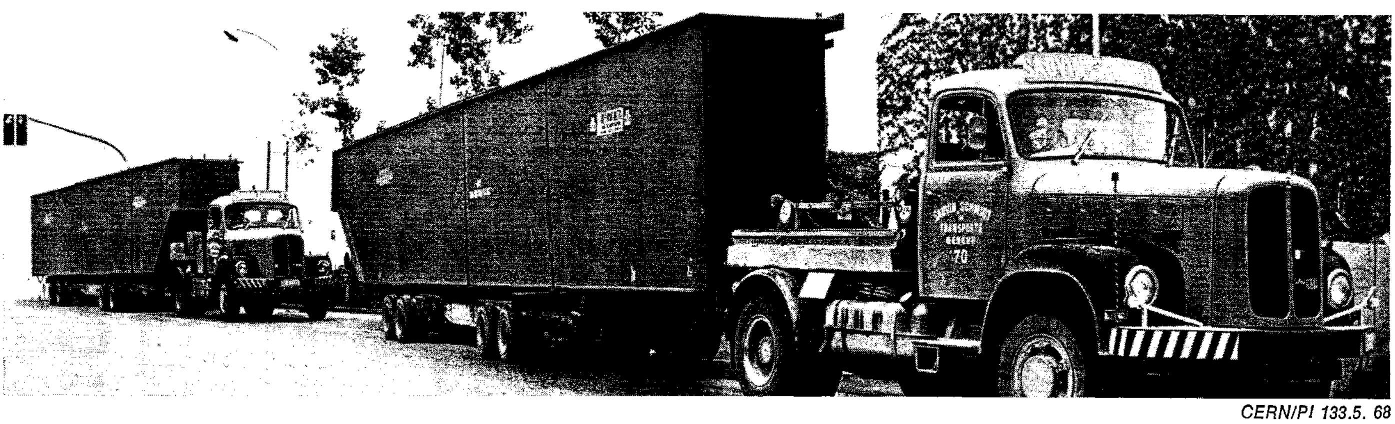
To stand now in the West Hall, where construction of the building itself is nearing completion, is like standing in a football stadium. It has a floor area of nearly 10 000 m² and the cranes are to span a width of 61.5 m and to move 160 m along the length of the hall. Two crane-bridges) will be installed, similar in dimensions but differing in the weights they can lift — 40 and 60 tons. The cranes will operate separately but could be coupled in case of need, to lift up to 100 tons. Each consists of two huge parallel beams the ends of which run on trolleys along rails on the side walls of the experimental hall.

Some other technical details: The cranes can lift equipment up to a height of 9.5 m at speeds of 5 m/min and 0.3 m/min. Each crane-bridge can move along the hall at speeds of 50 m/min, 10 m/min and 0.2 m/min and the crane chariots can move across the hall (across the bridges at speeds of 30 m/min, 4 m/min and 0.2 m/min. The more powerful crane has a total weight of 200 tons and is powered by a 140 kW motor; the other weighs 180 tons with a 110 kW motor.

The manufacturer is Bartolomeis from Milan, Italy who has supplied a number of other cranes to CERN including the six cranes for the magnet ring tunnel of the ISR, two of which are already being installed. The total cost, including transport, assembly and testing, approaches 800 000 Swiss francs.

The crane-bridge sections are now waiting in the West Hall to be mounted in the next few weeks ready for their tests which are scheduled in July.

Arrival at the beginning of May of sections of the huge crane-bridges for the West experimental hall on the intersecting storage rings site. The total weight of one bridge is 200 tons. The sections in the protograph are the outer parts of a bridge which will be connected by a central piece 20 m long of 2.8 m by 1.3 m cross-section.



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News from abroad

Daresbury Laboratory

The Daresbury Nuclear Physics Laboratory brought their 4 GeV electron synchrotron, NINA, into operation in December 1966. By now, considerable experience has been gained in operation of the machine and a lively experimental programme is under way involving teams from UK Universities, the Laboratory itself and other European research centres.

NINA

Over the last ten cycles NINA has provided 'good beam' for an average of 72½% of the experimental time. The regular operational cycle has now increased the machine time to 10 days on, 4 days off. Selected energy has varied from 1 to 4 GeV, though beams have been accelerated as high as 5 GeV. Average intensity has been about 1 μA and, though NINA is designed to cope with 10 μA, not much effort has yet been given to pushing the average figure higher; 'machine physics' has, instead, been concentrated on achieving a thorough understanding of the machine.

One reason for not moving to higher intensity has been the unsteady performance of the injector. It was designed to meet a rather stringent specification (to pack the beam within 1 % energy spread around the injection energy of 40 MeV) and the required stability has proved difficult to achieve. Several measures are being taken or will be taken to improve its performance. A motor alternator set, locked to the main ring magnet cycle, is at present being installed to power the injector at the pulse repetition rate of the machine, 53 Hz. This will avoid a 3 Hz beat which appears on the beam current when the injector is powered at the mains frequency of 50 Hz.

Components for a positron injector have arrived at the Laboratory and are being installed; tests on positron beams will probably begin in the Autumn. The target where the positrons are produced by bombardment with the 40 MeV electron beam, is followed by a positron acceleration stage before injection into the ring. This positron accelerator is along the line of the injector and, since taking the electron beam through the positron accelerator during normal electron operation would result in beam loss, a bypass involving four 45° magnets has been built. Use is to be made of this bypass for refined control of the intensity and energy of the electron beam. A collimator and beam position indicator are installed at the mid-point of the bypass and are connected to one of the klystrons powering the electron accelerator in an energy servo-system.

The intensity from the injector is, at present, usually held down to 60 to 100 mA since higher currents caused leaks in the vacuum vessels at the injection point. This led Daresbury to follow the example of two other electron Laboratories (Cambridge, USA, and DESY, Federal Republic of Germany) in installing ceramic vessels to replace their original ones of stainless steel, titanium and fibre glass. A sufficient number have been ordered to replace half the vessels in the ring and two have recently been installed at the injection point. (A nice balancing act has arisen in that DESY found their best contract with Ferranti, UK, while Daresbury found theirs with Feldmule, Germany.)

One ejected electron beam is already in use and a further ejection system is being built and will probably be installed before the end of the year. The system in operation achieves an ejection efficiency of about 80 %, with spill times up to 1 ms, and can be focused to a spot about 10 × 1 mm² at the target used in the experiment. Its operation is temporarily restricted to one pulse in three at 3 GeV due to the limitations of the power supplies for the kicker magnet. New supplies have been built and are being connected to cope with both higher energies and operation on every pulse.

Use of a data-logging computer (an IBM 1800) in the machine control room is quite advanced. 120 parameters are now on call via the computer and their behaviour over the previous six hours can be obtained. A system is being developed which will give a visual histogram every few seconds of the intensity of the accelerated beam (over 200 to 300 pulses). The computer will also be used to provide some administrative information such as the causes of breakdown and the total number of pulses fed to each experiment.

Experimental Programme

The Laboratory is situated in the North of England and is intended to serve particularly the Northern Universities. Teams using or planning to use the machine come from Glasgow, Lancaster, Liverpool, Manchester and Sheffield. In addition, a Strasbourg-Orsay group is scheduled to start an experiment in a few months time, and scientists from Pisa and Rome are planning an experiment in collaboration with Daresbury. There are three groups based on the Laboratory itself and it is not intended to increase the resident experimental staff beyond this level.

The programme is as follows: A Manchester team are looking at the interaction

$$\gamma + p \rightarrow K^0 + (\Sigma^+)$$

The aim is to look at the cross-section for the photo-production of the neutral kaon and its angular distribution, taking a gamma beam from NINA onto a hydrogen target. This will check production mechanisms such as the 'Drell process' and, if it proves that production of the neutral kaons is as high as expected, it will be possible to use NINA as a source of neutral kaon beams of intensity as high as or higher than equivalent proton machines. The neutral kaon is measured by regenerating short-lived kaons and looking at their decays into two charged pions by a system of wire spark chambers (core read-out, on-line to a PDP 8 computer) and a large spectrometer magnet. Measurements at 9° have been completed and the detectors are being repositioned at 3°.

A Liverpool team are investigating the photo-production of neutral pions, and eventually of higher neutral meson resonances, over a wide angular range

$$\gamma + p \rightarrow \pi^0 + p$$

They have initially concentrated on the energy range around 1250 MeV. A spectrometer detects the emerging proton and the neutral pion is seen in its decay to two gammas in a large lead glass counter with 49 photo-multipliers. This experiment also uses a PDP 8 on-line computer. They will measure production cross-sections and angular distributions eventually moving to higher energy to investigate the eta meson.

A Glasgow, Sheffield collaboration are examining elastic electron-proton scattering in an experiment set-up on the ejected electron beam. Analysis of this scattering usually assumes that any two-photon contribution is negligible. Measuring the polarization of the recoil proton is a way of testing this assumption. In the experiment, the recoil protons will be momentum analysed in a magnetic spectrometer and then scattered from a hydrogen target (50 cm long). The left-right asymmetry of the scattered protons gives the polarization. Four optical wide-gap spark chambers are used to observe the proton scattering and the film from these detectors will be measured on 'Cyclops' at the Rutherford Laboratory (see below).

One of the resident Daresbury groups is looking at wide-angle symmetric pair production of electrons and muons

$$\gamma + p \rightarrow e^+ + e^- + p$$
$$\rightarrow \mu^+ + \mu^- + p$$

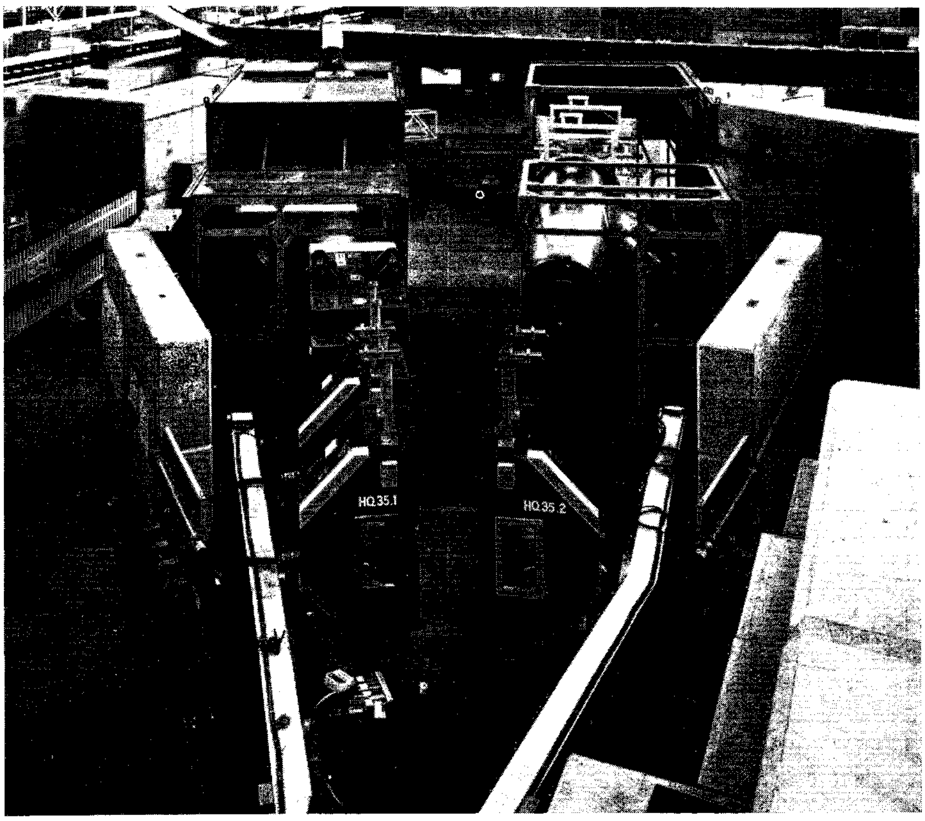
(wide-angle in this case means angles between 5 to 10° as the cross-section drops off very rapidly with increasing angle). The initial work will be on electrons. It is an important check of the validity of quantum electrodynamics down to distances of the order 10^{-14} cm, following in the wake of a Harvard experiment which seemed to show a breakdown of the theory and a Columbia/DESY experiment which restored faith (see CERN COURIER vol. 6, page 194). The Daresbury experiment will achieve higher accuracy and can take advantage of the higher intensity from NINA to use a hydrogen target (rather than a carbon target as at DESY) to ensure being free of nuclear interactions. Two identical spectrometer arms follow the target, each including a threshold gas Cherenkov counter and shower counters capable of distinguishing an electron from a pion (which can produce a 'knock-on' electron) to better than 10 000 to 1.

Following this electron check, the experiment will concentrate on muons and will serve to probe the mysterious similarity between the muon and the electron. Simple but ingenious muon range counters have been built with large scintillation counters preceeded by absorbers whose thickness can be varied. They each consist of two large forged-steel wedges, one of which is fixed while the other can slide up and down to present different total thicknesses of steel to the beam. The momentum of the muons will determine the thickness through which they can pass, and the counter will be able to cover the range 0.9 to 2.5 GeV/c with a resolution of about 5 %.

A Lancaster, Manchester group are beginning to install equipment for an experiment on the electroproduction of nucleon resonances in inelastic electron-proton scattering. A second Daresbury group are collaborating with Pisa and Rome in an experiment which will study the electroproduction of pions near threshold to measure the pion form factor. A group from Orsay and Strasbourg have proposed an experiment on the photoproduction of positive pions in the backward direction. This will extend an investigation already carried out at lower energies on the Orsay Linear Accelerator.

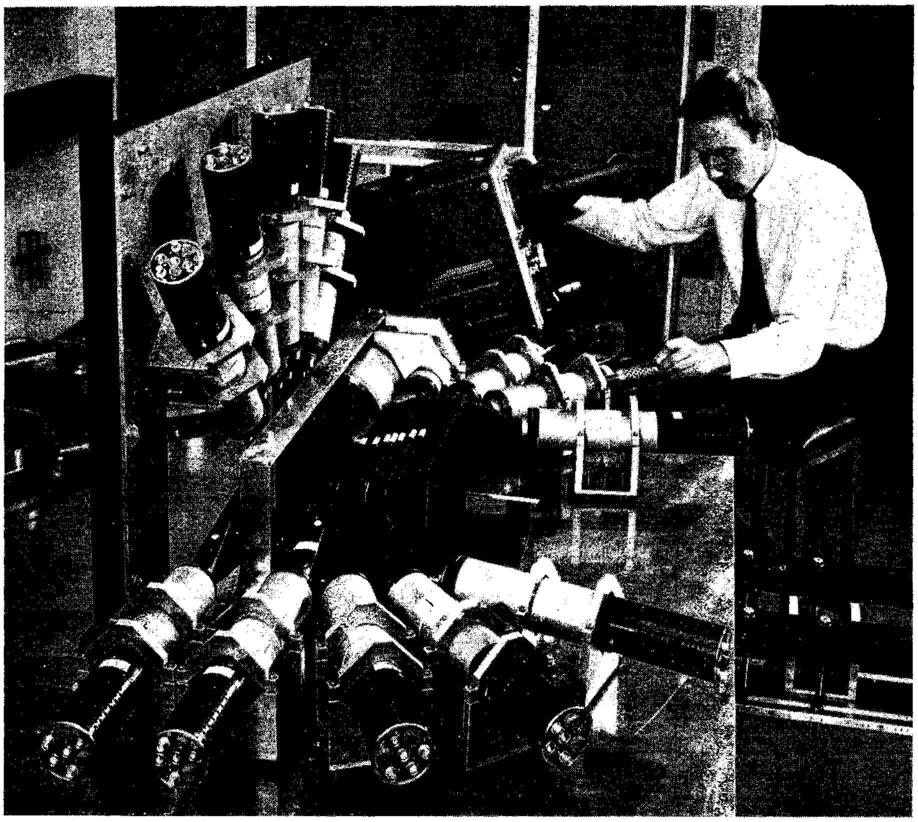
Finally, a Daresbury group are working with physicists from Glasgow, Manchester and Sheffield in the 'Track Chamber Collaboration'. Their initial aim is to carry out a survey of photoproduction processes using a tagged photon beam. To do this they will construct a large magnet containing streamer chambers and will be the first European group to construct such a large, universal detector employing the new technique of streamer chambers. (See CERN COURIER vol. 7, page 219).

The intention is to insert two streamer chambers in a magnet aperture 150 × 120 × 75 cm^3. Each chamber will have transparent planes 100 × 100 cm^2 with a gap of 30 cm. The electronics to provide a 600 kV, 10 ns pulse across the gaps will be virtually identical to those used on the Stanford streamer chamber (a Marx generator designed for 1 MV and a Blumlein transmission line). The interactions in the chambers will be recorded by three cameras looking through a hole in the top yoke of the magnet. One important change by comparison with Stanford is the hope that it will prove possible to use a liquid



The two identical arms of the experiment to study the photoproduction of electron and of muon pairs, coming together in the experimental hall at NINA. (Photo Daresbury Laboratory)

Testing a counter hodoscope at Daresbury. (Photo Daresbury Laboratory)



hydrogen target (50 cm long, 2 cm diameter) in one of the chambers; Stanford used gaseous hydrogen. This project will be completed in about 18 months time.

A higher energy machine

The major project under consideration for the future development of the Daresbury Laboratory is the construction of a higher energy electron synchrotron. A detailed design study is nearing completion.

It has been designed for a peak energy of 15 to 20 GeV and for high intensity (initially 1 μA possibly rising to 3 μA). This would extend the range of electron and photon physics which could be done in Europe and it is estimated that it would provide high energy secondary particle beams with intensities higher than at equivalent energy proton machines. It would enter the energy range of the electron linear accelerator at Stanford (20 GeV), with the advantage of longer duty cycle to make possible many electronics experiments which cannot be done at Stanford. The only other comparable electron synchrotron is at Cornell. This machine will probably rise to an energy of 15 GeV from the initial design figure of 10 GeV but it was conceived and built essentially as a University machine rather than a national machine and its facilities are limited in terms of the number and complexity of experiments with which it can cope.

Daresbury plan to use the existing machine, NINA, as injector for the higher energy machine tapping off at 3 GeV when the beam size is small (about 12 × 2 mm). This makes it possible to accept a very small vacuum vessel aperture (50 × 25 mm) and small magnets. A preliminary cost estimate gives the cost of the new machine as just above £ 3 million.

Symposium on Intensity Measurement

A symposium on beam intensity measurement was held at Daresbury on 22-26 April bringing together about 45 specialists on this subject from accelerator Laboratories throughout the world. (V. Agoritsas, C.D. Johnson and H. Wachsmuth attended from CERN.) Below is a brief description of the most popular methods of measuring beam intensity.

The most reliable one is still the long-established 'Faraday cup', though it has become a little more sophisticated in design with advancing years. The beam is fired into the thick base of a cup-shaped block of metal. A small magnetic field is applied to bend any electrons scattered from the base (which would be of comparatively low energy) into the walls of the cup. The cup sits in a vacuum box with a protruding snout, at the end of which is the window through which the beam passes. A magnet around the snout prevents any secondary electrons from the window reaching the cup. Measuring the charge collected and knowing the unit of charge carried by the particles gives the number of particles in the beam directly. Simple but effective; and people believe in the accuracy of these devices to considerably better than 1 %.

Calorimeters could also give a direct measurement by recording the rise in temperature produced when the beam strikes the calorimeter, but they have proved rather cumbersome in practice. A large block of metal is needed to absorb all the beam and it takes many beam pulses to give a reasonable rise in temperature.

All other devices measure the intensity indirectly by observing effects produced by the beam; to convert their readings into absolute measurements, they are calibrated against a Faraday cup. 'Quantameters' are used to measure the intensity of photon beams. They consist of thick metal plates where the photons produce showers of electrons. Twelve to twenty of these plates sit in a gas such as argon with the spacing between the plates specially arranged so that the read-out of the charge they receive gives a Simpson integration of the beam intensity. Gold-plating of the plates has removed a lot of trouble due to instabilities of the metal surface. The conventional gas-filled quantameter is not however suitable for high intensities.

Another method using the phenomenon of electron emission from a metal, which is suitable for high intensities, is the 'secondary emission chamber'. Here, very thin foils are set up in vacuum and the number of electrons knocked out of the foils is recorded. These devices are used for proton as well as electron beams — for example, they are used to monitor the ejected proton beams at the CERN synchrotron. They are however very sensitive to contamination of the foil surface.

All the above devices destroy, or interfere with, the beam they are measuring. Two types which are transparent to the beam are toroid and cavity monitors. Toroids use the beam as a single turn of a transformer — passing it through a ferrite ring which has windings to tap off the current induced as a pulse of particles goes through. Cavity monitors are tuned to a harmonic of the r.f. structure of the beam and as the beam passes through, the voltage induced on the cavity can be measured. Both these methods are very useful for setting up beams and for rough measurements but are not accurate beyond about 10 %.

Rutherford Laboratory

The Rutherford High Energy Laboratory has been carrying out an experimental programme with a 7 GeV proton synchrotron, Nimrod, since 1964. University groups from throughout the UK participate in this programme but visiting scientists from Europe and the USA are also involved. Major events in European collaboration involving the Laboratory have been the use of their 1.5 m hydrogen bubble chamber at CERN, and the use of a 81 cm hydrogen chamber from Saclay, France, at the Laboratory.

NIMROD

Nimrod is operated on a three week cycle which includes 16½ days of continuous high energy physics. Operational efficiencies for these physics periods approach 90 %. Beam intensities vary from about 1.3 to 1.6×10^{12} protons per pulse and 2×10^{12} has been achieved. At present, the repetition rate is down to 10 pulses per minute (with a 500 ms flat top) since one alternator of the main magnet power supply is out of action with a damaged rotor; it will be reinstalled during the summer.

One ejection system, involving a plunged quadrupole and bending magnet, is used to feed two ejected beam lines. An ejection efficiency of about 35 % (up to 5×10^{11} protons at a target) is achieved from one of the ejection systems which is a fairly high figure for a constant gradient machine. A further ejection system is being developed to feed a large new experimental hall (4300 m²) which will be completed by the end of 1968. Work on a Piccioni system using a septum magnet and on resonant ejection is continuing in parallel. The ejected beam will be computer controlled and some preliminary beam lay-outs for the large new hall have already been prepared.

The planning of the beams drawn from Nimrod aims to make the fullest use of the available protons. One ejected proton beam-line, for example, feeds five experiments. They all draw secondary particles from the same target and three can take data without interfering with one another. At present, there are in addition four beam-lines using internal targets. Seven experiments have run simultaneously on the same machine pulse and it is quite usual to have five counter experiments and a bubble chamber in action on the same pulse.

The major proposal for the development of Nimrod itself is called PLANIM. It is a project to increase the injection energy into the main magnet ring from the existing 15 MeV to 50 MeV. This could be comparatively economically achieved by using the Laboratory's second machine — the PLA (proton linear accelerator) — which is otherwise scheduled to finish operation in October 1967. This 50 MeV machine has served nuclear physics experiments successfully for nine years and is unique of its type in supplying polarized proton beams and in having a sophisticated time of flight system for beam momentum measurements. However, in assigning priorities for nuclear structure research in the UK, it has been decided to close down the research programme based on the PLA. It was then that the possibility of retaining the PLA itself as a higher energy injector for Nimrod arose.

Investigations of the injected beam behaviour in Nimrod indicate that the machine is operating at, or very close to, its space charge limit. (Some phenomena will be examined more thoroughly in the near future to check that this conclusion is correct.) By increasing the injection energy to 50 MeV the space charge limit should be increased by a factor of 3½. The knowledge which has been gained about the radiation problems on Nimrod now make an increase in beam intensity of this order entirely acceptable.

Since a current of 70 mA would be needed for Nimrod, some modifications would be carried out on the first accelerating cavity of the PLA, replacing grid focusing (which results in high beam loss) by quadrupole focusing. The costs of rebuilding the PLA next to Nimrod, and of leaving it in its present position and transporting the beam over 200 m to Nimrod, have been compared. The second alternative appears the more economical. The total cost of PLANIM is estimated as about £ ½ million.

Experimental programme

Bubble chambers

There are three bubble chambers at the Laboratory. One of them, an 80 cm helium chamber, is not at present receiving beam. It completed a very successful run for an Oxford team gathering 700 000 pictures predominently with negative pions. It will possibly come back into action for large scale (high statistics) experiments involving pions and proton beams. Since the helium nucleus has zero spin, it is possible to analyse some interactions more simply using helium as the target.

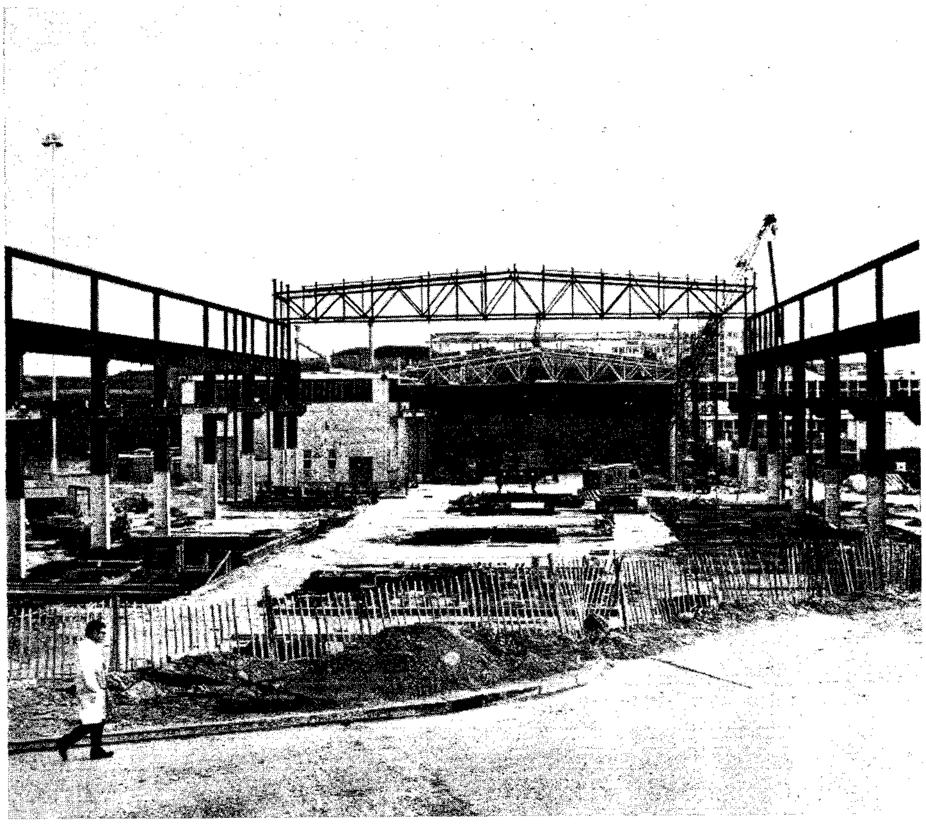
The biggest chamber is the 1.5 m British National Hydrogen Bubble Chamber, which was first operated at the CERN proton synchrotron. It has recently started physics again on Nimrod fed by beams derived from an ejected proton beam. It can receive pions, kaons and protons up to a momentum of 8 GeV/c.

One interesting part of its experimental programme is the planned use, later this year, of a hyperon beam into the chamber. Since hyperons are relatively short-lived particles, it is necessary to set up the target, where they are produced, almost immediately in front of the chamber. Lambda hyperons will be used to look at lambda — proton interactions on which very little information exists at present. If this work proves successful, a sigma hyperon beam may be used later.

A major development in the use of the chamber will involve installing a hydrogen target (1.5 m long, 4 cm diameter) surrounded by a 10 % hydrogen/90 % neon mixture. (See CERN COURIER vol. 7, page 112). This technique, retaining the simplicity of the hydrogen target while gaining from the shorter conversion lengths in the hydrogen/neon mixture, was developed at CERN and DESY. CERN are building the target and will participate with scientists from University College London and Rutherford in the first experiment ever to use the new technique. This experiment, proposed by the Rutherford Laboratory, will look at the leptonic decay of lambda hyperons produced using a narrow pencil beam of pions

$$\pi + p \rightarrow \Lambda + K$$
$$\Lambda \rightarrow p + e + \nu$$

The neon mixture makes it possible to recognize the electron. In half a million pictures, perhaps only 500 will show the event but they will be very easy to pick out. Oxford University are also planning



The large new experimental hall with an area of 4300 m² taking shape next to Nimrod. (Photo Rutherford Laboratory)

to use the target filled with deuterium, surrounded by 5 % hydrogen/95 % neon to catch the gammas coming from neutral meson resonances.

Another development on the chamber will be a new expansion system to make it possible to cycle the chamber faster so that pictures can be taken twice on one pulse from Nimrod.

The third chamber is a 1.4 m heavy liquid chamber which has been in almost continuous operation for several years. It is at present filled with propane and a team from University College London are using a 2.3 GeV/c negative kaon beam to investigate the cascade particle.

Electronics experiments

The experimental programme covers investigations of the weak interaction and studies of resonances and of elastic scattering.

A Birmingham/Rutherford team are using separated kaon beams of momentum between 0.5 and 1 GeV/c to look at elastic scattering on protons. Their equipment includes acoustic spark chambers and a DDP 116 on-line computer linked to the central computer. They will concentrate on positive kaon scattering to look at the disturbing 'bumps' which other groups have observed and which may not be true resonances as they do not fit SU6 theory.

A Westfield College/Rutherford team are using a pion beam onto a hydrogen target to produce the sigma hyperon

$$\pi^+ + p \rightarrow K^+ + \Sigma^+$$

The aim is to measure the non-leptonic decay parameters of the sigma by detecting the decay into a proton and a neutral pion. This will also check the $\Delta I = 1/2$ rule. Their equipment includes videcon spark chambers and an IBM 1130 computer.

A Rutherford team are using a polarized proton target to investigate positive pion-proton elastic scattering. This is a complementary experiment to one the group carried out with negative pions when they identified three new resonances. Their detection system includes about 150 hodoscope tubes and the electronics to cope with the volume and complexity of the data involve the use of very advanced tunnel diode circuits. The Laboratory has made a considerable contribution to the progress of fast electronics.

A Cambridge/Rutherford team are carrying out one of the many studies of the neutral kaon which are under way at accelerators throughout the world. They produce the neutral kaon using a 1 GeV/c negative pion beam onto a polythene target and look with optical spark chambers for the leptonic decay into a pion, an electron and a neutrino.

$$K^0 \rightarrow \pi + e + \nu$$

The branching ratio is measured over the first few kaon lifetimes. The experiment will check the $\Delta S = \Delta Q$ rule to an accuracy of 1 to 3 %. The best accuracy achieved to-date is about 10 %.

A Queen Mary College/Rutherford/AERE team are measuring the electron asymmetry in the decay of the sigma hyperon. They produce the sigma using a negative pion beam onto a hydrogen target and the detection system includes wire spark chambers, with core read-out, on-line to a computer. The branching ratio for the electron decay is low so that only a few events per day are recorded. The experiment will give a measure of the parameter α relating vector and axial vector currents.

An Oxford team have a separated negative kaon beam in the momentum range 1 to 2 GeV/c and look at the production of neutral particles (such as the lambda hyperon and the neutral pion). They have optical spark chambers and wire spark chambers with magnetostrictive read-out.

A University College London/Rutherford team are looking at negative kaon (1 to 2.3 GeV/c) proton elastic scattering using wire spark chambers with core read-out on-line to a PDP 8 computer.

A 'Symposium on the use of Nimrod for Nuclear Structure Physics' was held at the Laboratory on 21-23 March. Nuclear structure physicists need access to higher energy machines for some experiments which will enable them to penetrate to shorter distances in the nucleus. The possibility of mounting such experiments on Nimrod has been under consideration for some time. They are quite demanding in terms of equipment and time and would have to be weighed against the in-roads they could make on the high-energy physics programme.

Computers

The computing system at the Laboratory is built around an IBM 360/75 as the multi-programming central computer. Via a satellite computer, a DDP 224, which collects and sends out information but does not do any processing itself, it is linked to an HPD and a CRT device for automatic film measurement, and has provision for up to six links with small computers (such as the PDP 8) which are on-line to experiments. Each of these stations can have a two-way typewriter at which it can receive messages from the computer and send messages to the computer to change parameters in a programme or modify the course of a programme. This feature has proved a vital asset to the computer users. The name DAEDALUS has been forced on this system, standing for Devices and Experiments Direct Access Link Using System 360.

The IBM has proved adequate for the present demand for computing in the Laboratory. It has a main memory of 512 K bytes, a mass core of 1 M and disc stores of 250 M and 28 M. It operates 24 hours a day with an efficiency around 95 % and most jobs are 'turned round' within an hour.

One HPD, very similar to the machine at CERN (see CERN COURIER vol. 8, page 80) has been in operation since 1967 and a second one is being built. The CRT film measuring device is called CYCLOPS. It involves a flying spot scanning up and down a single line while the film is moved across this line. As usual, photomultipliers detect the changes in light intensity caused by tracks on the film. It has been used to measure the CERN/Rutherford/Aachen experiment on the long-lived kaon decay to two neutral pions and is now working on an experiment from Rutherford (leptonic decay of the neutral kaon) and an experiment from Daresbury (electron-proton scattering). It may then take the CERN experiment on interference of the neutral pions in long-lived kaon decay. (All these experiments use optical spark chambers.) The measurement rate varies with the experiment (affected by such things as the film size) and can be as high as 2000 events per hour.

An IBM 1130 came into operation on 2 May; it is to be connected on-line to the rough digitizers (equivalent to the Milady scanning tables at CERN) for the HPD. It will control the preliminary rough measurements on the film which passes to the HPD to be precisely measured. The computer has a disc store capable of collecting a day's worth of information to be passed to the central computer.

Other developments on computers include the intention to use the central computer for some administrative data processing, and a test of the practicality of remote computing using a small computer in London linked to the IBM 360 via a telephone line.

Static Compensator

It seems appropriate that the Laboratory which has been most plagued with power supply troubles should be the one to pursue vigorously the idea of dispensing with local rotating machinery in supplying power to an accelerator magnet.

The problem is briefly this: Synchrotrons operate as pulsed machines — this means that say once every two seconds a great surge of current is required to power the magnet ring to hold the protons in their orbits. Taking this power directly from the electricity grid without any intermediate stage would cause the voltage on the grid to dip and rise with the synchrotron pulse to an extent generally unacceptable to other electricity consumers.

The solution universally adopted to-date for large proton synchrotrons has been to install a power supply for the magnet where energy can be stored as kinetic energy of the heavy rotating machinery. This power supply then gives the surges that the magnet requires and averages out the effect on the grid. However, the mechanical engineering problems in the design of such a power supply are unique and fiendishly dificult, and it is not surprising that practically every accelerator Laboratory has had trouble from this source. The Rutherford Laboratory, which has the largest magnet power supply, has had two major breakdowns which have stopped or slowed the experimental programme.

The new idea rests on two developments. First, it is now possible to build a static system of heavy electrical plant which will hold the voltage at the grid steady. Such a system has been called a Static Compensator. Second, it is still necessary to deal with the large pulse of energy (the strain felt by the Laboratory rotating plant is really being transferred to the rotating plant feeding the grid) but electricity networks have now become so large that when this pulse of energy is distributed over the grid, it should be absorbed without difficulty.

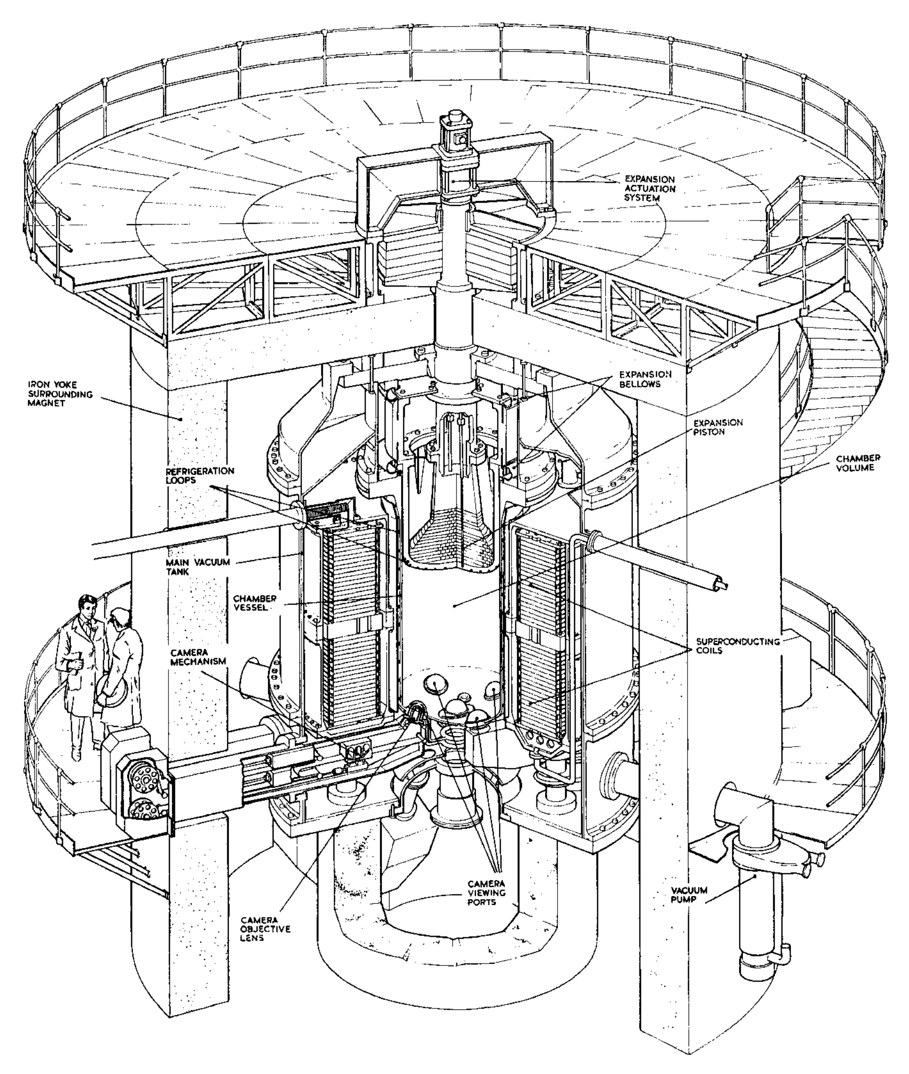
In order to test this second statement, Nimrod, without its rotating plant, was connected to the grid on 14-15 November of last year. This was the first time that any electricity network had taken such a large pulsed load. The test was carried out with the co-operation of the Central Electricity Generating Board, the Southern Electricity Board, the Atlas Computing Laboratory, and Daresbury Laboratory who used their instrumentation to print out the fluctuations of the grid frequency as Nimrod pulsed 150 miles away. A large part of the UK network, which has a maximum generation capacity of 40 000 MW was connected up. Tests were carried out around mid-day, when there is a heavy load on the network (the generation condition was about 30 500 MVA) and around midnight, when the load on the network is light (the generation condition was about 18 000 MVA). Nimrod was creating a cyclic energy swing of about 70 MW on this network.

When the results appeared, the effect of Nimrod could not be distinguished, at first sight, from the general 'noise' on the network. However, using a computer programme (called BOMM) for time series analysis developed by the geophysicist Prof. E.C. Bullard and his collaborators, the effect of the regular Nimrod pulse could be picked out quite clearly.

The surprising result was that the disturbance due to Nimrod was lower that had been calculated. (To give an example of the figures involved — in one test series the maximum frequency disturbance due to Nimrod was 0.0187 % compared with a calculated 0.0320 %). Also the discrepancy between the calculated and the observed disturbance was greater in the tests conducted at night. It is thought that this was due to an unexpected partial response of some of the turbine governors at the generating stations. The calculations had assumed only kinetic energy exchange without any governors exceeding their control 'threshold'. During the day when there was maximum energy in the network, probably only a few generators receiving their proportion of the load pulse, were taken over threshold. At night, with minimum energy, the same pulse caused more generators to respond.

The tests showed that the impact of a large pulsed load on an electricity network is more favourable even than expected.

There are some other developments on this topic. CERN will carry out tests, with the 28 GeV proton synchrotron as a pulsed



An artist's impression of the proposed high field bubble chamber. The volume of liquid hydrogen is 1.5 m diameter by 1.8 m high, and a superconducting magnet establishes a field of 70 kG at the centre of the chamber. (Photo Rutherford Laboratory)

load on the Geneva grid, later this year. The CERN plans have benefited greatly from discussions with J. Fox. It is intended to dispense with rotating plant for the American 200 GeV accelerator at Weston. Some calculations have already been done at the Rutherford Laboratory concerning the use of a static compensator for the proposed European 300 GeV accelerator.

'Frequency Variation of the United Kingdom Electricity Grid System during the 90 MVA Cyclic Pulse Loading Test on 14/15 November 1967' by J.A. Fox and P. Kent.

High Field Bubble Chamber

An important proposal for the future development of the experimental facilities at the Laboratory is a 1.5 m hydrogen bubble chamber with a magnetic field of 70 kG. An initial design study of this high field bubble chamber (HFBC) was presented in January 1967. The chamber was originally optimized for the analysis of strong interactions at low (Nimrod) energies. Further study, however, and the development of the two-phase neon/hydrogen systems to provide gamma detection, indicate that the design is well suited to the study of strong interactions at all energies up to about 300 GeV. The estimated cost is £ 2 ½ million, and the estimated construction time is four years.

The aim behind the proposal to construct a chamber of, by now, modest volume with a very high magnetic field rather than a chamber of larger volume with lower field, is primarily to improve the precision of particle momentum measurements. This is of particular interest for the analysis of strong interactions where present accuracies are insufficient. The HFBC will give momentum measurements of an accuracy better than 0.5 % at about 10 GeV compared with the present accuracies of about 3%. This will improve the resolution of the mass of a resonance, for example, to within 1 to 3 MeV compared with 10 to 30 MeV. This will also give unique assignment of events to the correct physical channels and thereby remove a major source of uncertainty with present experiments. For many experiments, the HFBC would be better than the large chambers now being built and it would generally be as good even used at the 300 GeV machine. It would not compete with chambers of larger volume for neutrino experiments and in many ways would be a complementary instrument to the 3.7 m hydrogen chamber being built for CERN. Also, it has been designed for very rapid cycling — capable of say ten pictures per pulse — which will make high statistics experiments possible in conjunction with the improved resolution and event identification.

The main characteristics of the proposed chamber are as follows: The chamber body is cylindrical in shape with the axis of the cylinder vertical. Its diameter is 1.5 m and height 1.8 m (total volume 3300 litres; 'useful' volume 2200 litres). A superconducting magnet produces a field of 70 kG at the centre of the chamber and has a stored energy of 300 MJ (approaching that of the 3.7 m chamber). The expansion system operates at the top of the chamber using a full diameter plastic piston sealed to the chamber walls with omega bellows probably made from fibre glass epoxy. The four cameras look from the bottom of the chamber.

Preliminary work at the Laboratory is concentrating on several technical problems. The magnet would be the first of its size to produce such high fields. The coils will experience very high stress levels (the attractive force between them is about 10 000 tons) and research is under way on coil materials and on methods of building the coils. It is intended to wind a 3 mm stainless steel strip with the superconductor, to give added strength. A small coil is being built and may be tested in BRARACOURCIX at CERN. On the optical system, investigations are being carried out on fish-eye lenses and on the possibility of using a dark-field scotchlite illumination system (see CERN COURIER vol. 7, page 144). Test rigs are being built for work on the resonant expansion system and on the problems of clamping the piston. Fibre glass epoxy omega bellows have been tested at room temperature for five million cycles without trouble. Other research of more general interest is under way at Oxford Engineering Department (trying to find out what starts nucleate boiling) and at Imperial College London (on the use of holography).

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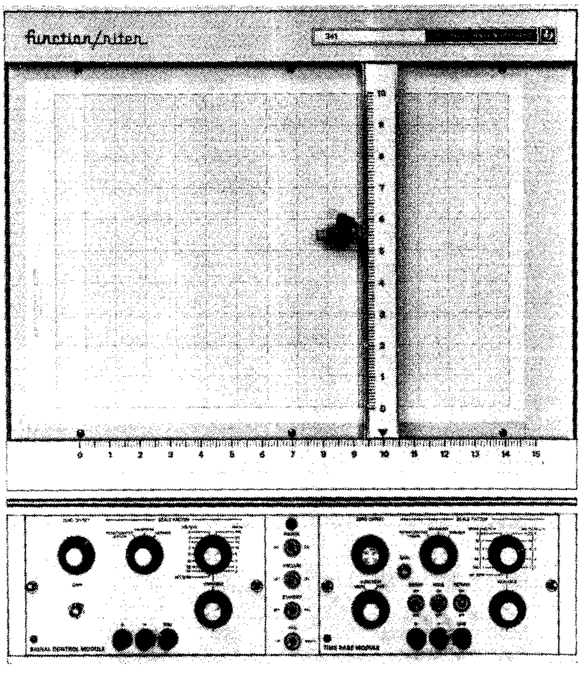

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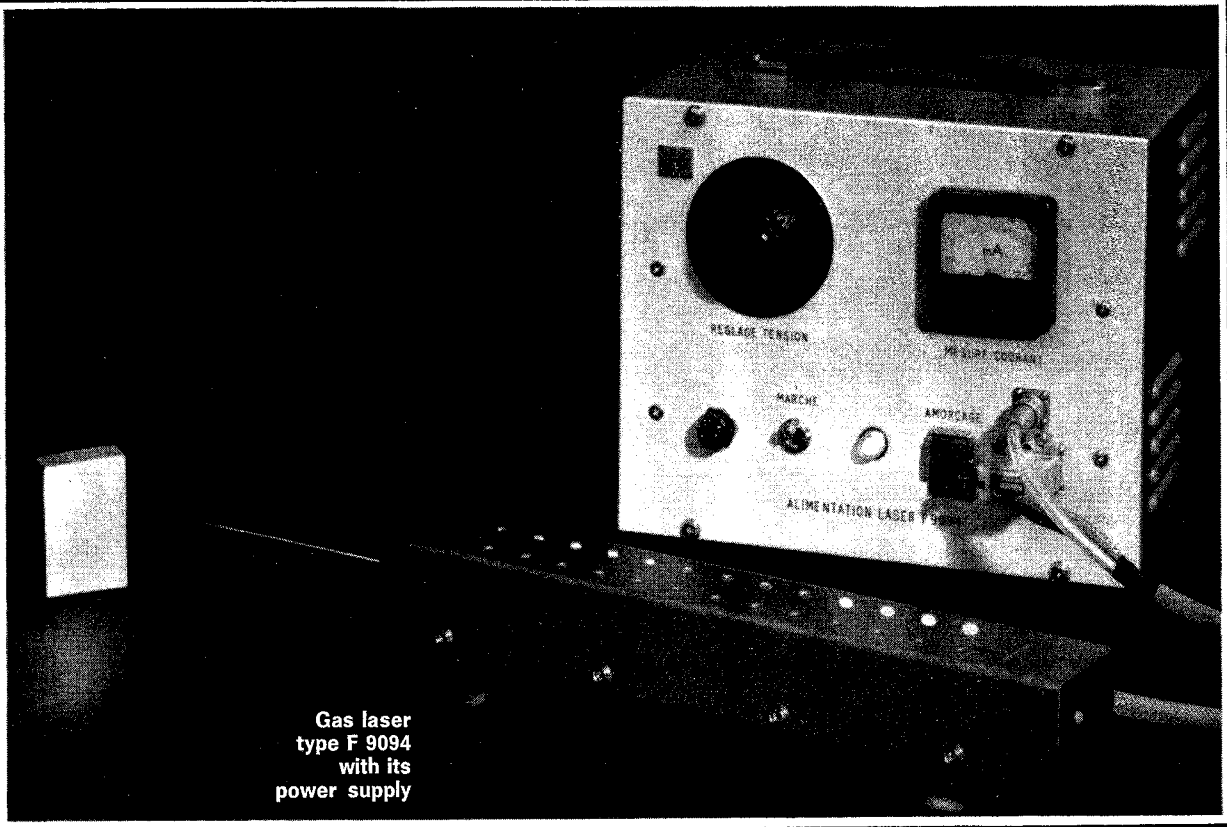

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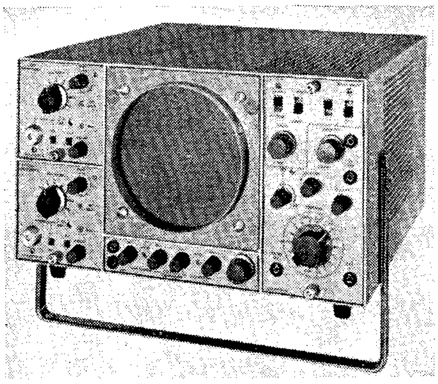

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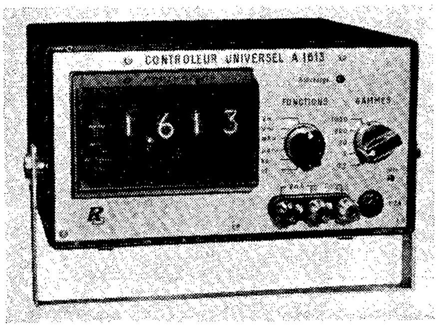

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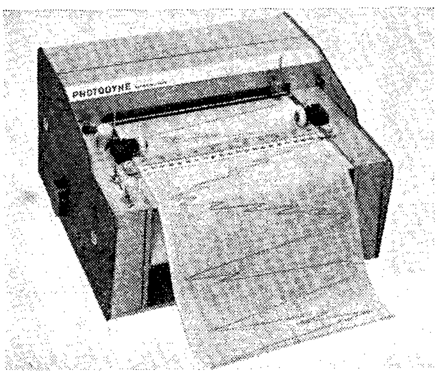

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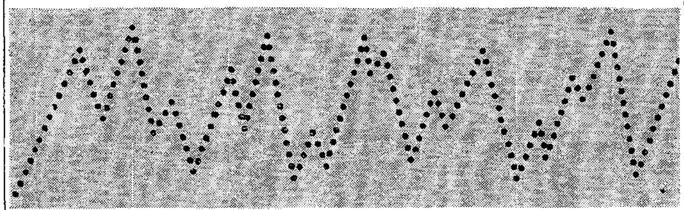

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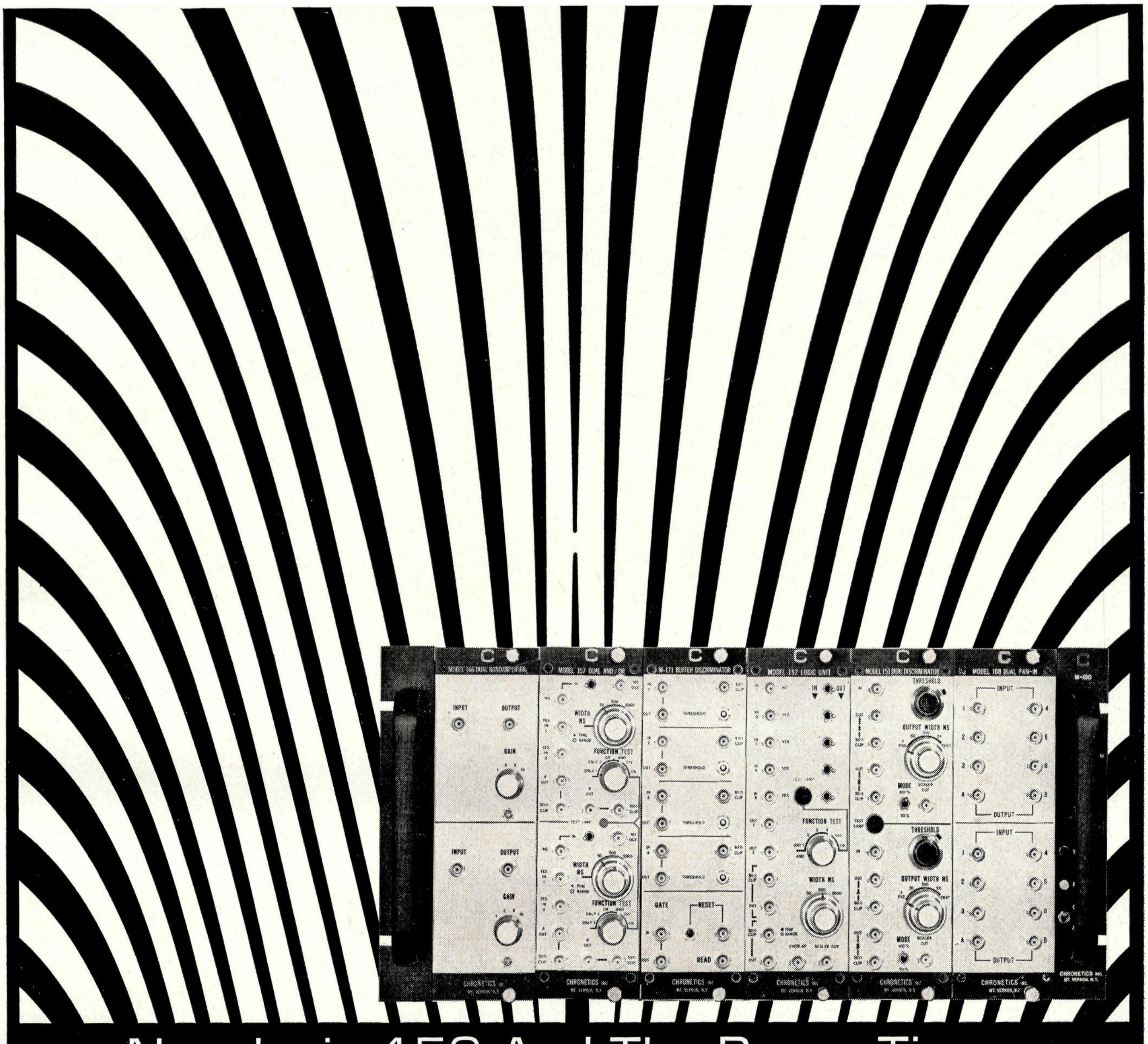

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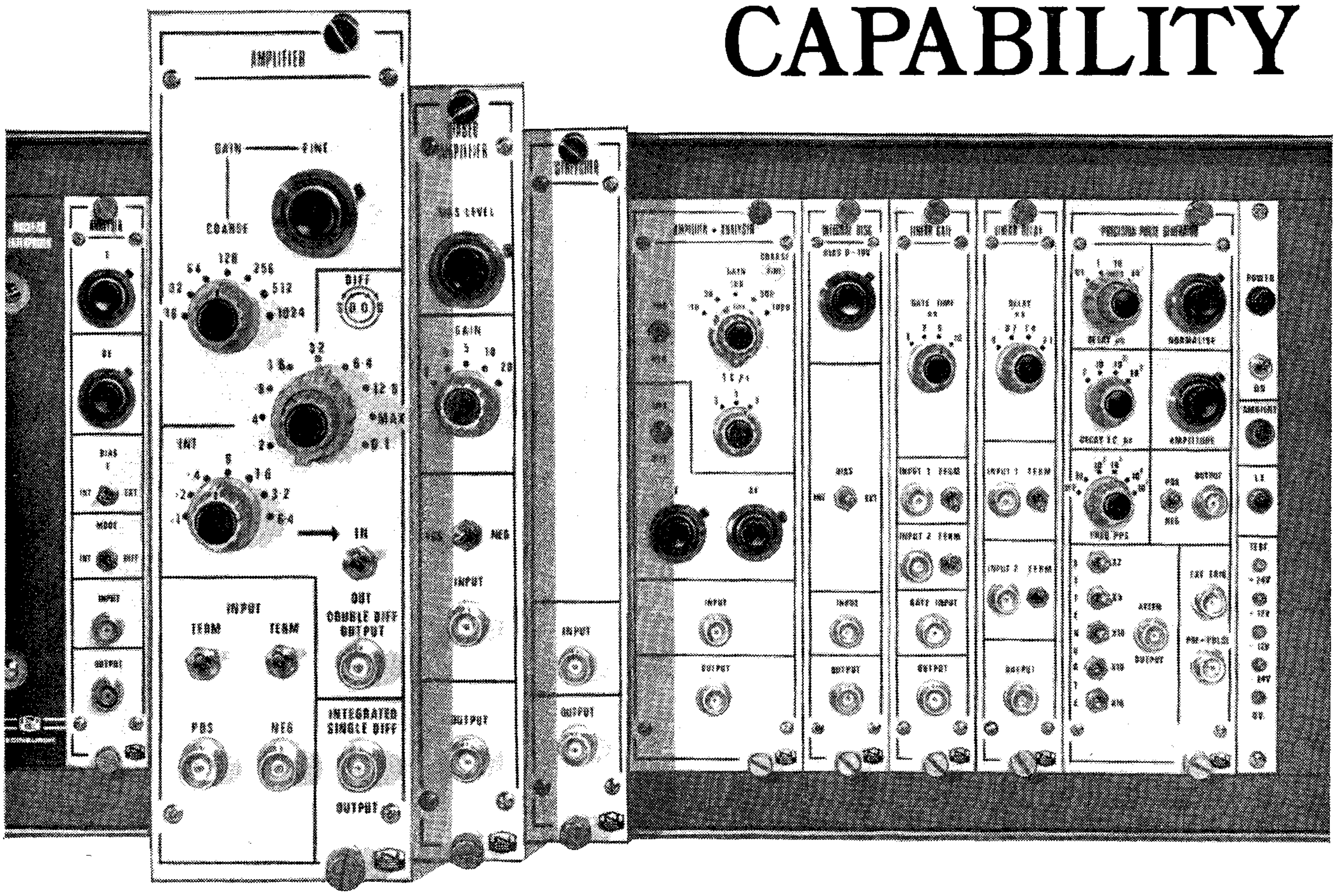

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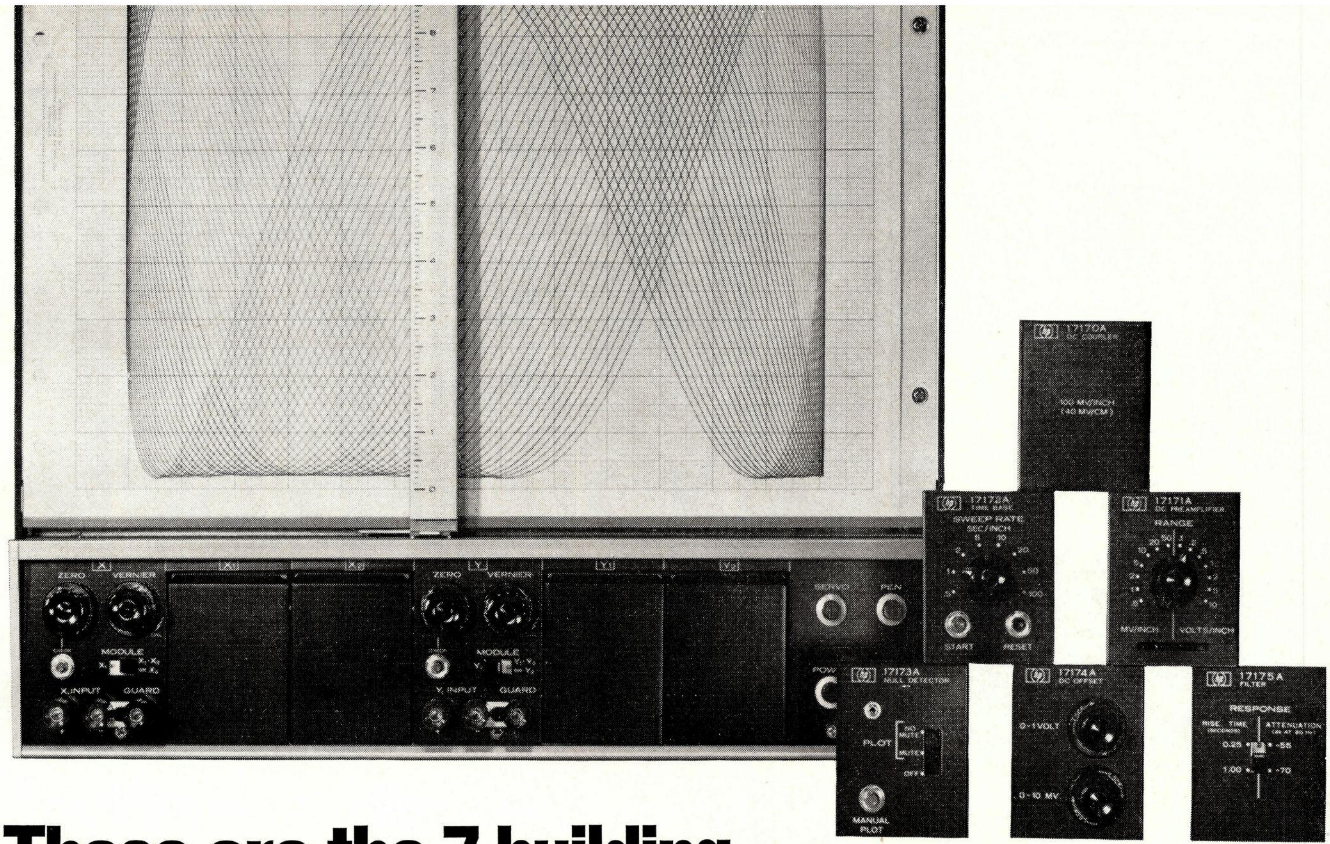

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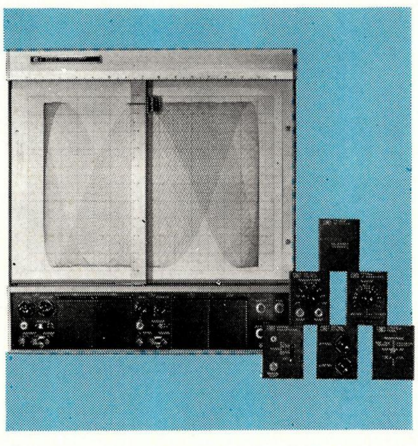

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