CERN COURIER

NO. 3 VOL. 15 MARCH 1975

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 1500 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 3200 people and, in addition, there are about 1000 Fellows and Scientific Associates. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 410 million Swiss francs in 1975.

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 400 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 1975 is 237.9 million Swiss francs and the staff totals about 450.

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Contents

Cover photograph: Strange reflections bouncing from a plexiglass surface which is being polished to serve as a mirror in a Cherenkov counter. The arm coming in from the top left carries the polishing disc which is impregnated with a special liquid. It leaves traces of this substance on the mirror as it revolves. Four liquid Cherenkov counters are using such mirrors in the Brussels/Orsay experiment which is just starting at the proton synchrotron. With two spectrometer arms they will look for the production of particles with masses between 1.5 and 5 GeV from proton interactions at 25 GeV. (CERN 88.2.75)

CERN News

The storage ring where the (g-2) of the muon has been measured to an accuracy of 20 parts per million. The forty bending magnets are C-shaped with the aperture opening facing towards the centre. Electrons from the muon decays can then emerge through this opening and be measured by counters spread around the inside of the ring.

The muon under scrutiny again

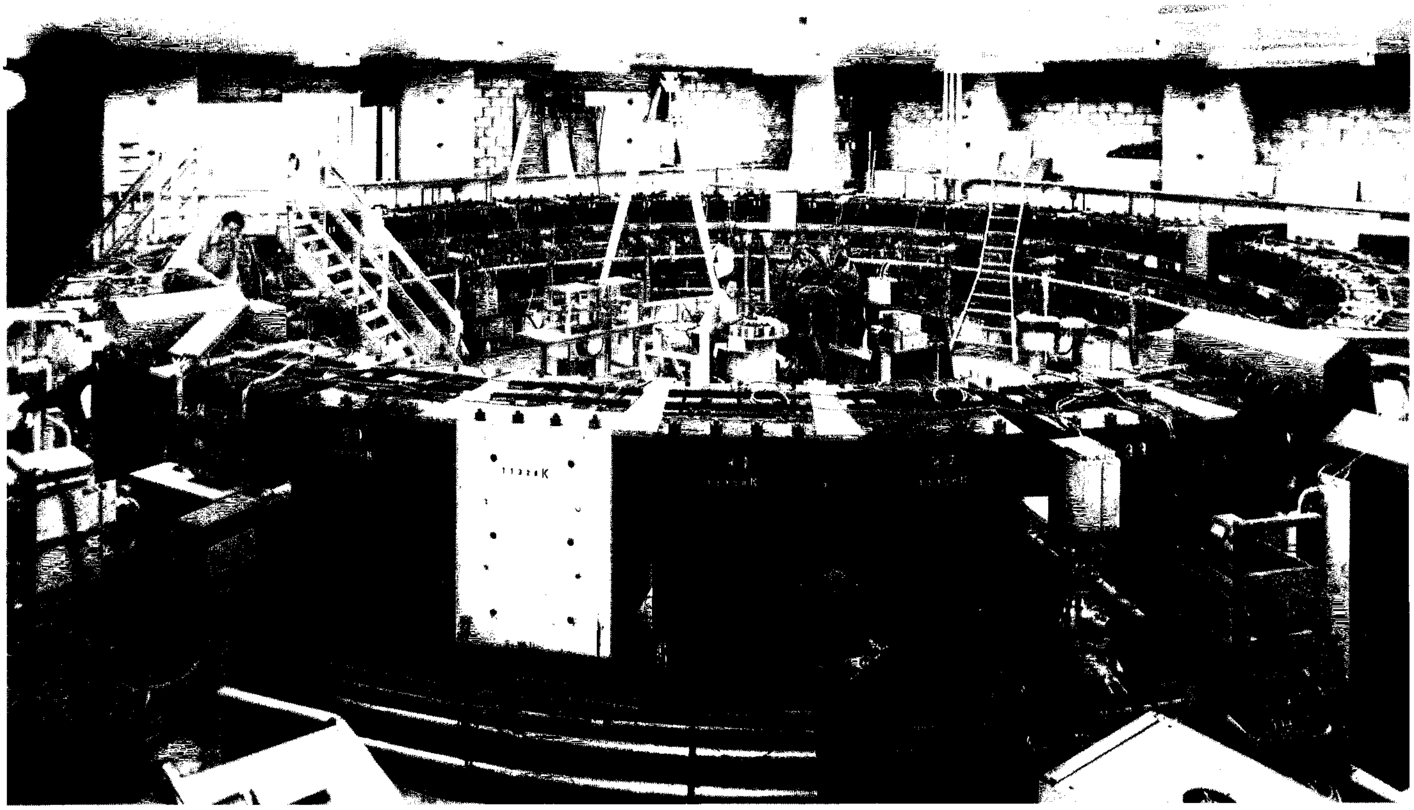
A new measurement on the muon has recently emerged from the CERN/ Daresbury/Mainz team using the muon storage ring. They have determined (g-2) of the muon to the remarkable accuracy of around 20 parts per million.

The (g-2) of the muon has been a topic in the CERN programme since 1960 and the present experiment is the third in the series aiming to push the accuracy of the measurement as far as possible. The reason for this determined pursuit is that the (g-2) value can be calculated with great precision using quantum electrodynamics — the theory of how the electromagnetic force operates. The experiment checks this calculation and therefore tells us how well we understand the electromagnetic force. One remark which illustrates the importance of this work is that 'the g-2 measurement acts as a great restraint on the imagination of theorists'; in other words, g-2 is precisely known and no theory can veer off in new directions without retaining the ability to calculate this value.

The muon, since it is a spinning charged particle, has a small magnetic field, as if a tiny bar magnet is lying along its spin axis. Its magnetic moment is proportional to the angular momentum associated with the spin. The classical value is multiplied by the gyromagnetic ratio, g, which, for particles which have spin ½ such as the muon, is equal to 2 in quantum theory. However, because the muon is involved in emitting and recapturing virtual photons, the value of the magnetic moment is slightly changed in a way which is calculated using quantum electrodynamics. This gives an 'anomalous magnetic moment' proportional to (g-2). (For a fuller exposition of this story, see August 1966, page 152 and May 1974, page 156.)

(g-2) can be measured by watching the rate at which the muon's tiny magnet swings around in a known magnetic field. In the new experiment, pions are injected into a storage ring where they decay into muons. The weak force involved in the decay makes things happen in a particular direction (parity is not conserved) and the muons are born with their spin axes predominantly lined up in the direction of travel of the muons. If 'g' were exactly equal to 2, the spins would stay aligned this way but due to the anomalous magnetic moment they swing around as the muons orbit the ring.

Subsequently, the muons themselves decay to produce electrons and again the electrons tend to emerge in a particular direction — the direction of the muon spin axis. These electrons have variable energy when they reach



CERN 54.9.74

a detector — highest when the muon spin axes point towards the detector and least when they point in the opposite direction. If the detector is made sensitive only to the highest energy electrons, its counting rate will rise and fall rythmically at the rate the muon spin axes are swinging around. This is the technique used in the CERN experiment.

The storage ring is 14 m in diameter and consists of 40 bending magnets, giving a field of 1.47 T, interspersed with electrostatic quadrupole focusing magnets (see April 1973, page 110). Pions, produced at the proton synchrotron, are injected at an energy of 3.1 GeV. About 10^6 of them begin to orbit the ring and about 10 % have decayed during 2/3 of a revolution yielding some 200 muons (over 90 % polarized) with the correct momentum and angle to be stored. The ring characteristics have been carefully tailored to hold muons of momentum 3.094 GeV/c. At this value, the influence of the non-uniform electric focusing fields is zero and only the uniform magnetic field works on the muon spins.

Having a uniform field is one of the main advantages compared to the previous experiment (where uncertainty concerning the average field seen by the muons introduced an error of 160 parts per million). Also, the muon momentum is higher (3 compared with 1.27 GeV/c) and this, in accordance with Einstein's relativity theory, increases the lifetime of the muons (64.4 μs compared with 27 μs). The muons can therefore be watched for longer times which again increases the accuracy of the measurement.

The electrons emerging when the muons decay are seen by twenty counters installed around the inside of the storage ring. They are 20 cm lead-scintillator sandwiches viewed by photomultipliers.

The ring began operation in June 1974 and almost immediately was working well. The first experiment has been carried out on positive muons for which the anomalous magnetic moment is now measured as $0.001165895 \pm 0.000000027$. This is below the theoretically calculated value by $(13 \pm 29) \times 10^{-9}$. The calculated value includes quantum electrodynamic effects down to sixth order (where the virtual photons leaving the muon can perform a series of contorsions before being recaptured) and also includes an estimate of the effect of the strong interaction which can normally be left out when considering the muon.

The experiment will continue throughout this year attempting to push the accuracy still further (to 10 parts in a million) and to measure also the negatively charged muon.

PS starts up

The Proton Synchrotron and the Intersecting Storage Rings have had a two month rest at the beginning of this year while a series of modifications and a general programme of maintenance was carried out (see January issue, page 7).

The Linac, Booster and PS Main Ring all came back into action at the end of February as scheduled. Thanks to a careful series of preliminary checks, the start-up went like clockwork. After a few hours checking the magnetic status of the PS using direct injection from the 50 MeV Linac, the 800 MeV Booster was switched into the circuit. Two hours ahead of programme, the ejection system to the neutrino target was in operation (receiving 19 of the 20 orbiting bunches of protons) giving beam to the Gargamelle heavy liquid bubble chamber.

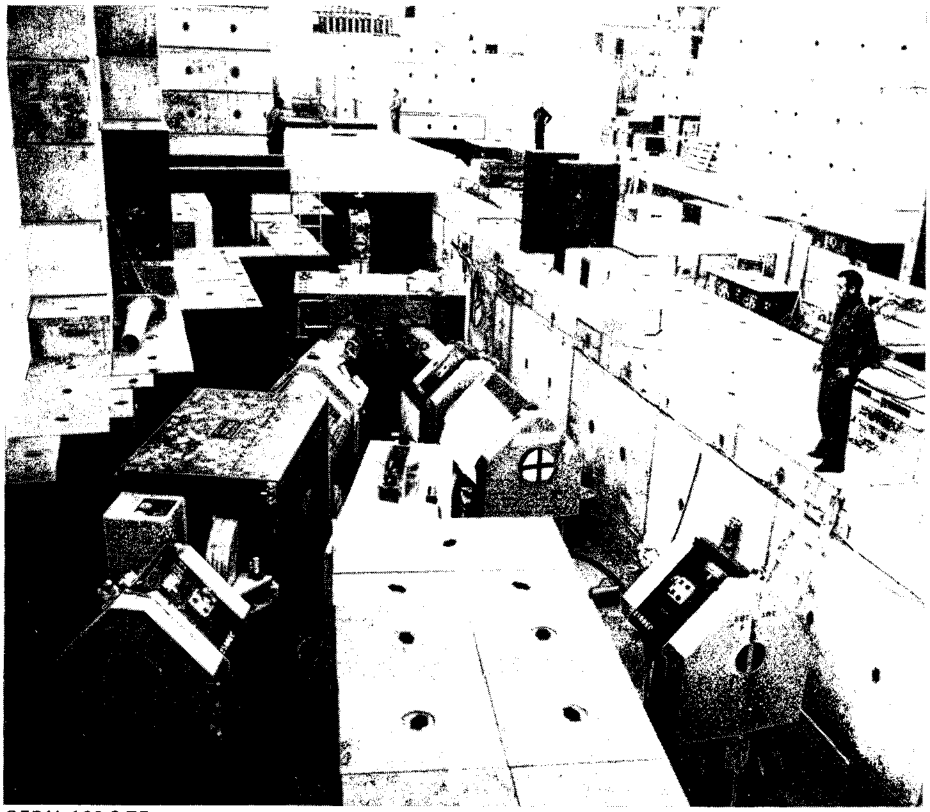
Following that, the new slow ejection system into the East Hall was tuned up using the remaining bunch. When the magnets in this new beam-line had been tuned to pass the protons efficiently, their currents proved to be very close to the theoretical calculations. It is on this beam that the Brussels/Orsay team have their double arm spectrometer which will search for new particles covering a wide mass range which includes the region where the new particles were discovered in November last year. They had five days of protons for preliminary tests after which the 20th bunch was sent in the opposite direction to the West Hall so that experiments in the Omega Spectrometer could sort themselves out.

Although the start-up of the machines went very smoothly, there was a mysterious hitch during the first twelve days of operation. Despite the fact that the Booster was feeding 6×10^{12} particles per pulse to the PS ring only 5×10^{12} were being accelerated. For tests when Gargamelle was off the air, the PS was fed directly from the Linac again since the lower energy beams are better for localising faults. It was found that beam loss was occurring at the junction box of a vacuum pump and opening up the offending region revealed that beam was hitting a connexion of one of 100 pairs of damping resistors which had been installed during the shutdown to cope with a resonance problem occurring at 1.5 GHz. With this out of the way, the intensity limitation is probably out of the way also.

The machine schedule through to Easter will also see internal target No. 1 receiving protons together with the slow ejection system 16, and fast ejection will feed the ISR and the 3.7 m bubble chamber, BEBC. For all these operations, at the request of the experimental physicists, the Booster will be kept in action (contrary to the initial plan) to ensure a healthy flood of protons.

At the time of writing the ISR restart

The two spectrometer arms of the Brussels/Orsay experiment during installation of the magnets. When the magnets were in place the target region was completely boxed in by concrete shielding to cut down background. Two small windows through the shielding along the arms, allow particles to emerge to detectors (mainly Cherenkov counters). The sensitivity of the system is very high and should allow a thorough search of the mass region from 1.5 to 5 GeV. Tests are now under way and data taking is scheduled for the beginning of May.



CERN 160.2.75

has not taken place so we shall come back to their experience in the next issue.

Experiments

During the machine shutdown, several new experiments were set up at the PS and ISR and the 1975 experimental programme could be a very exciting one, with much more information emerging, for example, on the possible existence of quarks and of charmed particles. This information is closely related to understanding the nature of the new particle discoveries at Brookhaven and Stanford.

The discoveries caused a flurry of excitement at the end of 1974 and the experimenters had a ten-day extension of the scheduled operation of the ISR before the shutdown in order to collect data in connection with these stable particles of high mass (3.1 and 3.7 GeV).

The CERN/Hamburg/Orsay/Vienna group investigated, with the Split Field Magnet, the production of muon pairs some of which could come from the decay of a 3.1 GeV particle — analysis is under way. The CERN/Harvard/Munich / Northwestern / Riverside group have started looking at the production of pairs from a charmed particle and its charmed antiparticle (they trigger on electrons and look for narrow mass peaks spotting kaons, lambdas, etc.). The CERN/Holland/Lancaster/Manchester and Daresbury/Liverpool/Rutherford/Scandinavia groups have put their wide and narrow-angle spectrometers together to study the production of electrons and associated pairs (pions, kaons, etc.) also looking for the narrow mass peaks which are expected if charmed particles exist. The CERN/Rome group studied the production of forward-emitted electrons and have put close limits on the increase in production when moving from PS to ISR energies.

The CERN/Columbia/Rockefeller/Saclay group, which stopped collecting data at the ISR last September, has results showing five events of a particle with a mass of 3.1 GeV decaying into an electron-positron pair. The cross-section for the production of the 3.1 GeV particle at ISR energies is about fifty times greater than that seen at the energy of the Brookhaven Alternating Gradient Synchrotron. This implies that the new particles are present in observable quantity around the ISR.

We shall be following up these experiments, and the others which are now starting, in the course of the year.

BEBC restarted

On 22 February the 3.7 m European bubble chamber, BEBC, started recommissioning after its rebuild. The large superconducting magnet had begun working again in December (see January issue, page 9) and the latest phase has seen the cool down of both chamber and magnet followed by picture taking with beam from the PS.

The magnet had been left isolated in its vacuum tank and its temperature had reached 140 K when cool down began in February. On 2 March, the 'technical run' with beam was used for a whole series of tests to determine the best working conditions for the chamber and to optimize the quality of the photographs. The quality is now looking very good.

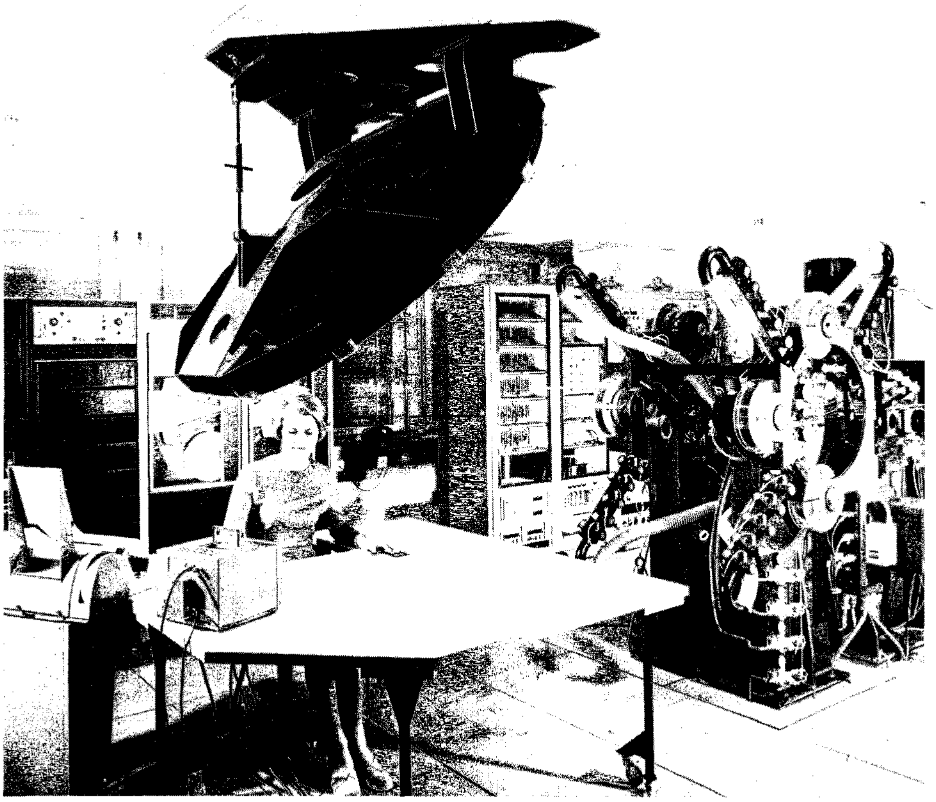
The 'technical run' will merge into a 'production run' beginning with an experiment being carried out by a collaboration of scientists from Germany, Italy and the U.K. They have 50 000 to 100 000 photos lined up with a 21 GeV negative pion beam into the chamber. The beam-line will then be switched to feed 12 GeV antiprotons until the end of operation of the chamber with the PS in July. After that the chamber will have some time to breathe while the West Hall is being made ready in anticipation of beams from the SPS.

Calculating Klein

In September of last year (see page 293) we reported Willem Klein's seemingly incredible achievement of deducing the 37th root of a 220 digit number in three minutes, 26 seconds during a lecture given to CERN summer students. Judging by his more recent performances he was only warming up.

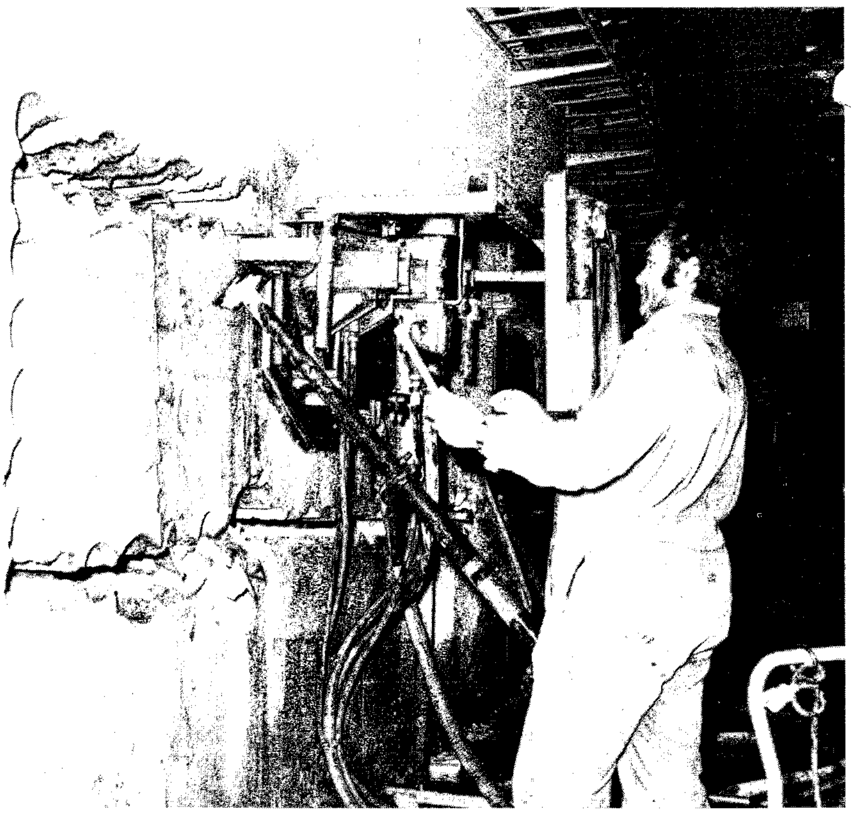
The latest feat was on 5 March during a demonstration at the Lycée Lacassagne at Lyon in France. He was confronted with a 200 digit number with the task of extracting the 23rd root. This is more daunting than his exercise of last summer since he had to pull out a nine figure number rather than a six figure number. Previously his record stood at eighteen minutes five seconds. At Lyon it took just ten minutes thirty seconds.

On 26 February, the Spiral Readers at CERN clocked up their millionth measured event on bubble chamber film. This type of semi-automatic measuring machine was initiated at Berkeley. Two of them have been built at CERN, the first coming into action for regular film measurement in 1970. They both now operate at a rate of about 70 vertices per hour and have a good record on the criterion of Swiss francs/event. A description of the CERN Spiral Readers can be found in October 1968, page 247.



CERN 271.1.69

The last physical obstacle to the free passage of protons between the PS and SPS falls to the drill during the annual shutdown. The wall is in the beam transfer tunnel where protons are taken from the PS to the ISR. At this point, protons will be bent off down a tunnel leading to the underground 400 GeV synchrotron ring. The tunnel is already dug and partly equipped.



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Around the Laboratories

Palermo Conference

The biennial International Conference of the High Energy and Particle Physics Division of the European Physical Society will be held at Palermo in Italy from 23 to 28 June. Attendance will be by invitation only with the quota for the various countries and Laboratories following established tradition.

The programme has the following major topics: The new particles, Lepton production by hadrons, $e^+e^- \rightarrow$hadrons, Neutrino physics, Deep inelastic lepton scattering, Hadron spectroscopy, High energy hadron collisions, Standard electromagnetic interactions of hadrons, Theoretical topics, New projects, Highlights in technical developments. These subjects will be covered by invited papers in plenary sessions with the possibility of organizing special sessions if needed.

Papers for the Conference should be sent to A. Zichichi, European Physical Society, PO Box 39, 1213 Petit-Lancy 2, Switzerland — abstracts by 15 April and full texts by 1 June.

NOVOSIBIRSK Electron cooling successfully tested

The Institute of Nuclear Physics at Novosibirsk has concentrated on the construction of storage rings incorporating many new ideas. One of their long-term aims has been to build a machine where proton-antiproton interactions can be studied (see May 1967, page 88); the big problem with such a scheme is to achieve adequate antiproton beam intensities. The idea of G.I. Budker, Director of the Institute, is to use an electron beam travelling along with the antiproton beam to 'cool' the antiprotons — damping their motion and making them less likely to be lost from the beam.

To test the scheme, a small storage ring, known as NAP-M, was designed in 1972. It has four bending magnets, 3 m bending radius, and four 7.1 m straight sections. It can hold protons up to 150 MeV and is fed with 1 mA beams at 1.5 MeV from a pulsed electrostatic injector. Circulating beam was achieved in September 1973 and its characteristics were studied during the subsequent six months. For the past year electron cooling experiments have been under way.

Electron beams of energy up to 100 keV and intensity 1 A, from a refined three electrode gun, can be run along with the proton beam in a 1 m length of a straight section. For the experiments, the proton beam was taken to 65 MeV and the ring magnet fields were then held constant while the electron beam at 35 keV was injected. Operation and observation was all under computer control (an Odra-1304). Probes with TV cameras, pick-up stations and scintillators (including one which could be moved across the beam) were used to monitor the beams. There was also an external telescope of scintillators and Geiger counters which spotted the formation of neutral hydrogen atoms emerging through a thin walled vacuum chamber at the cooling section. This could be used to optimise the lining up of the two beams by looking for the maximum production of the neutral atoms.

The experiment showed that cooling occurs when the proton and electron velocities are identical to one part in a thousand or better. When this is achieved, the effect of the electron beam on the proton beam is to reduce its energy spread, to reduce the amplitude of the proton betatron oscillations and to increase the proton beam lifetime. This does not necessarily say that electron cooling is the best route to intense antiproton beams but it does confirm the original thinking that went into the electron cooling concept.

Three other storage rings are in operation at the Institute. VEPP-2, a 500 MeV electron-positron machine, works mainly as injector for VEPP 2', a 660 MeV electron-positron machine which has low beta insertions to increase the luminosity. VEPP 3 is a 3 GeV electron-positron machine. Its performance remains limited by inadequate positron intensities. There is no high energy electron linac to help in positron production; they are obtained by bombarding a tungsten target with 450 MeV electrons which gives a low yield of 250 MeV positrons.

For the future, VEPP 4, which was originally intended as a 25 GeV proton-antiproton machine incorporating electron cooling, has been redesigned as a 6 GeV electron-positron machine. To tackle the positron beam intensity problem, a linac is likely to be built. It is hoped to bring VEPP 4 into action in 1978.

INFN Conference on applications in biomedicine

A conference dedicated to 'biomedicine and the methodology of fundamental nuclear physics' was held at Istituto Superiore di Sanita in Rome on 14, 15 February. It was the first of a series of interdisciplinary conferences organised by INFN (Istituto Nazionale di Fisico Nucleare) the aim of which, as stated by Prof. C. Villi, President of INFN, at a Press Conference, is to encourage the 'fall out' of knowledge acquired in nuclear physics research into other fields of research and technology. In the case of biomedicine, there is occasional application of nuclear techniques but use is rarely made of the methodology of research in fundamental nuclear physics.

The first conference was dedicated to the presentation of advanced methodologies of high diagnostic and therapeutic power which can be derived from nuclear research and to a discussion between doctors and researchers working in the biomedical field as to their practical application. Twenty-five papers, illustrating contributions in the various fields, where the use of nuclear methods is most meaningful, were presented and discussed.

The topics included: Measurements of biological parameters and the detection of trace elements using backscattering methods, x fluorescence, etc.; Advanced semiotics using detectors, such as multiwire proportional chambers and drift chambers, phonopneumography and radiofrenography; Digitization of semiotic data, such as electrocardiograms, radiographs and microphotographs by using flying spot and CTR techniques; Digitization and analysis of clinical data using large and small computers; Use of new therapeutic instruments such as microtrons, heavy ion accelerators and short-lived isotopes; Computer control of therapy, particularly of radiotherapy and dosimetry.

The interest in the use of heavy ion accelerators in the treatment of cancer without damaging surrounding tissue, was prominent, as was the possibility of obtaining three-dimensional radiographs using 1.2 GeV proton beams as analysing particles and drift chambers as detectors. Another impressive possibility is that of using the automatic machines which measure bubble chamber film for digitizing radiographs and microphotographs so as to analyse them with computers and present the data to doctors in a more accessible form.

The technique of listening directly to respiratory sounds in order to obtain thoracic phonographs of high semiotic value also seems of great interest.

This first conference demonstrated that in practically all sections of INFN there is a strong interest in the biomedical applications of the abilities acquired in the course of nuclear and high energy physics research. It also brought out the receptivity of the more advanced sections of the medical world towards these new prospects in diagnosis and therapy.

The conference was organized by Prof. I.F. Quercia, who is now preparing two further conferences scheduled to be held in 1975. They will be dedicated to the application of nuclear methodologies in informatics and in astrophysics.

DARESBURY
Research programme changing shape

The research programme at the Daresbury Laboratory will be almost completely restructured in the next few years. The 5 GeV electron synchrotron, NINA, is to be closed down and the research will instead be centred on a Nuclear Structure Facility (a 30 MV tandem Van de Graaff now under construction), and a Synchrotron Radiation Source (a 2 GeV electron storage ring which is on the brink of authorization). Thus the community that the Laboratory will be serving will become increasingly more involved with nuclear physics and the many fields of physics, chemistry and biology using synchrotron light.

Construction of the Nuclear Structure Facility (see May 1973, page 150) began a year ago. It will be the highest energy tandem Van de Graaff in the world (its nearest rival being a 25 MV machine recently authorized at Oak Ridge) and is designed particularly for the acceleration of heavy ions. With 100 % duty cycle, good energy resolution and flexible control of the energy it will be an important addition to the machines for nuclear physics studies and will complement the Darmstadt UNILAC and the proposed GANIL accelerator in France.

Work on the tower to house the tandem and on the huge pressure vessel (45 m high) is about on schedule. Vessel sections will be lowered into the tower in May for welding together. Its pressure test is scheduled for November. Meanwhile, a lot of development work is being done with the pilot machine (operating up to 9 MV) so as to master the technical problems involved in going to much higher voltages than other tandems. Such things as the laddertron charging system, a rotating power drive shaft, the optical data link system and accelerator tube sections are being given severe testing.

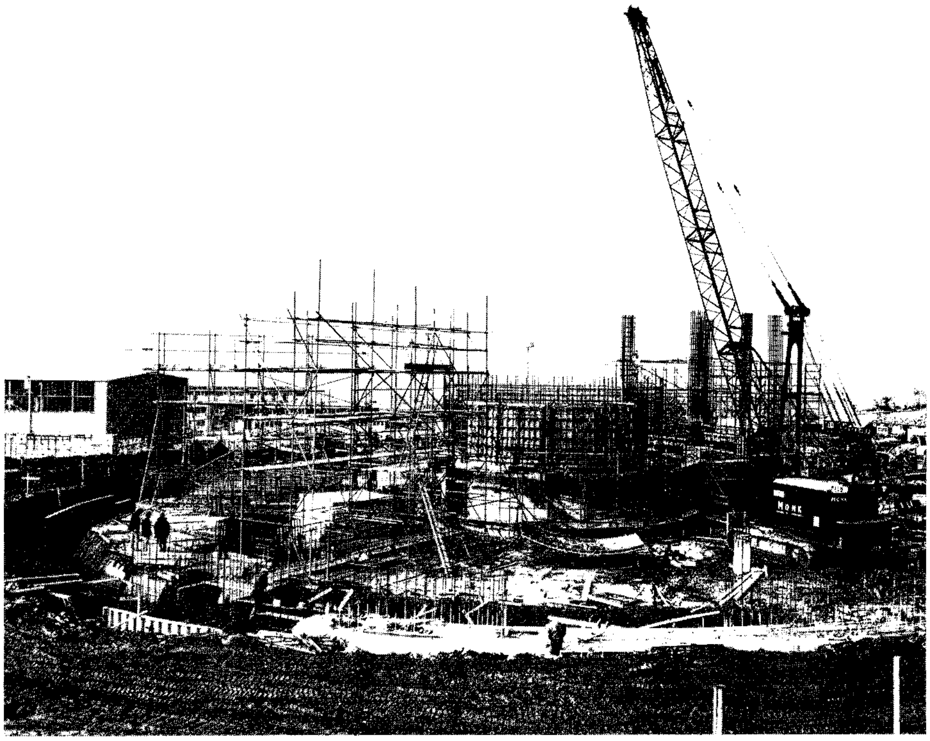
The NSF is due for completion in 1978. A Users Committee has already been formed with representatives from many Universities (Birmingham, Bradford, Edinburgh, Glasgow, Liverpool, London, Manchester, Oxford). In the near future this Committee will be involved in the decisions on the larger experimental facilities such as spectrometers and computers. Participation in the use of the NSF by scientists from other countries will be encouraged and it is likely that particularly close ties will be established with the UNILAC and GANIL Laboratories.

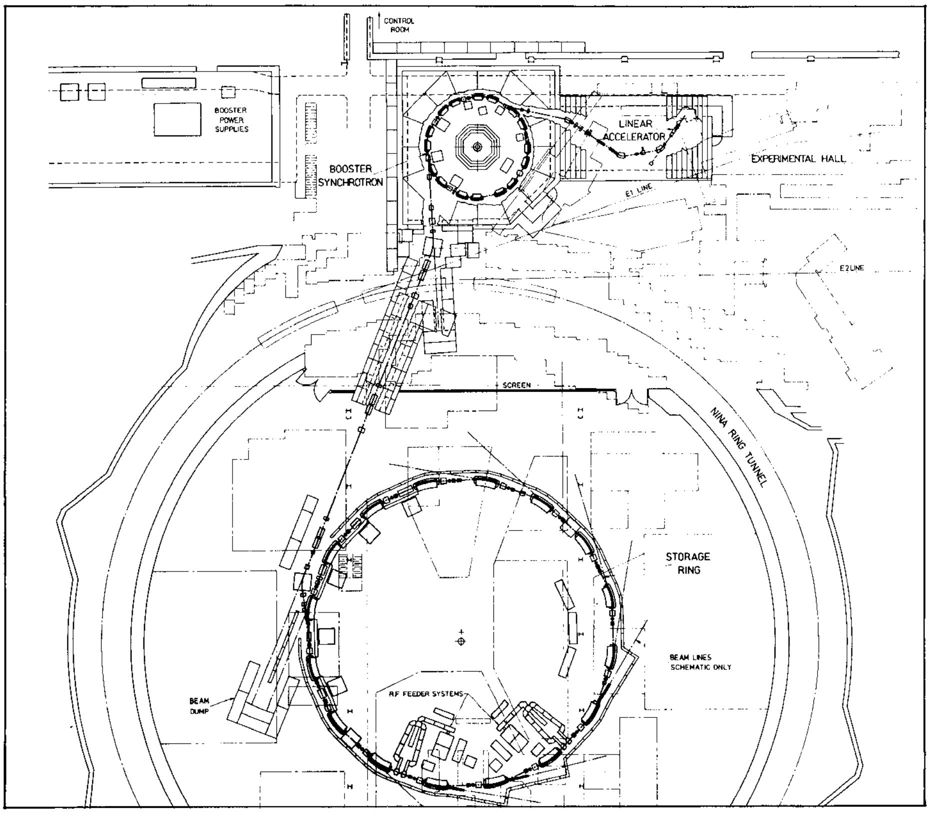
The proposed Synchrotron Radiation Source is a 2 GeV electron storage ring capable eventually of handling beams up to 1 A intensity. The project was described in the November 1973 issue, page 338. Since then a few changes have been introduced; there is a new layout of the linac-booster injection system and it has been de-

The tower, which will house the tandem Van de Graaff of the Nuclear Structure Facility, rising from the ground at the Daresbury Laboratory.

(Photo Daresbury)

Layout drawing of the Synchrotron Radiation Source planned for the Daresbury Laboratory. A 2 GeV electron storage ring (fed from a linac and booster synchrotron) will hold high currents to give intense fluxes of radiation. The ring sits in the Nina power supply hall.





cided to operate the r.f. cavities at 500 MHz. The SRS will provide usable fluxes of radiation in the wavelength range from about 0.5 angstroms out to radio wavelengths. In the first stage the aim is to achieve 0.5 A currents and to feed three beams. A beam lifetime of 8 to 10 hours is planned and this will demand exceptional vacuum conditions (10^{-9} torr) in the presence of high radiation fluxes. Subsequent developments will increase the current, the number of beams and possibly take the wavelength limit lower (to 0.1 angstroms) with the use of superconducting magnets called 'wigglers' (a development which has been studied at the Rutherford Laboratory).

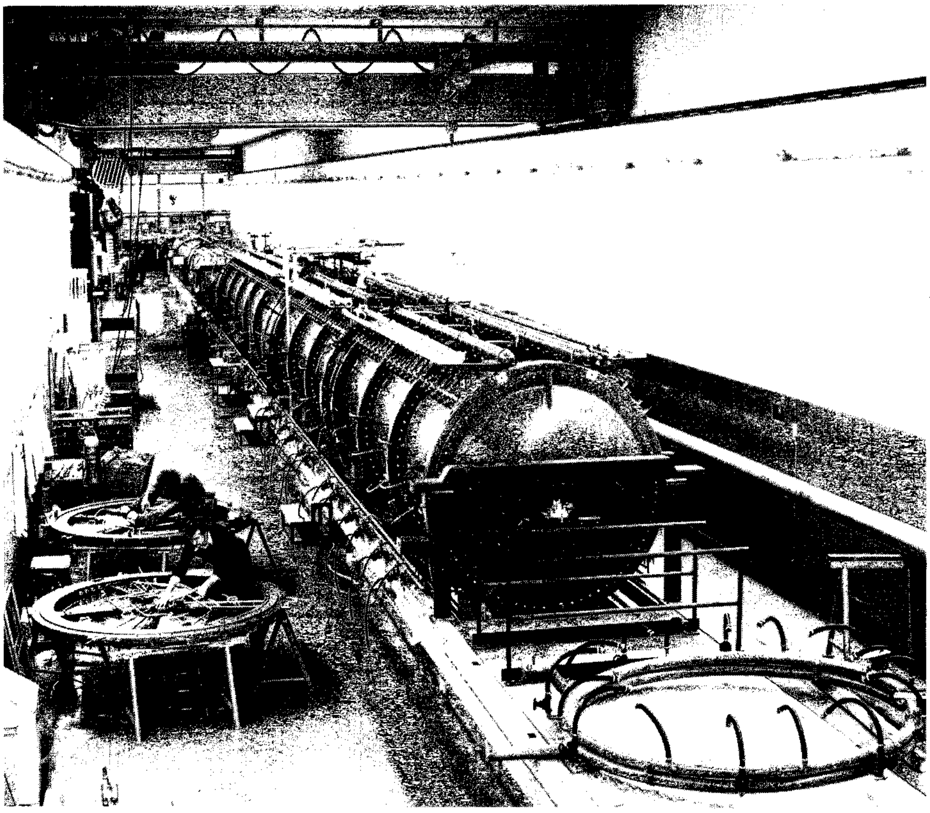
If authorization for construction is forthcoming soon, commissioning could start in April 1979, about fifteen months after the planned close down date for NINA (the SRS will be built in the hall now containing the NINA power supplies). It is expected that a Users Committee will be set up as for the NSF. There are already about 60 scientists from 16 Universities involved in the experimental programme at the synchrotron radiation facility on NINA. The number is likely to grow considerably as the SRS takes over.

Daresbury is obviously in the unusual position among national Laboratories in Europe at the present time of having a rather clear programme in front of it for some time ahead. It is also an interesting programme tackling new areas of research with facilities as fine as any in the world.

DARMSTADT UNILAC progress

It had been hoped that the versatile heavy ion accelerator, UNILAC, being built at the Gesellschaft für Schwerionenforschung (GSI), Darmstadt, *The Alvarez section of the heavy ion accelerator UNILAC at Darmstadt. Ions have already been accelerated to low energies and final construction and commissioning is under way. Full energy beams are scheduled in about six months' time.*

(Photo GSI)



would provide its first full energy beams at the beginning of 1975. There have, however, been some delays in the delivery of components and first operation is about six months away. Nevertheless, most machine components are in place and under test and there has been the satisfaction of seeing some accelerated heavy ions.

The machine is a multi-tank device using different acceleration techniques — a Wideroe section, an Alvarez section and a single gap cavity section. The last of the 60 outer drift tubes for the Wideroe section, which has four tanks, arrived at the Laboratory in January. Tank III was completed last July and has been successfully tested with full r.f. power (520 kW). Frequency stability was very good and the axial field distribution is within 1 % of the design values. Tank I was completed in December (it had previously been tested with some dummy drift tubes) and, a few days later, argon ions were accelerated through the tank to 0.22 MeV per nucleon. 25 % transmission was achieved, without the buncher in action, which is in agreement with the theoretical prediction. Tank II is now undergoing r.f. tests and Tank IV is near completion.

In general, the tests on the Wideroe section have so far gone well. Multipactoring was encountered at the expected r.f. levels but conditioning of the drift tube surfaces for several hours cleared the problem. It is hoped to have a beam through the full section (giving 1.4 MeV per nucleon) and into a small experimental hall in April. A beam-line to take the accelerated ions is already in place.

The two Alvarez tanks are assembled and r.f. tests are under way. Tank I has taken 200 kW peak r.f. power at 5 % duty cycle. The prototype final stage of the 108 MHz r.f. generator has operated at 1.6 MW peak power at 12.5 % duty cycle.

Delayed delivery of quadrupoles is holding up assembly of the single gap cavity section. However, the r.f. components have been tested (using a debuncher as load) and the 50 kW r.f. generators are going through their acceptance tests.

The aim is to have accelerated ions into the main experimental hall by October 1975 but some experiments taking beam from the end of the Alvarez section at 5.9 MeV per nucleon may be possible a few months earlier.

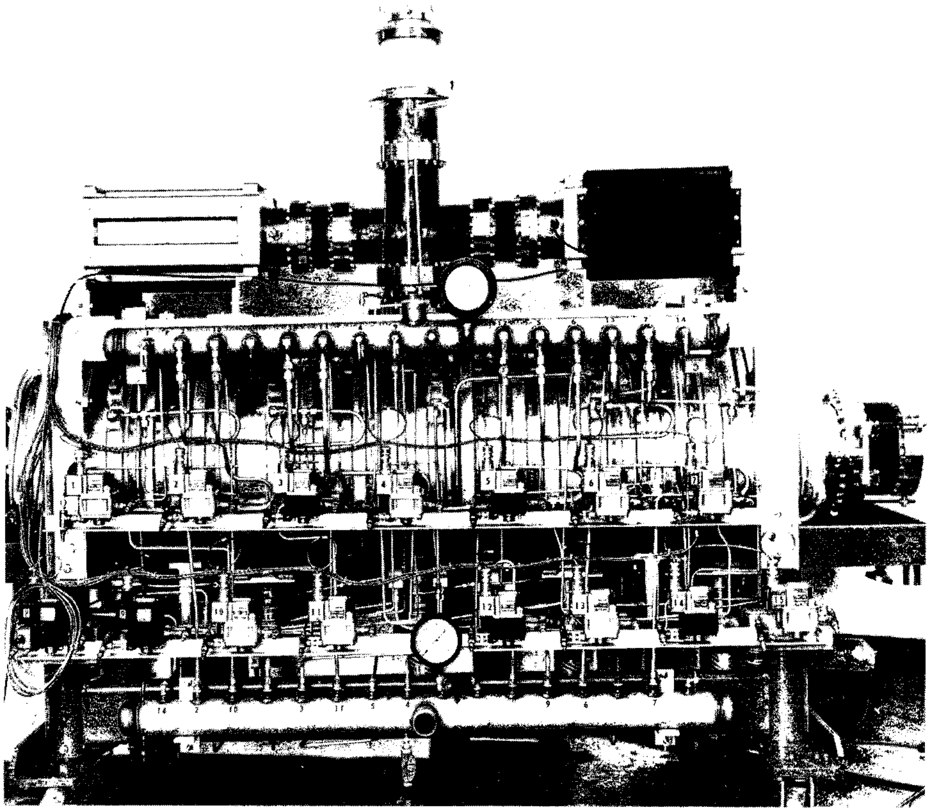
STANFORD
The next fiscal year

As reported briefly in the February issue, the USA President's budget for Fiscal Year 1976 does not contain authorization of the PEP project — the joint Berkeley/Stanford proposal for the construction of a 14 GeV electron-positron storage ring. Nevertheless, for the first time in seven years, the trend of decreasing financial support for the research programme has been reversed. If the recommendations in the President's budget are accepted, SLAC will see an increase of 14 ½ % in its 'costs' for the year beginning 1 July, which should enable the Laboratory to keep its nose ahead of inflation.

Work on PEP will of course continue, prodded even more by the new particle discoveries on the SPEAR storage ring. The present research facilities are likely to be operated at about 40 %, on average, of their full potential, as they have been during the present year. SPEAR will obviously be prominent and its improvement programme will be completed. This involves reaching higher energies (up to about 4.2 GeV per beam compared with the present peak of 3.8 GeV) and higher luminosities (with maximum

One of the four new r.f. accelerating structures installed in the SPEAR electron-positron storage ring at Stanford. The new structures will enable the peak energy of the beams to be pushed to about 4.2 GeV.

(Photo SLAC)



currents of 100 mA in one bunch (compared with the present 70 mA).

On the linear accelerator there will also be a gradual move to higher energies using the SLED scheme of increasing the energy gain per sector of the machine (see July 1974, page 259). In addition more powerful klystron tubes (30 or 40 MW compared to 20 MW) will help take the peak energy beyond the present maximum of 22.74 GeV.

Beams of polarized electrons are a new possibility in the experimental programme and the special electron source, PEGGY, built at Yale University (see July 1974, page 260) is now providing polarized electron intensities approaching 10^9 per pulse. It gives pulses 1.5 μs long at a repetition rate of 180 pulses per second, from photoionization of a polarized beam of lithium-6 atoms. Polarization can be measured by a Mott scattering monitor at 70 keV which has recorded 75 ± 10 % polarization of a beam with intensity 8×10^8 electrons per pulse. Moller scattering is used to monitor the high energy beam and has recorded similar polarizations. An experiment using the beam from PEGGY, together with a polarized proton target POPCORN, will begin soon to check spin dependence in deep inelastic electron-proton scattering where different predictions are made by different models of the proton structure. It will be followed by an experiment with an unpolarized target to check parity violations in electromagnetic interactions.

Other new facilities for experiments which are likely to come into action during the year are the Large Aperture Solenoid Spectrometer (LASS) and the 40 inch bubble chamber operated in the hybrid mode. LASS has a superconducting solenoid which has proved hard to master — leaks, a shorted turn and helium filling difficulties have delayed operation during the past year. It has a large array of detectors, including multiwire proportional chambers, and is likely to be amassing vast quantities of data by the end of 1975. The 40 inch bubble chamber has pulsed at rates up to 12 per second. Used in association with counters and spark chambers, it can select the interesting events to photograph.

BROOKHAVEN
More antiprotons

The ramifications of the new particle discoveries have led to a flood of new experiments. In particular, if the stability of the particles can be explained on the basis of a property known as charm, then many other charmed particles are expected to exist. All high mass, narrow (i.e. stable) objects are under suspicion and one of these is an object which was observed in 1974 in a proton-antiproton experiment at Brookhaven. They observed an 18 mb cross-section at a mass of 1.9 GeV.

A look is being taken at this object in the 2 m bubble chamber at CERN. The incoming momentum of the antiprotons is fixed as precisely as possible, the superconducting field shield (see June 1971, page 150) is used to manoeuvre the low momentum particles through the bubble chamber magnet fringe field and the field in the chamber is held down at 0.5 T. About 170 000 pictures were collected before the annual shutdown and are now being analysed aiming for a mass resolution of ± 2 MeV.

Brookhaven are following up their first experiment and have tried several ways of increasing their antiproton beam intensity. Using an 'energy degrader' they succeed in achieving much higher fluxes of antiprotons in the low energy separated beam and in extending the useful range down from

600 to 450 MeV/c. The optimum performance is obtained when the degrader (a block of material in the path of the antiproton beam) is located at the target. A single block, high Z (platinum or 'hevimet') material serves as target and degrader. The flux is optimised by moving the block across the incoming proton beam, effectively altering the thickness of the degrader, since the antiproton beam emerges at an angle of 10.5°. Since they are in focus in the beam, multiple scattering of the emerging antiprotons is reduced and good beam optics are retained. The antiprotons are fully momentum analysed by the subsequent beam-line elements.

The number of antiprotons per 10^{12} protons on the target is over 2×10^3 at 700 MeV and about 2.5×10^2 at 450 MeV.

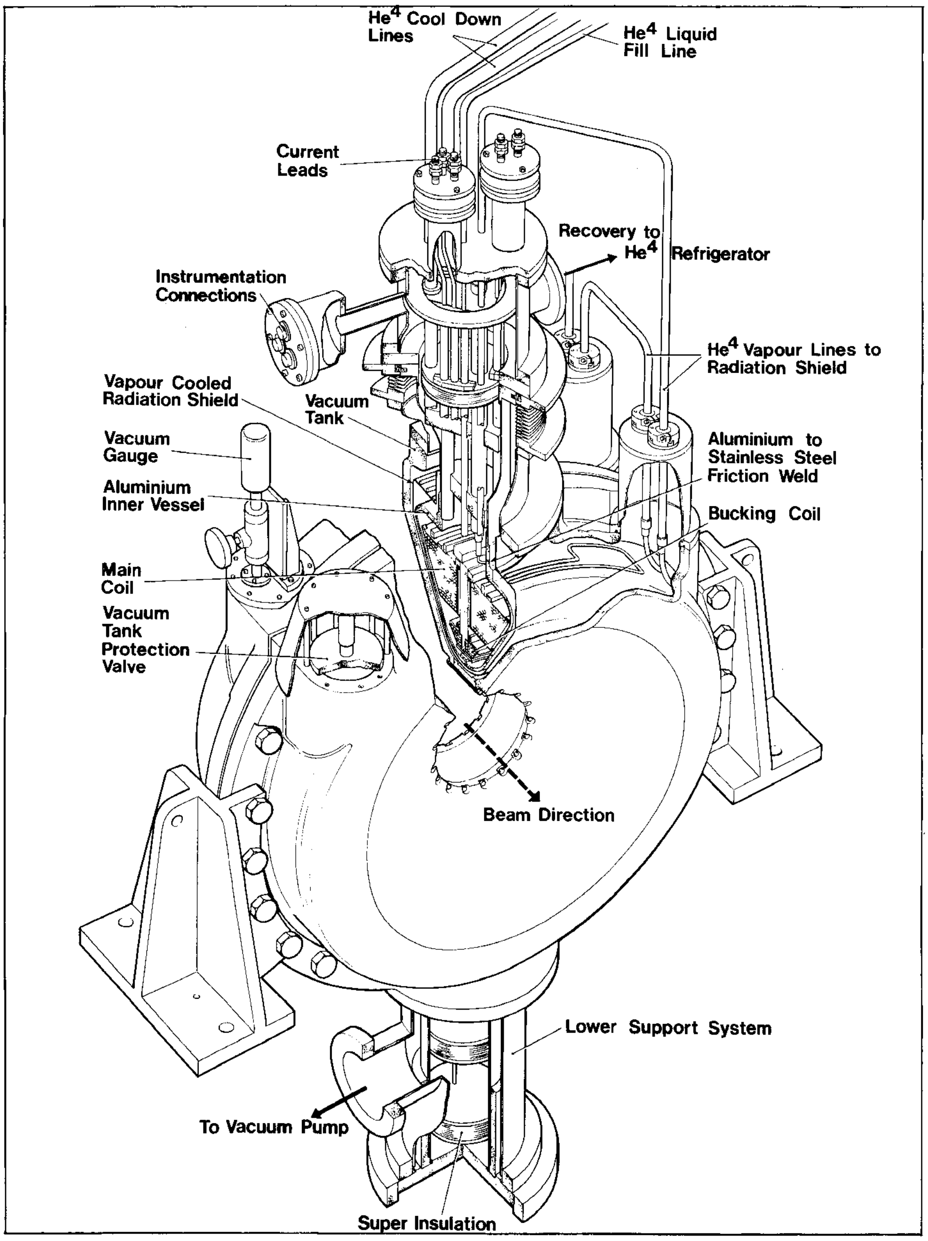
RUTHERFORD Superconductivity to the fore

The contribution of the Rutherford Laboratory to the development of superconducting magnets has been prominent for many years. They led the move to multi-filamentary conductors and are now, in association with the neighbouring Harwell centre, among those pushing the application of niobium-tin filamentary conductor.

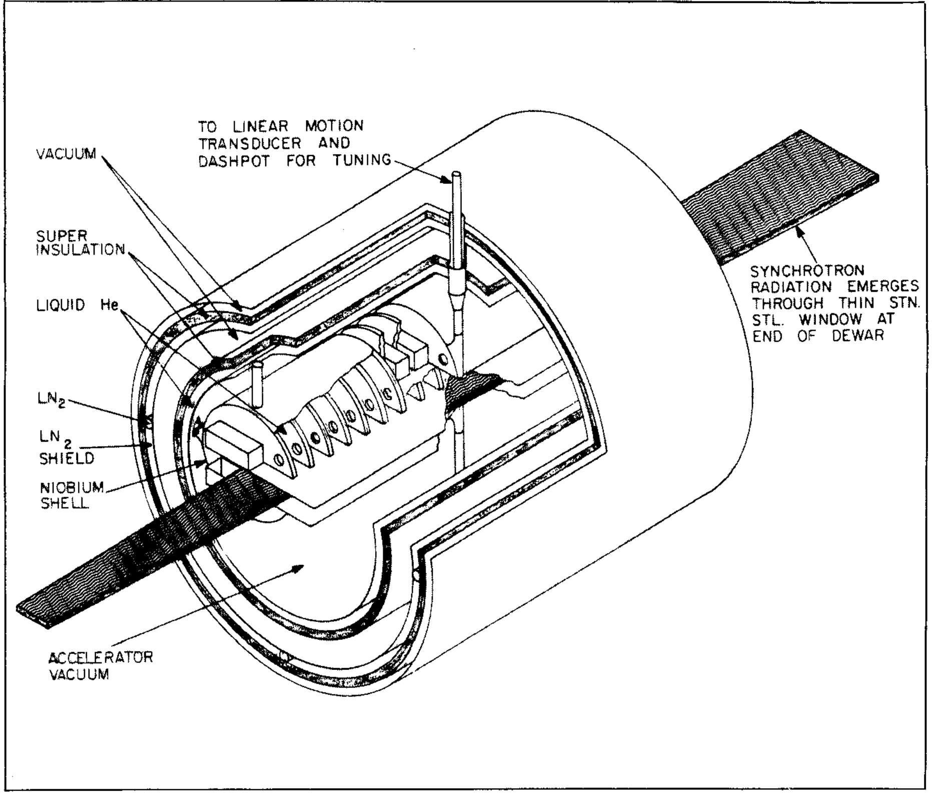
Recently several large magnets have been built for use in physics experiments. These include the BASQUE solenoid for the TRIUMF cyclotron in Canada (see May 1974, page 173) and a magnet for a 'frozen spin' polarized proton target which has operated well in an experiment recently completed on NIMROD.

In January another polarized target magnet was successfully tested. It is designed to give a central field of 2.5 T with a homogeneity of 2 parts in 10^4 over a target volume 30 mm in diameter and 50 mm long. The magnet consists of two pairs of solenoid coils mounted around the horizontal axis giving a large exit cone (60° semi-angle) for secondary particles to emerge. To leave this large cone free, the magnet had to be well away from the axis and the pair arrangement — a main coil and a smaller inner coil powered to oppose the main field — was needed to ensure the field homogeneity. Despite the comparatively low central field, the field at the main coil is 5.6 T. The design field was reached after a single quench and the homogeneity was achieved after minor adjustments to the currents to the smaller coils.

A superconducting hexapole magnet is under construction for use in neutron beam experiments at the France/Germany/UK high flux reactor



Drawing of the new superconducting magnet for a polarized proton target at the Rutherford Laboratory. It has a wide exit cone for secondary particles to emerge and this required a two solenoid arrangement with the coils set well back from the axis. The magnet has achieved its design central field of 2.5 T with a homogeneity of better than 2 parts in a thousand.



A sketch of the superconducting accelerating cavity and its cryostat as designed for use at the Cornell electron synchrotron. A prototype is performing well in the ring accelerating electrons to GeV energies. The cavity seems happy in the synchrotron environment.

centre in Grenoble. It is 1 m long has a 5 cm bore and a peak field of 5 T. High current density is desirable in hexapole magnets and they are an obvious candidate for the application of niobium-tin superconductor which can take much higher current densities than niobium-titanium. A niobium-tin model 30 cm long is being planned, using the 'wind and react' technique — see October 1974, page 349 — and construction may start before the end of the year.

Perhaps the major remaining concern in the construction of superconducting magnets is to master the phenomenon of training — the progressive approach to a peak field over a series of 'quenches' (the magnet losing its superconducting property). It seems that we still do not manage to avoid small movements of the superconductor which generate heat and send the conductor normal. Research on this phenomenon has continued at Rutherford with a series of small coils and two large magnets are now being built with the aim of suppressing training very much in mind.

One is a 5 T d.c. dipole without iron yoke which is intended for an optical spectrometer to be used in Zeeman splitting studies at Imperial College London. It is being impregnated with epoxy resin under high pressure. This should take a firm hold on the conductor. The other is the fifth generation of pulsed superconducting magnets, AC 5. The design of this magnet seems to incorporate every possible technique to ensure that the superconducting coil is held rigidly under compression. It is hoped to have tested both these magnets in time for the Magnet Conference at Frascati in April and we should be coming back to them in more detail at that time.

The work on pulsed magnets, particularly, is carried out in close liaison with the Karlsruhe and Saclay Laboratories in the GESSS collaboration (Group for European Superconducting Synchrotron Studies). GESSS is contributing to the applications of superconductivity at CERN. The experimental programme at the 400 GeV proton synchrotron calls for superconducting magnets (Karlsruhe, for example, are to build two quadrupoles for a hyperon beam). There is also the challenging prospect of a set of superconducting magnets for a 'low beta insertion' to increase the luminosity in one intersection of the Intersecting Storage Rings.

CORNELL
Novel idea for storage ring filling

A novel idea from M. Tigner has led to a proposal to extend the electron synchrotron facility at Cornell University by the addition of a storage ring, housed in the same tunnel, which will permit electron-positron colliding beam research with beams of energy up to 8 GeV or more. A major difficulty in the operation of such storage rings is to achieve high enough positron beam intensities in an acceptable time (see, for example, the note on Novosibirsk, page 73). The Cornell invention is a 'phase-vernier system' which would enable the synchrotron to become a much more efficient positron injector.

In effect, the synchrotron does double duty. After completion of its injector function, it becomes a bypass into which individual bunches of particles may be shunted from the storage ring for a predetermined number of revolutions and then returned to the ring. During injection, conventional beam stacking occurs in the storage ring. As many as sixty equally spaced bunches can be spread around the ring thus using the synchrotron's long duty cycle to the maximum. When this stacking is complete, the bunches can be diverted, one at a time, back through the synchrotron. Since the path length here differs from that around the storage ring, it can be arranged that the bunches are all superimposed serially back in the storage ring into a single intense circulating bunch.

The process can be completed within about one second for electrons. Positron filling times would be about one or two minutes. Clearly, the scheme increases the luminosity dramatically and fills the ring at a very acceptable rate.

Intensive design studies for a colliding beam facility using this idea are under way and a formal proposal is likely to be submitted to the National Science Foundation in the next few months.

Meanwhile work on the development of superconducting accelerating cavities has continued to show promising results on the Cornell synchrotron. A 0.6 m length of standing-wave, S-band niobium accelerator was installed in the ring in December 1974. When not operating, the cavity was kept at 150 K, with brief periods at room temperature. The accelerator has maintained its initial Q of 1.1×10^9 and breakdown field of 4 MeV/m (effective) under these conditions indicating that it should be able to survive in a synchrotron environment.

The superconducting cavity was used alone to accelerate a beam to 4 GeV and in concert with the normal r.f. system to take a beam without loss to 12 GeV. Limited helium reservoir capacity at present restricts such operation to three hours but a cryogenic system is being added to permit continuous operation at 1.9 K.

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COMPOSITION (% By Weight)

GLASS TYPE (Optical Glass)	PEMG 1 (SF 2)	PEMG 2 (F2)	PEMG 2A (F2W)	PEMG 4 (SF5)	PEMG 5 (SF1)
SiO_2	41	45	45	38	35
PbO	50	45	45	55	61
K_2O	5	6	6	5	2
Na_2O	3	3	3	1	1

PHYSICAL PROPERTIES

	PEMG 1	PEMG 2	PEMG 2A	PEMG 4	PEMG 5
Radiation Length (cm)	2.84	3.22	3.22	2.54	2.17
Refractive Index (nd)	1.64769	1.62004	1.62004	1.67270	1.71736
Abbe No. (vd)	33.8	36.3	36.3	32.1	29.5
Specific Gravity	3.85	3.61	3.61	4.08	4.47
Coefficient of Thermal Expansion (x10 - 7) (—30 - +70°c)	88	87	87	85	81

INTERNAL TRANSMITTANCE (Ti) FOR 25mm THICKNESS

Wavelength (nm)	PEMG 1	PEMG 2	PEMG 2A	PEMG 4	PEMG 5
330		0.07	0.10		
340	0.15	0.41	0.45	0.02	
350	0.47	0.703	0.741	0.27	0.01
360	0.708	0.843	0.875	0.57	0.14
370	0.837	0.911	0.932	0.753	0.35
380	0.894	0.934	0.955	0.850	0.55
390	0.940	0.965	0.975	0.915	0.711
400	0.968	0.973	0.984	0.953	0.829
420	0.981	0.984	0.988	0.975	0.925
440	0.985	0.985	0.989	0.982	0.960
460	0.988	0.988	0.991	0.985	0.973
480	0.992	0.989	0.992	0.987	0.985
500	0.994	0.990	0.993	0.990	0.990
550	0.995	0.992	0.995	0.991	0.993
600	0.995	0.993	0.996	0.992	0.993
650	0.995	0.995	0.997	0.993	0.993
700	0.995	0.995	0.997	0.993	0.994

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Transmittance Range	Tolerance on Above Value Ti
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0.50 to 0.985	Minus (1 minus Ti) x 0.2
Over 0.985	Minus 0.003

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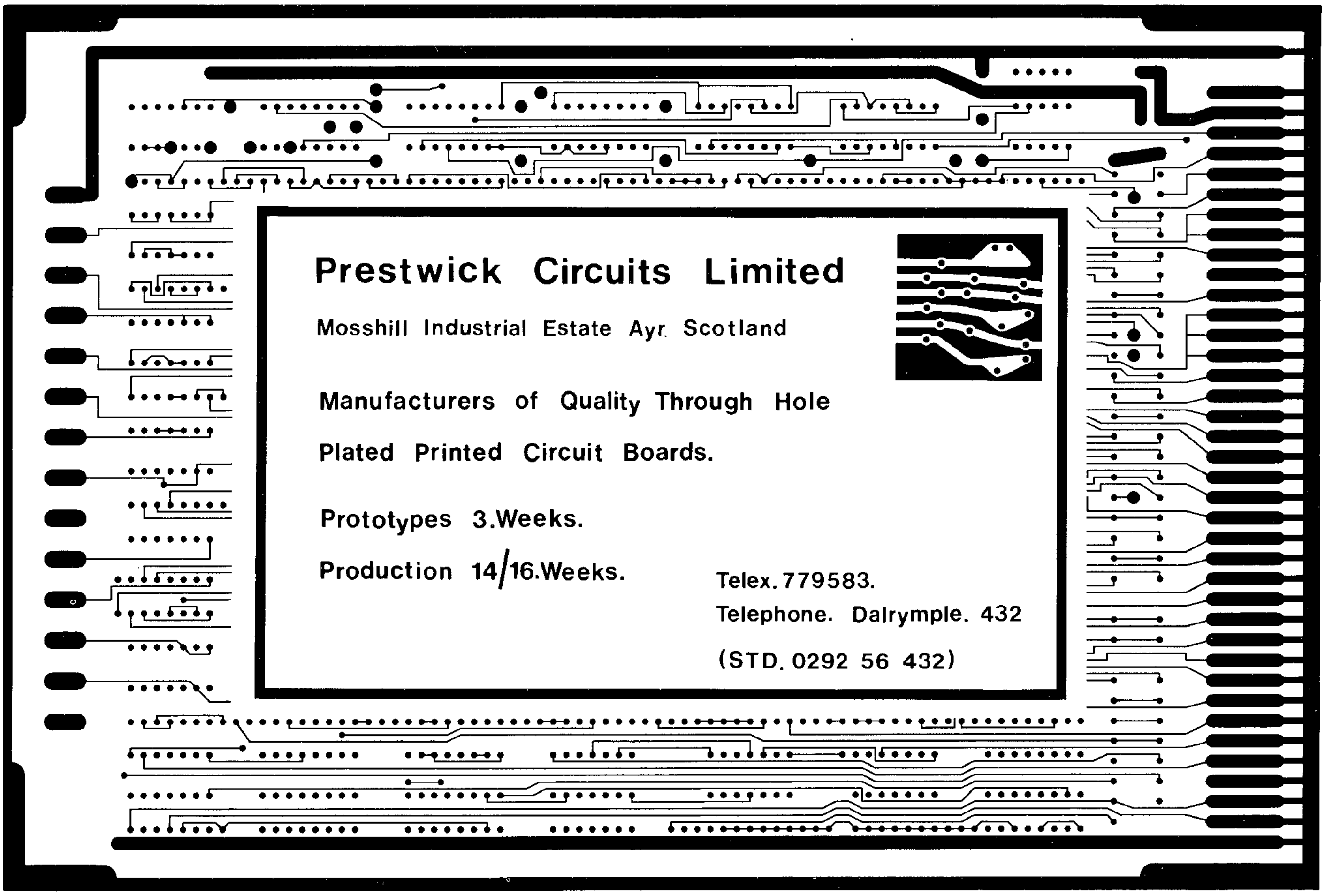
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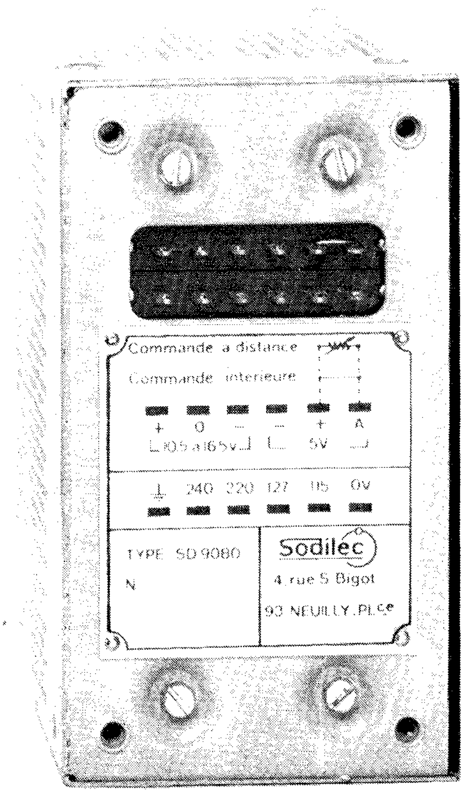
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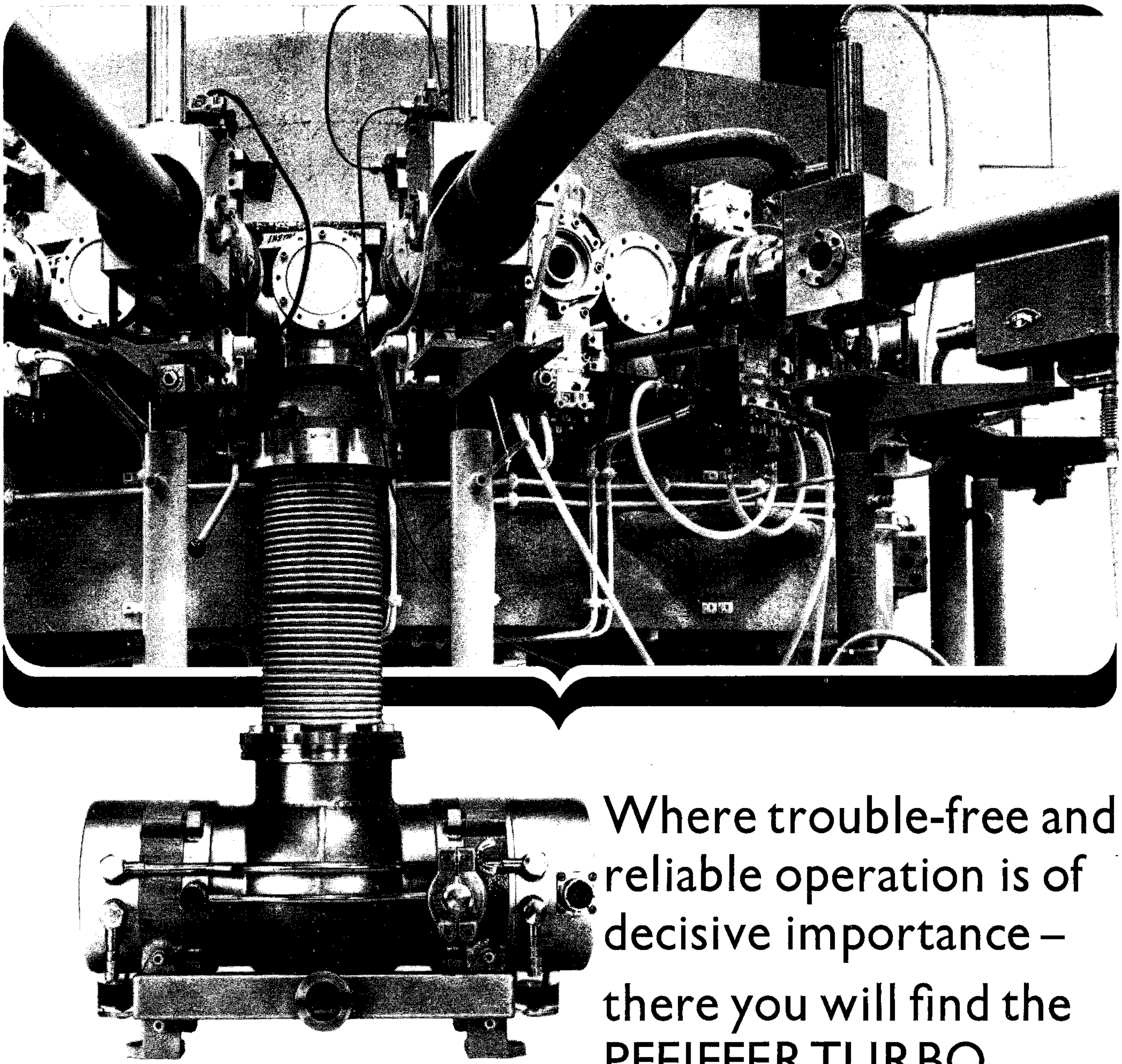

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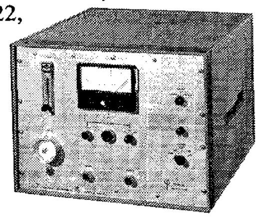

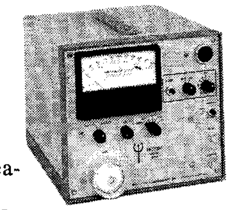

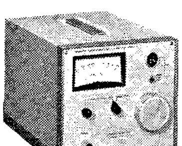

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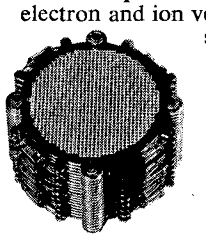

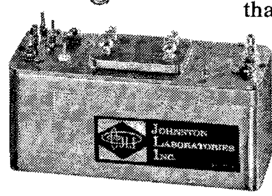

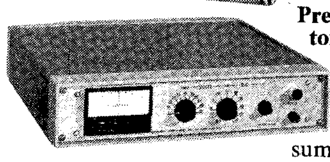

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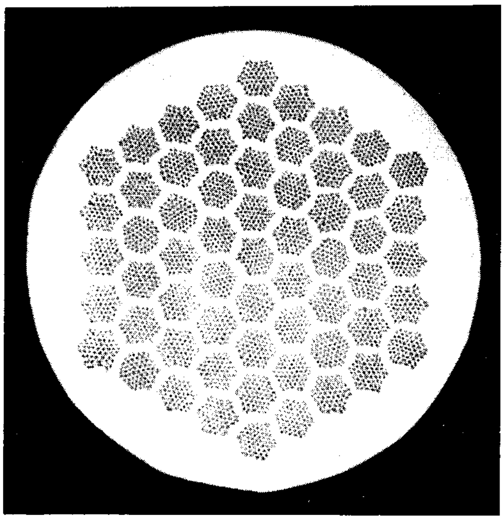

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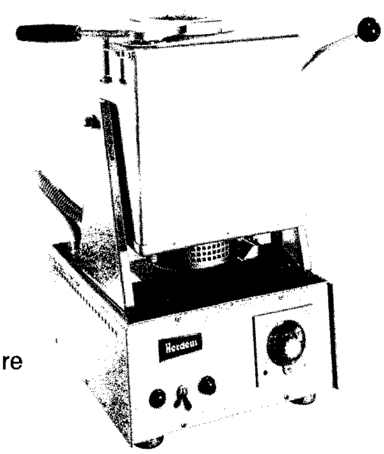

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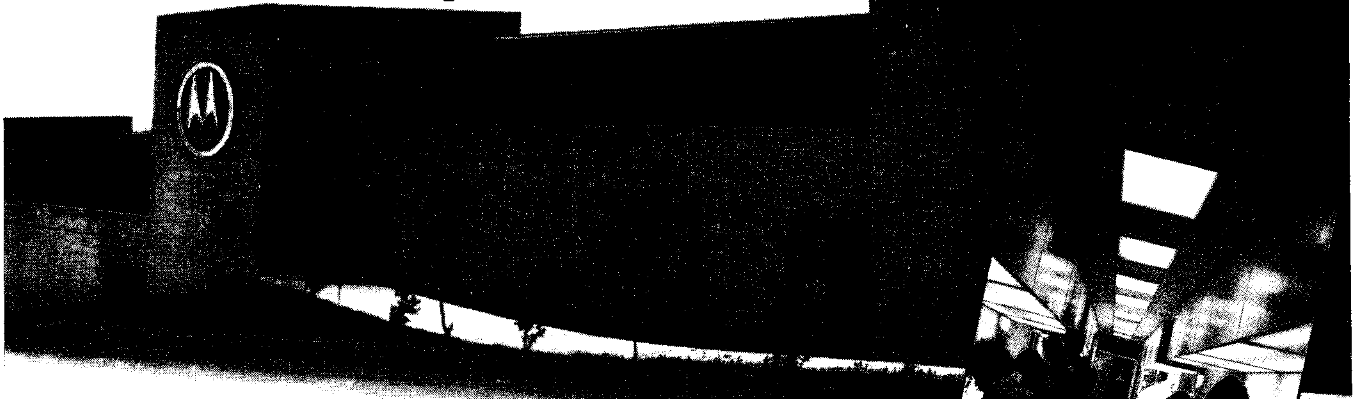

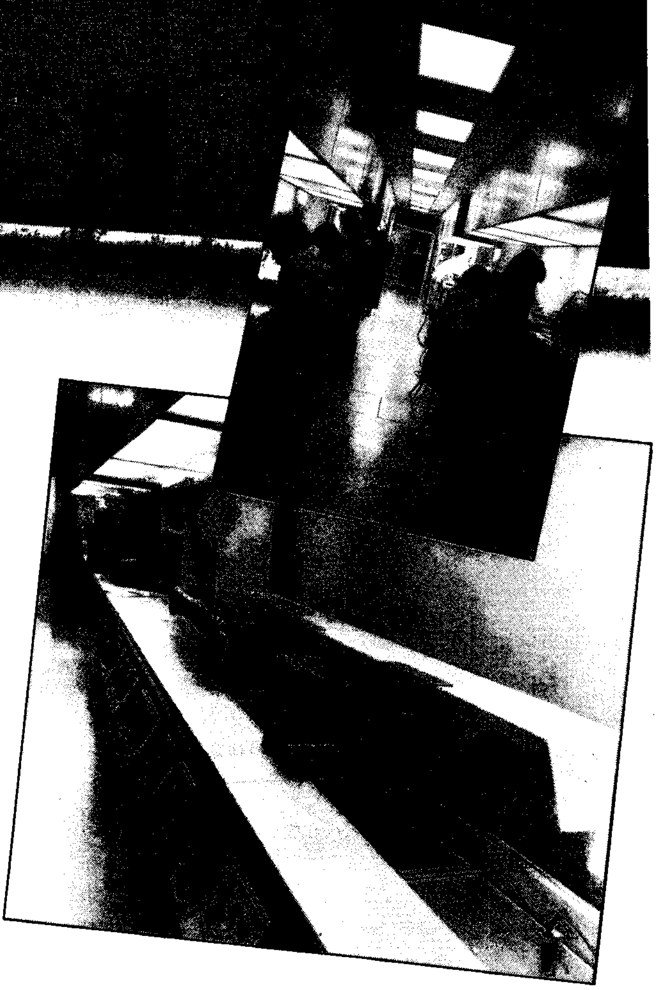

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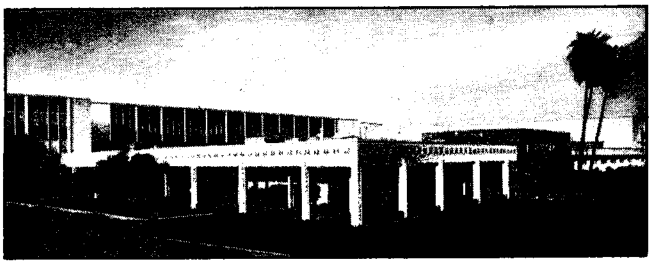

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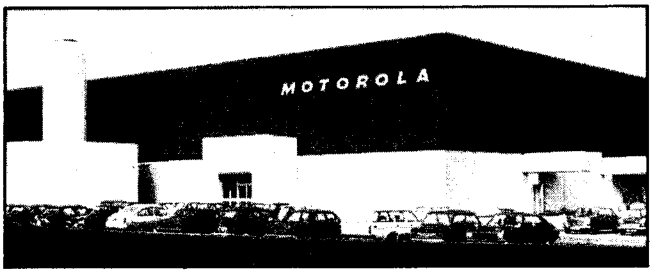

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FAN-IN
and
FAN-OUT

Both...in a single package!

No longer is there a need to use an expensive 4-fold logic unit to provide the simple function of logic fan-in/fan-out. And no longer is it necessary to use an additional amplifier or to operate your phototubes at higher voltage to drive both a discriminator and an ADC from a split, linearly mixed signal from a counter array or hodoscope. The new LRS LOGIC and LINEAR Fan-Ins/Fan-Outs offer cost-savings and conveniences heretofore unavailable with separate fan-in and fan-out modules.

MODEL 428
LINEAR
Fan-In/Fan-Out

- 4 independent channels . . . each with 4 inputs and 4 outputs.
- Dynode or anode compatibility via front-panel "inverting" switch.
- Large dynamic range with maximum amplitude $>$ 2.0 volts. into 50Ω.
- $<$ 2.5 ns risetime and falltime.
- Stage delay $<$ 6 ns.
- Improved DC offset temperature and noise stability.

MODEL 429
LOGIC
Fan-In/Fan-Out

- Performs logical "OR" of input signals.
- 4 normal outputs . . . 2 complements.
- Switch-selectable 4, 8, or 16 input operation . . . with corresponding $4+\overline{2}$, $8+\overline{4}$, or $16+\overline{8}$ outputs
- Direct-coupled.
- Rise and fall $<$ 2 ns.
- Front-panel LED's signify programmed state of unit.

LRS

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