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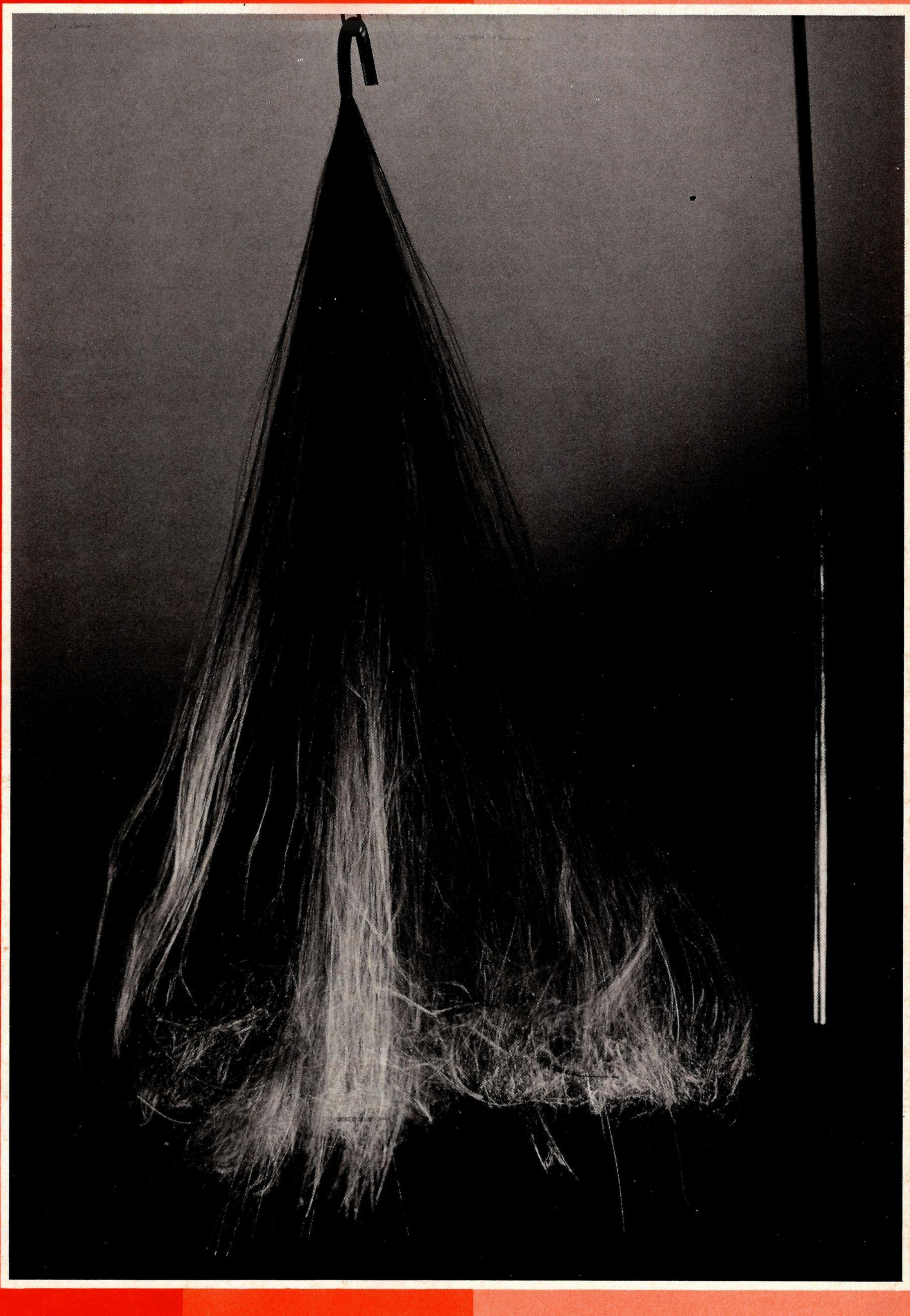

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, 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 3100 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 391.1 million Swiss francs in 1974.

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 1974 is 227.1 million Swiss francs and the staff totals about 350 plus 10 Scientific Associates.

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Cover photograph: A fascinating shot of niobium-tin wire taken at Harwell where they are attempting to master the metallurgical problems of using this superconductor. The wire, as seen on the right, is approximately life size (2 mm in diameter) and, on the left, the bronze matrix has been etched away releasing the 41 000 niobium-tin filaments 3.5 μm in diameter. The need for such a higher-field superconductor is brought out in the report on the Accelerator Conference in this issue. (Photo AERE Harwell)

Stanford Accelerator Conference

The IXth International Conference on High Energy Accelerators was held at the Stanford Linear Accelerator Centre from 2-7 May. It was attended by about 300 specialists who were treated to a very well organized Conference (the organization being under the responsibility of R.B. Neal) and to typical American hospitality from the host Laboratory and from the nearby Lawrence Berkeley Laboratory. This included an evening at the fascinating Lawrence Hall of Science, an excursion to the Californian redwoods and the Pacific coast and a taste of the rather unusual atmosphere of Kresge College at Santa Cruz University (a few participants managing somewhat more than a taste).

At the Conference itself, there was an air of confidence and optimism in sharp contrast to the previous International Conference in 1971 (see vol. 11, page 275). There is an awareness that the recent machines (ISR, NAL and SPEAR) have given fresh insights which have stirred high energy physics into its most exciting state for a decade. There is a conviction that the violent swing away from basic research is now being reversed and despite the tight budgets which still prevail, there is a belief that construction money will be forthcoming for some of the projects now on the table. From the pain of recent years a more modest but, perhaps, more balanced allocation of resources to high energy physics is emerging, which, if it is sustained in a predictable way, will still give scope for some exciting new projects.

At the Conference sessions, a novel presentation technique was tried in having rapporteurs review a topic before more detailed papers were given. This worked extremely well in bringing out the important features, in refreshing memories and in avoiding the need for general introduction to each paper. The rapporteur returned at the end of each session to attempt a 'summation and reconciliation' but this did not work. Thorough comment is difficult in an impromptu talk and, in any case, people are too polite (at least in public).

The big machines

In 1971 the star of the Conference was undoubtedly the CERN Intersecting Storage Rings. At Stanford the star was the NAL 400 GeV proton synchrotron. (Since the Laboratory has now been formally named the Fermi National Accelerator Laboratory, as reported in the May issue, we will convert NAL to Fermi Laboratory from now on.) In 1971 this synchrotron was giving a plausible imitation of a missing magnet design, but its problems are now ironed out and in recent months it has been performing excellently. To quote L. Lederman, who had the modesty to describe himself as a 'standard user': 'The machine is a thing of great beauty. We sit three kilometers from the accelerator and watch a beam hitting a target half a millimetre in cross-sectional diameter with an intensity and a duty cycle which is positively embarrassing.'

The accelerator performance was described by P. Reardon. The machine now operates routinely at 300 GeV and there have been several extended runs at 400 GeV. During the Conference a new condenser bank was being connected so that an attempt at 500 GeV can be made in the near future. Power consumption and the low pulse repetition rate are likely to mean, however, that 500 GeV running will be comparatively rare. In normal operation the 8 GeV rapid cycling booster feeds twelve pulses in 0.8 s to the main synchrotron ring which then accelerates to 300 or 400 GeV. During a 1 s flat-top (during a 6 s total pulse) protons are then sent to three experimental areas. The protons can also be used at all energies from 8 to 400 GeV on internal targets in one of the long straight section regions which is in the process of being enlarged. The average beam intensity is about 6×10^{12} protons per pulse and a peak intensity of just over 10^{13} was reached in April.

The schedule allocates about 75 % of calendar time to high energy physics, 11 % to accelerator studies, 5 % for tune-up and the rest for maintenance. In recent months the operational efficiency has been about 75 % with week-long periods of 93 and 94 %. Slow ejection efficiency is 97 % with good reproducibility and stability using computer feed-back in the ejection system. Seven targets are fed with beam in a single pulse using four beam-splitting stations with electrostatic septa.

About twenty-five experiments are installed at any one time and about thirteen are taking data simultaneously. Over fifty experiments are completed and some fine results are anticipated at the International Conference on High Energy Physics to be held in London at the beginning of July.

Present performance of the major machine components is as follows: The linac normally provides a current of close to 100 mA to the booster at an energy of 205 MeV and is performing very reliably. The last of the linac cavities is tuned to reduce the momentum spread. The spread, about 2.5×10^{-3}, is better than the design figure but, as one of the steps to improve beam transmission through the booster (which seems to be the factor at present limiting the intensity of the accelerator), a debuncher is being installed in the transport line from the linac. (It is said that the blackboard carrying the words 'No debuncher' will be burned in the next Laboratory barbecue.)

The booster further accelerates the beam to 8 GeV in 33 ms so that

A view from the high rise building at the Fermi Laboratory looking out over the 8 GeV booster ring with its central cooling pond. The 200 MeV linac is in the building on the right and the transport line to the main ring on the left. They are linked by a 'cross gallery' where the control room is situated. It is the booster that is presently receiving most attention in the advance towards achieving an intensity of 5 × 10¹³ protons per pulse at 400 GeV.

(Photo Fermi Lab.)

External view of the electron-positron storage ring, SPEAR, at the Stanford Linear Accelerator Centre. The ring is in the tunnel of concrete blocks with two straight sections, covered by larger buildings, where experiments are installed. It is fed by the linac beam coming in from top left. The performance of SPEAR and the experimental results it has yielded have been prominent among the success stories of the past few years. Since this photograph was taken, another building (12 m wide, 24 m long) has been added as a synchrotron radiation facility.

(Photo SLAC)

twelve pulses can be fed to the main ring to nearly fill its circumference. To reach design intensity of 5×10^{13} particles per accelerator pulse, the booster has to provide at least 4×10^{12} particles per pulse but present performance is limited to about 1.2×10^{12}. The debuncher, plus modifications to the r.f. system (including two new cavities bringing the total to 18), should improve transmission efficiency with single turn injection. The measured acceptance of the booster has proved to be considerably down on the design figure and steps are being taken to improve this so that four-turn injection can be carried out efficiently. More beam-position detectors are being installed to check alignment more precisely. Additional quadrupoles in the transport line from the linac will improve beam matching and a new injection magnet power supply will make it possible to play with injection conditions over a wider range.

In the main ring, reliability of components improved so that attention could be turned to detailed studies of beam behaviour. For example, looking at third and fourth order resonances caused by remanent fields at injection led to control via beam dampers, sextupoles, skew-sextupoles and octupoles which doubled beam survival at injection and improved general stability in operation. With single-turn injection from the booster, beams up to 7×10^{12} can be accelerated readily with only 10 % loss. With multi-turn injection, beams up to 10^{13} have been accelerated but with 40 % loss. Problems with the r.f. system — window seals cracking and ferrite tuner failures — are receiving attention and three additional cavities are being built. This will make it possible to accelerate at a rate of 150 GeV/c (compared with up to 125 GeV/c at present) and have two cavities in reserve. Power supply modifications for 500 GeV operation are under way, as already mentioned.

Development of the experimental areas will be more appropriately discussed in another context and the future plans for extending the capabilities of the accelerator are mentioned later under the superconductivity heading.

Progress in the construction of the European 400 GeV machine was reported by R. Billinge. At the time of the Conference 'the mole' had bored its way around three quarters of the tunnel circumference. Well over 100 main ring magnets had been received, assembled and measured showing satisfactory field characteristics. Twelve of the small control computers were delivered. The low power part of the r.f. system was completed. Since we cover SPS construction regularly (and will in fact be coming back to it in our report of the June CERN Council Meeting) we will move on here to other machines.

The number of our Soviet colleagues at the Conference was less than anticipated and thus the coverage that we can give in this report to their efforts in the accelerator field does them less than justice. There was however a talk by Y. Ado on the 76 GeV proton synchrotron at Serpukhov. They are now operating reliably at an intensity of 2.2×10^{12} protons per pulse. The intensity limit is set by the energy of injection (100 MeV) from the linac into the main ring. This will be overcome by constructing a 1.5 GeV booster with eight to ten turn injection from the linac at 30 MeV. It will operate at 25 Hz and fill the main ring during 0.8 s giving increased accelerated intensities of up to 5×10^{13} protons per pulse. Construction is expected to start at the end of this year. The Soviet specialists continue to study the possibilities of building a synchrotron for energies of

2000 GeV or higher and electron/positron/proton colliding beam systems.

Progress in the construction of the 12 GeV synchrotron in Japan was reported by T. Nishikawa. The 20 MeV preinjector and linac are installed. The 500 MeV booster magnets are assembled and satisfactorily tested and installation of the main ring magnets has started. First operation is scheduled for next year with experiments starting in 1976.

Storage rings

The tremendous success of the ISR at CERN and of SPEAR at Stanford continue to light up the storage ring scene. Storage rings provoked about as many papers to the Conference as accelerators and all the proposed big projects for the near future are based on colliding beams.

A. Sessler introduced K. Johnsen's talk on the Intersecting Storage Rings by describing the ISR as one of the greatest achievements of mankind. In terms of their performance and of their reliability, the proton storage rings have far exceeded all expectations. During the Conference itself new records were being set.

A physics run started with a luminosity of 6.6×10^{30} per cm^2 per s (the design figure being 4×10^{30}) and the run was terminated after 34 hours when the luminosity was still 5×10^{30}. This implies an almost unbelievable perfection of the machine. Protons were being lost at the rate of about one per million per minute and if the operating crew neglected to switch the machine off, there would still be protons orbiting two years later. The great improvement of the past year has been in refining control of the machine still further, achieving these low decay rates and excellent background conditions for the experiments.

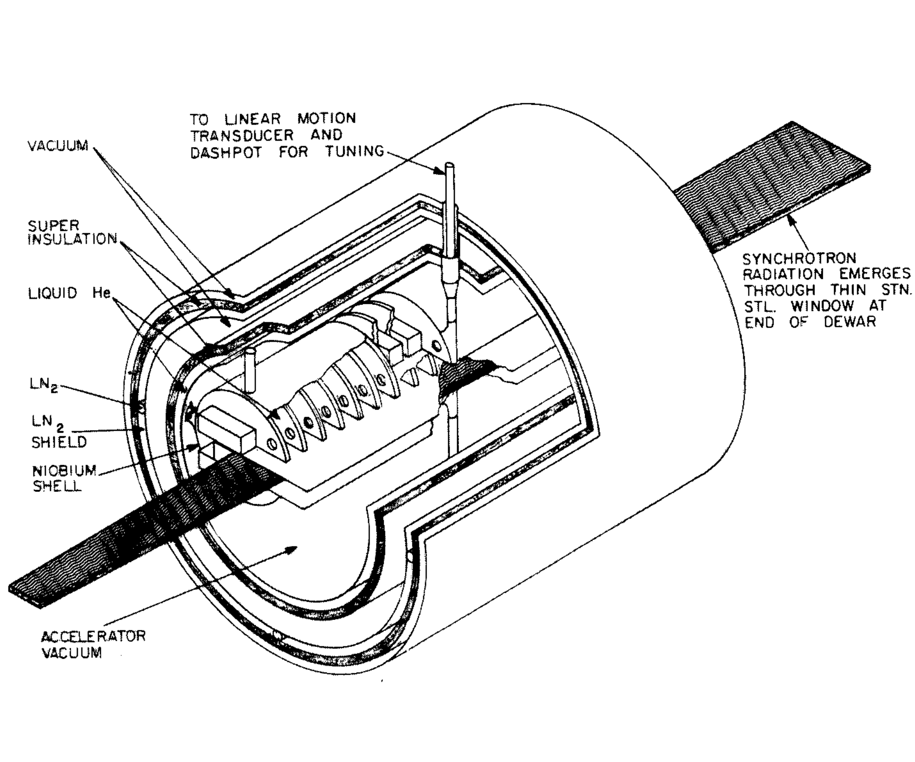
The design luminosity has thus been considerably exceeded and it is hoped to pass 10^{31} in the near future. To take the luminosity much higher than this will involve some new measures. A low beta section (where the beams are specially treated to change their shape at the crossing point) will be introduced initially with conventional focusing magnets. This will begin this year and should increase the luminosity at that intersection by over a factor of two. It does, however, leave only 1.7 m for the installation of detectors and this could be increased to 3.5 m, in addition to a further increase in luminosity, by the use of superconducting magnets at the intersection. It is however a severe environment for superconducting magnets and the possibilities are being studied with the usual ISR thoroughness.

Beyond that stage, really major modifications would be involved in pushing the luminosity to the 10^{33} region. For example, the rings could be rearranged so as to have a smaller crossing angle. Longer term, if the full rings were replaced with superconducting magnets, they could receive protons of 150 to 200 GeV from the SPS. If the development of the physics and of the financial climate in Europe made any such a scheme desirable and feasible, it would need to be balanced against the possibilities of using the full potential of the SPS in completely separate rings.

At SPEAR, colliding beam experiments with electrons and positrons of energies up to 2.6 GeV have been in action for over a year and the storage ring performance was described by E. Paterson. With the exciting results reported in our February issue (see page 39) under their belts, the physicists are looking forward eagerly to the start of operation at higher energies (over 4 GeV per beam), scheduled for October of this year.

The main addition to achieve the higher energies is in r.f. power to compensate for the synchrotron radiation losses which climb rapidly with energy. The new r.f. cavities (see March issue page 89) are made of aluminium and are prone to multipactor but a thin titanium-nitride coating has cleared this.

A first set of cavities has successfully undergone high power testing (up to 80 kW) with long term testing at 60 kW. Three other sets of cavities



A sketch of the superconducting accelerating cavity and its cryostat as designed for use at the Cornell electron synchrotron. A prototype has recently achieved the first ever acceleration of electrons to GeV energies using superconductivity. Such cavities, with their low power consumption should make it feasible to raise the synchrotron energy beyond the present peak of 12 GeV. Their successful operation could lead to widespread use in electron machines.

are well on the way. More vacuum pumps and r.f. power supplies are being installed. It is hoped that at the new high energies it will be possible to reach luminosities of 5×10^{31} per cm^2 per s compared to the figures around 5×10^{30} which are normal with the present machine.

The start of operation of the electron-positron storage rings, DORIS, at the DESY Laboratory was described by D. Degele. At present, peak energies are limited to 3.5 GeV but further equipment (particularly power supplies) will be installed in 1975 to enable the beams to be taken to 5 GeV. Proton injection (see vol. 12, page 281) is also planned for 1975. Meanwhile DORIS is struggling to achieve good conditions for physics. Just as with ADONE some years ago, it seems that many bunches orbiting in electron-positron rings are much more difficult to tame than single bunches as in SPEAR. The situation will improve when some beam diagnostic instrumentation problems are ironed out and when all the vacuum chamber bakeout equipment is in operation.

Progress in construction of the 1.8 GeV electron-positron rings, DCI, at Orsay was reported by P. Marin. The first magnets are installed and an r.f. cavity has been tested. By the end of this year one ring may be completed and colliding beam experiments could begin in 1975.

Superconductivity

The sessions on superconductivity were somehow rather frustrating. For many years now the potential of superconductivity, both in radio-frequency applications and in magnet applications, has seemed on the brink of opening new doors in terms of what could be done with accelerators. By now we might consider the doors to be just about open but they are not very wide. A lot has been achieved in practical realization and in increasing basic understanding but, for many factors which are important for the future big projects, it is extremely difficult to get convincing answers. There was a woolliness about many of the discussions which needs to be cleared up.

On the r.f. side, superconducting cavities could give high accelerating voltage gradients and low power absorption allowing cavities to be operated for longer times resulting in high duty cycle linacs and separators. In r.f. conditions the losses do not disappear completely using superconductors but fall exponentially with temperature near absolute zero. Hence there is interest in pushing temperatures lower than is adequate for superconducting magnets. The currents flow in the surface layer of the superconductor and the major problems have been concerned with achieving good quality surfaces in large r.f. structures and retaining their properties in operation.

The results from small test cavities suggested that Qs in the region 10^{11} and voltage gradients of over 25 MV/m were feasible but it has proved impossible to repeat such performance in large scale structures. Q's are normally in the 10^9 region and gradients are around 3 MV/m. This sort of performance takes some of the edge o the use of superconductivity for linear accelerators though the high duty cycle attribute largely remains. For r.f. separators to handle long beam spills these values are adequate and a Karlsruhe/CERN collaboration is progressing satisfactorily in the construction of such a separator (see February issue, page 53).

The cradle of much of the interest in superconducting r.f. applications was the Stanford High Energy Physics Laboratory. They produced the first exciting results on small cavities and had ambitious plans for a 2 GeV linac. The early optimism was not borne out and they have scaled down their plans to a superconducting 'recyclotron' for energies from 500 to 2000 Me accepting linac performance figures of 3 MV/m and a Q over 10^9. The special feature of the recyclotron should be an intense electron beam (100 μA) with very good energy resolution (10^{-4}). R.E. Rand reported that two 6 m linac sections have been operated with up to 500 μA currents and field gradients of 3.5 MV/m. Two more 6 m sections are scheduled to be in operation by the end of the year and a multichannel magnet is being designed to allow the electrons to be recycled through the linac section.

The most interesting paper on r.f. superconductivity came from Cornell where a cavity has been brought into operation at the electron synchrotron. It is a prototype 0.6 m long, eleven-cell waveguide, made of niobium and operating at 2856 MHz. On 18 April it

Superconducting quadrupoles (a doublet enclosed in the cryostat on the right) and a superconducting bending magnet which have operated successfully in a beam-line feeding a physics experiment at the Berkeley Bevatron. Reliable performance of several superconducting magnets in accelerator environments was reported at the Conference.

(Photo LBL)

was installed in a straight section of the synchrotron ring and tested with an electron beam.

A beam of 1.5×10^9 electrons per pulse was successfully accelerated to 2 GeV. This is the first time a GeV beam has been obtained with a superconducting r.f. cavity. The energy gain matched the design goal of 3.3 MeV/meter but the unloaded Q was only 10^8 instead of the 10^9 obtained in single cell cavities. This was traced to the propagation of unwanted wave modes which are believed to have been caused by slight misalignments. One entertaining finding was that dust gathered in the superconducting cavity probably due to charged dust particles being carried round the ring. So if the superconductivity work is not wholly successful, at least Cornell will have an efficient vacuum cleaner.

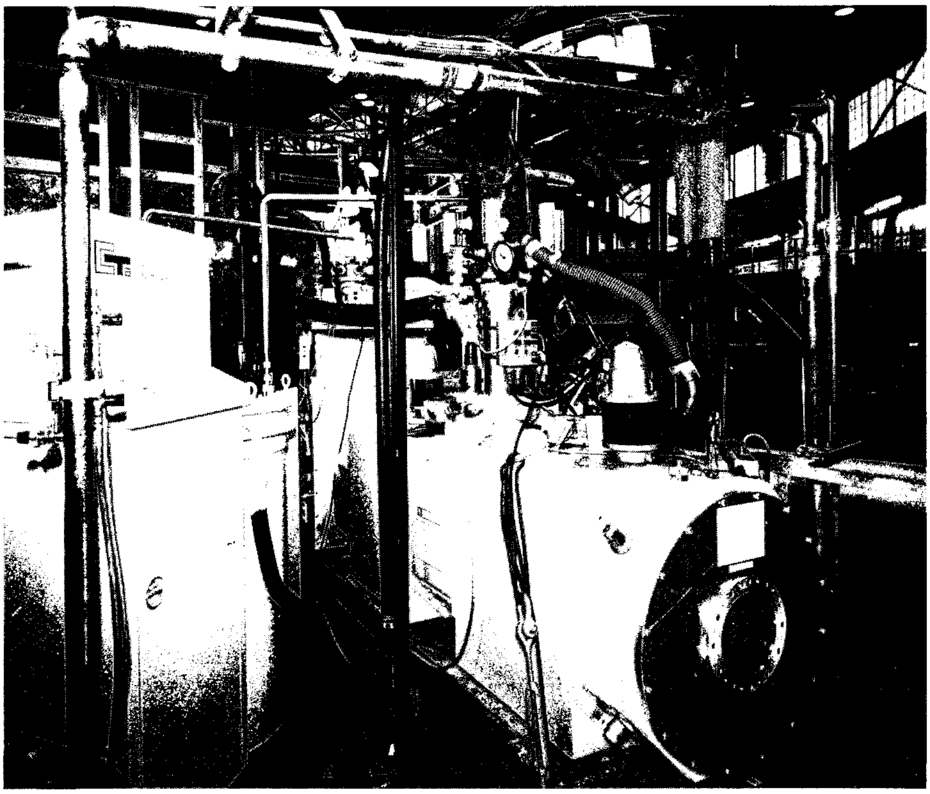
Their next step is to improve the Q and then to make a lifetime test of the prototype. The eventual goal is to fill a major fraction of the available straight section space in the ring with superconducting r.f. cavities and thus btain a significant increase in the maximum synchrotron energy, which is now limited to 12 GeV mainly because of the r.f. power needed to take the electrons to higher energies. If this hopeful start is sustained, r.f. accelerating cavities could become an important asset in synchrotron construction.

The news of the work on superconducting magnets was equally frustrating. On the one hand, the past few years have seen d.c. superconducting magnets being brought into reliable operation at accelerators (for example, the OGA quadrupoles at Saclay and beam-line magnets at Berkeley and Brookhaven). These magnets have thousands of hours of physics use under their belts. Also many pulsed magnets have been through their paces in the laboratory with reasonable success.

On the other hand, all the magnets have exhibited training to some degree — a fact which D. Thomas in his forthright rapporteur's talk put down bluntly to bad design. In other words, we still do not manage to avoid small mechanical movements of the superconductor and because of this, in a multimagnet project, would need to design the machine for a field considerably lower than the optimum, since we would not be sure to what fields the magnets would 'train'.

Among other factors which could lead to accepting lower performance figures is the temperature sensitivity of the superconductor. Under usual operating conditions, with niobium-titanium superconductor at liquid helium temperature of 4.2 K giving fields of about 4.5 T, fluctuations of a few tenths of a degree can flip the magnets out of their superconducting state. The need to develop other superconducting materials, such as vanadium-gallium or niobium-tin (see photograph on cover), was stressed by G.K. Green. These materials have a much higher critical temperature (about 17 K) and could be operated at higher current densities to give fields of 6 T or above with comfortable temperature stability. The materials are however extremely brittle and the metallurgical problems of using them are not yet solved.

New superconductors will not be available tomorrow and P. Reardon pointed out that even niobium-titanium superconductor in its advanced multi-filamentary forms is not yet as 'available' from industry as we might think in the quantities that we are beginning to require. In addition, the characteristics of separate lengths of superconductor can easily vary by 5 %. Design performance figures also need to take account of this and it may prove necessary on large projects to shuffle superconductor, in the same



way that steel is shuffled for conventional magnets to help even out properties around an accelerator ring.

In terms of operating pulsed magnets, we have covered regularly in our pages the work of the European GESSS collaboration (Karlsruhe, Rutherford, Saclay) and of Berkeley and Brookhaven. New information came from Argonne where J.R. Purcell's group is building dipoles and quadrupoles with a view to a superconducting stretcher ring. Such a ring would be built in the 12.5 GeV ZGS tunnel to provide nearly 100 % duty cycle for ejected beams, extending the possible range of experiments and enabling polarized proton experiments to be run simultaneously. Its design has 96 dipoles with modest peak fields of 3 T and 64 quadrupoles with gradients of 32 T/m. When the ZGS booster has been brought into operation it is hoped that intensities of over 10^{13} protons per pulse will be available for feeding a stretcher ring.

New information came also from the Fermi Laboratory where progress on building superconducting magnets for an energy doubler was reported by D.A. Edwards. The present proposal involves slow pulsed magnets (100 s cycle, 20 s flat-top) installed in the 400 GeV accelerator tunnel and capable of 4.5 T fields corresponding to a peak energy of 1000 GeV. The aim is to make higher energy protons available and possibly to reduce power consumption at the presently available energies. Using construction money remaining from the building of the 400 GeV machine, it is hoped to build the energy doubler over at least a sixth of the ring to check out the various systems. Employing that special brand of optimism which thrives in the mid-West, two 6 m long superconducting dipoles have been built. Excessive training was experienced and the final performance was less than 50 % of short sample characteristic. However the Fermi Laboratory has emerged before by using the philosophy of 'build it and then work at it'.

With all this varying experience around, it is good that someone is really getting down to the detailed problems of building a superconducting accelerator. Berkeley is to build a 4.2 GeV accelerator/storage ring known as ESCAR (see February issue page 51) with final design beginning in July. It is being treated as a research and development project with a view to answering the questions on superconductivity which are important for the second stage of the PEP project. The estimated construction time is 2 ½ years and the accelerator world will be watching progress with great interest.

New projects

This leads us naturally into the discussion of new projects since PEP looks the most likely to fly in the near future, one reason being that it does not require superconducting magnets for the first stage of construction which concerns an electron ring where high bending fields need to be avoided so as to reduce power loss via synchrotron radiation.

PEP is a joint project of the Lawrence Berkeley Laboratory and the Stanford Linear Accelerator Centre (to the great astonishment of the U.S. Atomic Energy Commission). The main features of Stage I were described at the Conference by J. Rees. It consists of an electron-positron ring about 700 m in diameter capable of holding beams of energy from 5 to 15 GeV. This will extend the colliding beam physics from the energies reached by SPEAR II. Luminosities from 10^{31} to 10^{32} are anticipated for experiments, using head-on collisions in five of six long straight sections. The peak magnetic field is about 0.3 T with 7.2 MW of installed r.f. power.

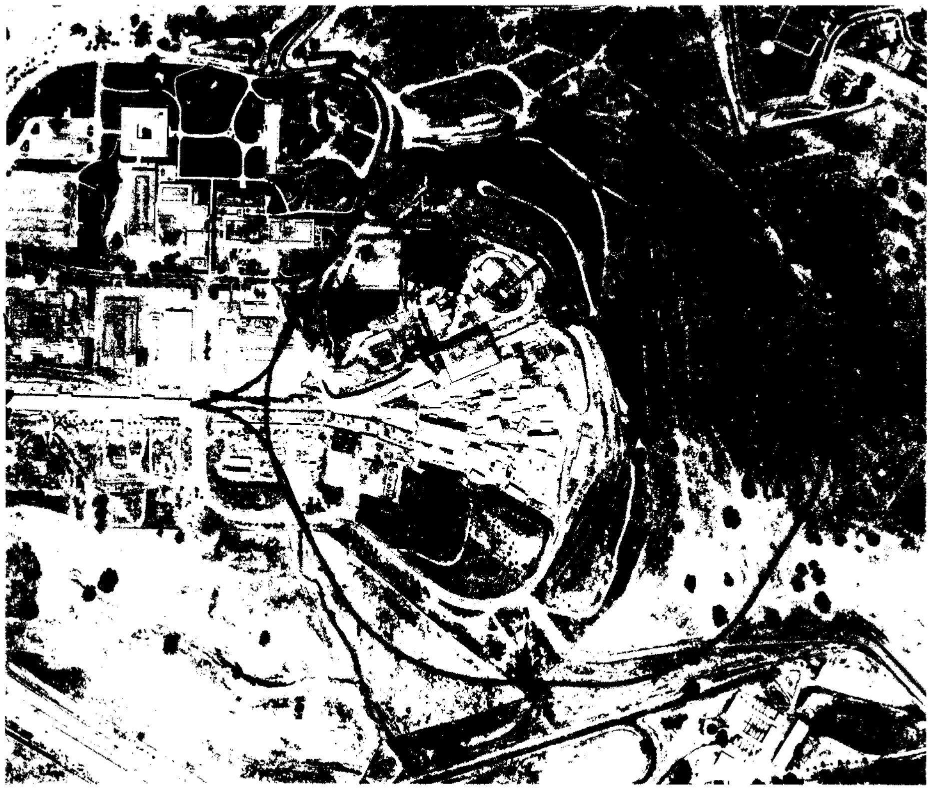
PEP Stage I has a flying start in being able to use the SLAC 22 GeV linac as its injector. This will help particularly as a copious source of positrons and it is intended to build up 100 mA beams orbiting in opposite directions in PEP. The main extension proposed for the future was described by L. Smith. It is a superconductin proton ring (installed in the same tunnel), allowing 200 GeV protons to be collided on 15 GeV electrons. A second separate electron ring is another future possibility. A Summer Study on physics with PEP is being held in August. Stage I is being promoted for construction starting late 1975 aiming for completion before this decade is out at a total cost of about $ 60 million.

On the opposite side of the USA, Brookhaven have a high energy proton-proton colliding beam proposal, known as ISABELLE. It was described at the Conference by H. Hahn. Two rings about 850 m in diameter hold protons up to 200 GeV energies using superconducting magnets with pea fields of 4 T. Four long straight sections are available for experiments with beams colliding head-on. It is hoped to store beams of up to 10 A per beam taking 250 pulses at 28 GeV from the AGS and to achieve luminosities of 10^{33} per cm^2 per s.

Further options include the addition of a 15 GeV electron ring for electron-proton experiments and an interesting scheme for achieving proton-antiproton collisions reported by R.W. Chasman. The possibilities of feeding antiprotons into the ISR at CERN have been investigated (particularly by K. Hubner) but the foreseeable luminosities are discouragingly low. The Brookhaven idea is to use 200 GeV protons to produce antiprotons from a target in a low beta section in a bypass. 30 GeV

The proposed location of the PEP storage ring sketched onto an aerial view of the Stanford Linear Accelerator Centre. (About the centre of the photograph, the SPEAR ring can be discerned.) The PEP ring is located at the output end of the 22 GeV electron linear accelerator which will be its source of electrons and positrons. The machine would be constructed in tunnels bored about 10 m below ground with just the experimental halls in the long straight sections appearing as surface buildings.

(Photo SLAC)



antiprotons are taken to the second ring. When the second ring is filled with antiprotons, acceleration to 200 GeV is implemented and the first ring is refilled with protons, orbiting in the opposite direction, which are also taken to 200 GeV. Collisions with the antiprotons can then be studied with luminosities which it is hoped could reach 10^{29} per cm^2 per s.

Moving West again, the Fermi Laboratory have begun thinking about colliding beam systems which might link with the energy doubler. The project has gathered the name POPAE (Protons On Protons And Electrons) and in its most ambitious form considers 1000 GeV proton-proton rings and a 20 GeV electron ring.

Similar projects are not lacking in Europe. We recently (vol. 13, page 373) described the EPIC project of Rutherford and Daresbury. This 14 GeV electron-positron scheme with the possibility of a 200 GeV proton extension was covered at the Conference by G.H. Rees. The DESY Laboratory have considered a scheme known as PETRA for 15 GeV electron-positrons and 120 GeV protons. Frascati has a preliminary design for a Super-ADONE, described by S. Tazzari, to provide 10 GeV electron-positrons. Finally, from Japan, a scheme known as TRISTAN for 15 GeV electron-positrons and 150 GeV protons was reported by T. Nishikawa.

Electron ring accelerators

A few years ago, electron ring accelerators were the great white hope as a novel technique to achieve particles accelerated to high energies (see for example, vol. 8 page 28). The essential idea was to form tiny intense rings of electrons, to hold positive particles in them by the Coulomb force and to accelerate the comparatively easily movable electrons, pulling the positive particles with them. Relative energies in relation to their relative masses could thus be achieved.

Sadly, the Stanford Conference had the air of a wake for ERAs. This was certainly true as far as high energy proton machines are concerned though there may still be a lot to gain in heavy ion acceleration and in basic physics such as atomic spectroscopy. G. Lambertson reviewed how difficult it has proved to handle the intense electron beams and to set up the conditions in which the rings will continue to hold particles as they are accelerated.

The work at Berkeley is being stopped at least temporarily (see the report on page 212). A lot has been learned on intense electron beam behaviour in their devices but there is still work to be done to achieve acceleration. Recently they observed that the rings are an excellent ionizer for studying atomic spectra. Even with xenon fed into the ring compressor vessel, there was such high ionization that it was possible to see X-rays coming from down in the K and L shells. It is probably a unique way to study these atomic levels.

V.P. Sarantsev had not much new to report from Dubna. They are building a second system, specifically for the acceleration of heavy ions, to be fed with a 3 MeV high current (650 A) linac at 10 Hz hoping for up to 5×10^{13} electrons per ring. On their main system, they are adding niobium-titanium accelerating sections which are being developed to operate at 1.3 GHz. This may prove an additional complication when ERAs, unfortunately, are showing complications enough. Dubna will soon be joined in the Soviet Union by the Institute for Theoretical and Experimental Physics when a 1.5 MeV electron injector is now being tested.

In Europe, Karlsruhe has abandoned

Some photographs from the Conference:

1. *Crowd scene at a reception at the home of the Stanford University President, R. Lyman.*
2. *W.K.H. Panofsky, Director of the Stanford Linear Accelerator Centre, opens the Conference with a welcome address.*
3. *Professor Panofsky greets V.P. Dmitrievsky of Dubna (the Conference organizer R.B. Neal is in the background).*

the struggle but Garching had the best ERA results of the Conference to show. They have accelerated electron rings and have demonstrated that they have an accelerating structure which avoids particle losses due to collective oscillations. They still have trouble, however, avoiding particle losses when they move the rings from the compressor to the accelerating structure. Their compressed rings contain 5×10^{12} electrons and are formed in 10 μs, only 100 ns of this compression time being spent in sweeping through the most troublesome single particle resonances.

Some good results are desperately needed to breathe life back into electron ring accelerators.

Other topics

There were many fine papers at the Conference on topics which we have little space to treat adequately here. For example, W. Schnell reported a completely new way of looking at details of a stored beam without interfering with the beam. It involves monitoring the 'Shottky noise' — the fluctuations in the beam current passing the monitoring point due to the slight variations in the numbers of protons orbiting at different revolution frequencies. The noise (which appears at all harmonics of a revolution frequency) is proportional to the square root of the number of protons orbiting at a particular frequency. It is proving possible to pull a lot of information out of listening to this noise — the density of the orbiting beam as a function of momentum, the position and extension of the working line in the Q diagram, the betatron amplitudes.

Other papers which illustrated the clever detective work and analysis that can now be carried out on beams were a paper on the Fermi Laboratory 400 GeV machine given by R. Stiening, on the CERN PS Booster by F. Sacherer (including some excellent theoretical work) and on the Stanford SPEAR storage ring by G. Fischer. In summing up this session F. Mills commented that measurements on beams are now very good and improved understanding of beam behaviour is in line with what is being seen.

Another topic was computer control of accelerators where M. Crowley-Milling gave a very thorough review talk. He ended on a light note by suggesting that since computer control has advanced so far in such a short time one might dream of the day when the accelerator, via the computer, would respond to a simple verbal instruction. Several participants were heard rehearsing what they might say to their machines. But before these particular instructions could be carried out there would have to be a considerable extension of the biological attributes of accelerators.

Applications of accelerator technology

It is symptomatic of the renewed feeling of confidence and optimism in the accelerator world that not so much time was devoted to the direct discussion of applications of accelerator technology in other fields. Little more than a year ago, at the 1973 Particle Accelerator Conference in San Francisco (see vol. 13, page 103) this had been a dominant theme, reflecting the unease at falling budgets for basic research and the relentless demand for 'relevance'. In August of last year, a full conference at Los Alamos was devoted to 'Practical Applications'. At Stanford there was less obsession with immediate practical applications.

This certainly does not mean that the question of applications is being

4. *W. Wallenmayer of the AEC (left) and M.G.N. Hine of CERN (centre) listening, seemingly sceptically, to the views of A. N. Other.*

5. *K. Johnsen of CERN (left) in conversation with M. Sands of the University of California, Santa Cruz.*

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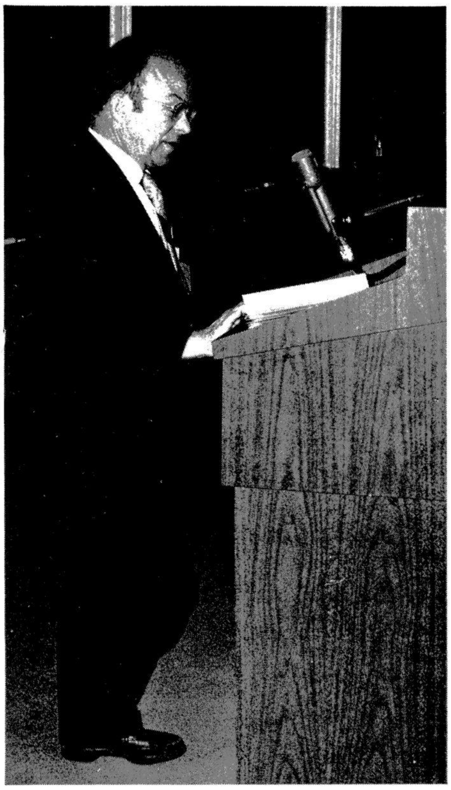

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ignored but it is now being tackled in a more balanced way. Anyone who has considered, for example, the review of applications of accelerators drawn up by L. Rosen (see vol. 11, page 159) will be aware that accelerators in their hundreds are in action in industry, in medicine and in other branches of physics. This is probably only the start of the use of accelerators in commercial and social applications.

Among the current activities in the accelerator world, the work on superconductivity looks particularly likely to have a major impact 'outside'. D. Thomas concluded his rapporteur's talk on superconducting magnets by remarking that, as applications extend into other branches of science and electrical engineering, the contribution made to this subject via the high energy physics programme is becoming increasingly recognized and that present work on higher field materials and magnets is also likely to be of wider benefit in the future.

With regard to other sciences, the synchrotron radiation facilities at electron synchrotrons and storage rings are enjoying a remarkable boom. A paper on this subject by S. Kapitza was read at the Conference. They provide continuous spectra of electromagnetic radiation extending from the infrared, through the visible region, the ultraviolet and far into the X-ray region. They are the most powerful light sources for spectroscopy at wavelengths below 2000 Å and have opened up completely new areas of research in atomic, molecular, plasma and solid-state physics with astrophysical phenomena and, especially, biological structures coming in for particular attention.

To pick out some of the major machines for this work: Wisconsin, where E.M. Rowe has carried the sychrotron radiation banner for many years, has a 240 MeV storage ring known as Tantalus supporting fourteen experimental teams and has a proposal on the table for a higher energy version. Since March, Tantalus has been fed by a microtron and it is appropriate in the context of an accelerator conference to record that this implied closing down the famous FFAG electron synchrotron. The 50 MeV Fixed Frequency Alternating Gradient machine was brought into operation by MURA (Mid-Western Universities Research Association) in January 1960 as a model with which to study novel concepts of accelerator design — such as colliding beams, adiabatic capture, beam stacking and multi-turn injection. In its initial configuration, it was actually able to accelerate counter-rotating beams of electrons simultaneously. A rebuild was completed in August 1961 and the machine was then used to study the behaviour of high intensity beams (5 A beams were achieved as early as February 1962). Techniques were developed such as the bucket scan method of measuring current in a stacked beam and r.f. knock-out for measuring beam parameters. For six years, the synchrotron was used to feed Tantalus. The FFAG machine was showing signs of age and in February its very fruitful life was ended.

A major synchrotron radiation facility is coming into action now at the SPEAR storage ring at Stanford and will benefit from the coming energy increase to over 4 GeV. In Europe, DESY has led this work on their 7.5 GeV synchrotron and will extend it on the DORIS storage ring. Daresbury have a facility on their 5 GeV synchrotron and a proposal for a 2 GeV storage ring specifically as a synchrotron radiation source which would probably be the most powerful research instrument in the field. In the Soviet Union, Novosibirsk has plans for the VEPP-2 and VEPP-3 storage rings and the Moscow Institute for Physical Problems plans a 1.5 GeV storage ring as a synchrotron radiation source. These machines and others are bringing research workers from a variety of disciplines into high energy physics Laboratories.

A far less immediate application is the field of energy from fusion brought about by colliding accelerated beams of deuteron and triton ions. Possibilities in this direction have been discussed in recent years but the problems look frightening. J.P. Blewett discussed two colliding beam configurations. The scale of the difficulties can be judged from the requirements to yield reasonable amounts of fusion power. It would be necessary to hold coincident ion beams of the same momentum (say 845 keV for deuterons and 564 keV for tritons), orbiting in approximately circular paths in a high magnetic field (6 T), focused by an electron beam (many kA) travelling in the opposite direction so that the ions are held together for a sufficiently long time against the Coulomb scattering forces. This could be done by having two storage rings with a common section. If ion densities of 11.7 C/m^3 could be achieved, 3.6 kW of power per metre length could be produced. Quite apart from the theoretical difficulties of predicting when beam instabilities might destroy such configurations, it will be obvious from the figures quoted above that the practical difficulties mean that it is not for tomorrow.

Probably much more imminent are new uses of accelerators in medicine. There is interest, which has grown particularly during the past year, in using comparatively low energy proton beams in radiography and tumour therapy. Studies on protons have, for example, being going on at Dubna, ITEP, Uppsala, Brookhaven and the Heidelberg Max Planck Institute. Although this was not a specific topic at the Conference, it found an eager advocate in the corridors where R. Martin projected his enthusiasm for studies in which Argonne is involved. For tumour therapy, protons have already been used on over a 1000 patients, particularly at Moscow. For radiography, quite low doses of proton radiation, 100 mr, make it possible to detect tumours which are only about 0.5 cm in diameter — long before they usually begin to cause physical discomfort. Thus it might be possible to carry out screening of the population at large so as to catch tumours at a stage when they are more easily operable.

Projects for proton clinics have been drawn up, for example, at Heidelberg and Uppsala. The proton sources would need to be as cheap and simple as possible so that they could become standard hospital equipment. At Argonne a 200 MeV synchrotron with a 300 keV injector is being studied. It accelerates negative hydrogen ions so that the protons are easily extracted by stripping off the electrons and using the synchrotron magnetic fields to bend out the protons. The vacuum system to keep the negative ions is likely to absorb half the cost of such a device but it should still be cheap to build and simple to operate. If this work yields such promise, it could lead to a major breakthrough in cancer diagnostics and therapy.

In high energy physics

But the most demanding work continues to be in the design, construction and operation of accelerators and storage rings for use in high energy physics research. W.H.K. Panofsky opened the Conference stating that progress in high energy physics has been paced by accelerator technology. Whenever the possibilities of a particular technique seemed exhausted, new ideas came along opening up new research possibilities by extending energy ranges, beam intensities, etc... At this point in time, really new ideas are not thick on the ground and the physics interests may select, more so than in the past, the next directions in which to move.

This is well in line with the strength of high energy physics at present. Prof. Panofsky expressed it as 'physics has never been in a more expectant state'. This was echoed by M. Gell-Mann in one of the concluding talks entitled 'Trends in Elementary Particle Theory'. He said 'there is the scent of a new grand synthesis in the air'. Let us hope that the renewed confidence which was evident at the Accelerator Conference will be given its head to a sufficient extent that the scent can be run to ground.

CERN News

View of the Split Field Magnet (SFM) installed at intersection I-4 of the ISR. Multiwire proportional chambers can be seen installed in the magnet aperture for observing the produce of the very high energy proton-proton interactions.

View of the muon storage ring where the g-2 of the muon is to be measured with very great accuracy (ten parts per million). First tests with the completed ring began on 4 June. The central pillar served to position the elements of the ring. Some of the forty C-shaped magnets can be seen and some of the twenty counters (close to the magnet apertures) which will detect the electrons coming from the decay of the muons. We will have more on this important experiment when it is under way.

The SFM detectors

The Split Field Magnet (SFM) at intersection I-4 of the Intersecting Storage Rings was built to study the high energy proton-proton collisions in great detail. Particles emerging in all directions from an interaction can be detected by means of a large array of multiwire proportional chambers located in the large aperture of the magnet.

To cater for a wide range of experiments, the detectors cover almost all the solid angle around the intersection region and can give a large number of measured points for each trajectory. The chambers are installed in the magnet aperture in two groups:

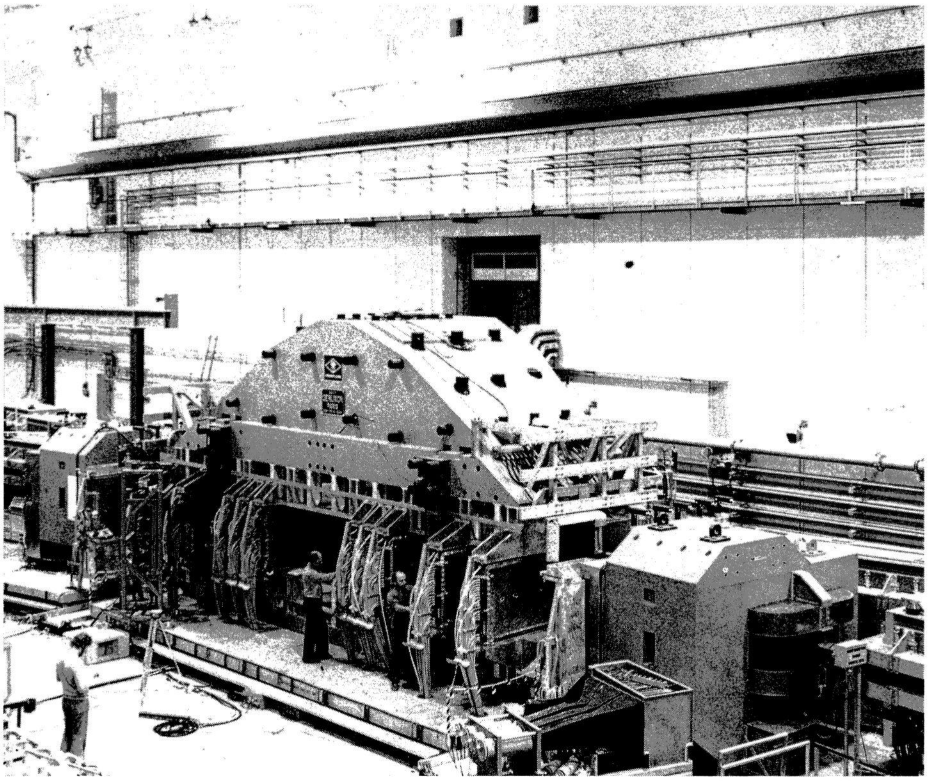
– the 'forward' chambers detect particles whose trajectories are at a narrow angle to those of the incident protons (this group comprises 28 chambers each with two planes of wires which are spaced 2 mm apart);

– the 'central' chambers detect particles emerging transversally to the incident protons (this group comprises 8 chambers each with a number of planes of wires which are spaced 4 mm apart).

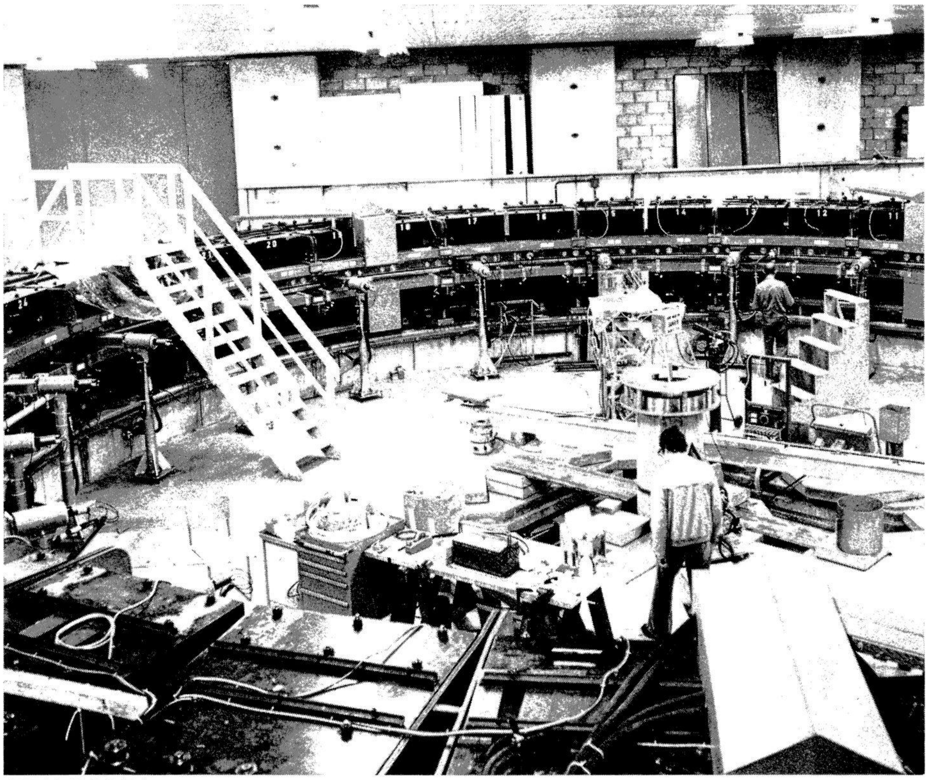
The 28 'forward' chambers are all installed, forming a network of 50 000 wires. The central detector has 4 of its 8 chambers installed and will eventually form a network of 20 000 wires.

The associated electronics, with 70 000 channels, is a very complex arrangement which has been positioned outside the intersection region to avoid radiation problems and to allow access at all times should repair be necessary. Only the pre-amplifiers are placed close to the chambers. Signals from the wires pass along 65 m of twisted cable to the electronics room.

The first task is to identify the wires which record the passage of a charged



CERN 222.10.73



CERN 430.5.74

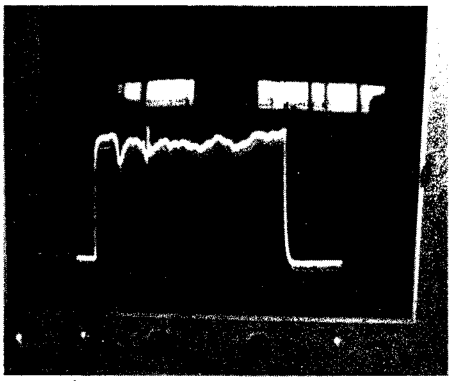
In the tests on the rotating capacitor, key instrument of the new acceleration system of the 600 MeV synchro-cyclotron, satisfactory results have been obtained.

1. *The oscilloscope records the acceleration voltage reaching 18 kV over the full frequency range from 30 to 16.7 MHz with full duty cycle.*

2. *The oscilloscope records the acceleration voltage reaching 30 kV in a narrow frequency band from 30 to 29.4 MHz with full duty cycle.*

Start-up tests for the improved SC, which were planned for June, have been postponed for several months because measurement and adaption of the magnetic field, mainly in the extraction region, has taken longer than envisaged.

An OPTRONICS S-3000 SPECSCAN measuring machine recently installed at the ESO Sky Atlas Laboratory. It is the first of its kind in Europe and is capable of measuring positions (to 1 μm) and densities (to 0.02 D) on astronomical plates up to 36 × 36 cm². The machine is used for measuring plates from the ESO 1 m Schmidt telescope. Many new and extremely interesting objects (like distorted galaxies) have already been found on these plates and form an exciting basis for the coming research with the new large telescopes.



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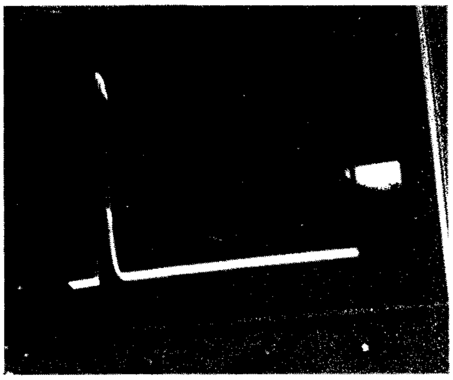

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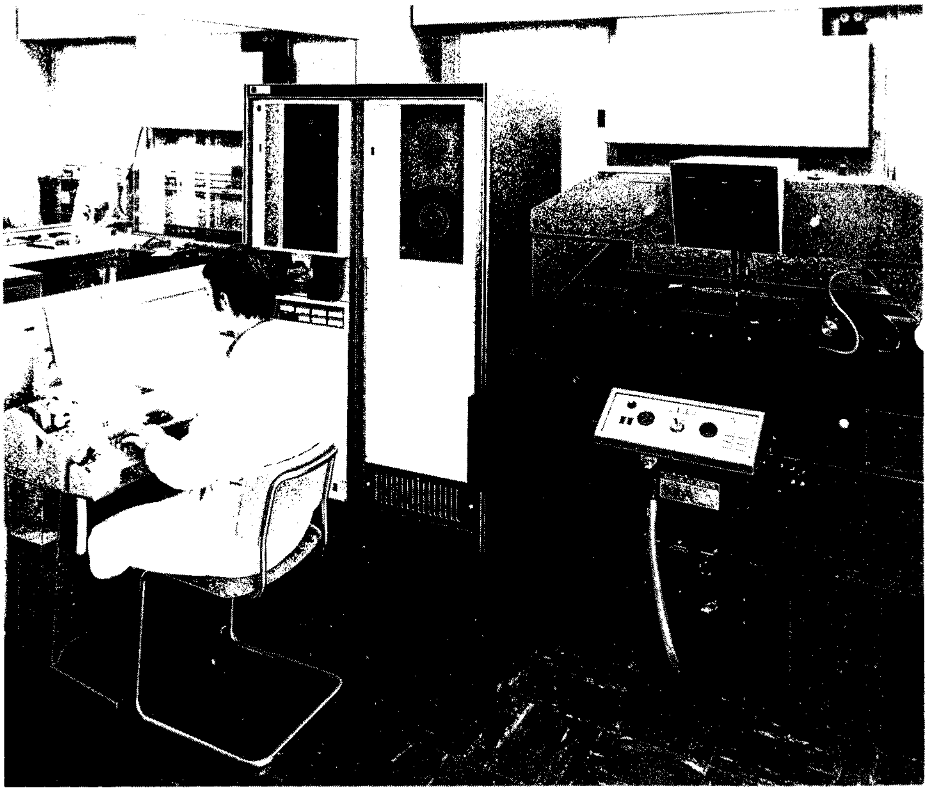


CERN 4.1.74

particle through the chamber. Signals are treated in two ways. The first involves a quick decision making process which checks that the triggering in fact corresponds to the produce of a proton-proton interaction fulfilling certain simple conditions. If the answer is 'yes', the signals are stored in memories until it is decided whether to finally collect them or reject them. The second involves a slower decision making process with special criteria depending on the experiment in progress. If the event is finally accepted, the signals are collected on magnetic tape by the SFM control computer, the EMR 6130. There remains the comparatively long job of reconstructing the tracks. This is done by a programme developed on the CDC 7600 and converted for use by the various computers of the experimental groups.

After data taking tests during the second half of 1973, experiments with the SFM began in February this year. The first experiment concerned diffractive dissociation (where just one of the colliding protons is seriously disturbed and sheds pions) and with interactions yielding particles of high transverse momentum (which occur at a much higher rate than anticipated). The second concerned a study of the N* resonance. The third experiment began in May and concerns a search for quarks. With the rate at which the SFM detection system can collect data, more information on these phenomena, under the conditions of very high energy interactions made possible by the ISR, will become available than ever before.

Turning to the infinitely large

In CERN's large Auditorium, where the talk is usually of very small particles, hunters of much bigger game came together recently. There was a meeting of about 180 astronomers from 27 to 31 May for a conference on 'Research Programmes for th New Telescopes'.

The conference was sponsored by the European Southern Observatory (ESO), whose 3.6 m telescope is at present rising from the ground in Chile, by the United Kingdom Science Research Council (SRC), which is building a similar telescope in Australia, and by CERN, which is participating in the development of the ESO telescope.

New facilities for observing the southern skies will be provided by these telescopes, due to go into service soon, and the time had come for European astronomers to give an account of the knowledge gained and to discuss the broad lines of the research programmes possible with these new instruments.

After a few words of welcome from

King Baudouin of Belgium, as part of an informal visit to Geneva to meet Belgians working in international organizations, paid a brief visit to CERN on 7 June. The photograph shows His Majesty (centre) being met on arrival at CERN Laboratory I by (from left to right) L. Van Hove, Ambassador J.P. Van Bellinghen, W.K. Jentschke (Director General) and Y. Goldschmidt-Clermont.

The Secretary of State for Education and Science from the Netherlands visited CERN on 4 June and toured the CERN site accompanied by senior members of the CERN staff. G. Klein is photographed (second from the left) while being shown the experiments installed at intersection region I-2 of the ISR. On the extreme right is J.H. Bannier, for many years a member of the Dutch delegation to the CERN Council, who was recently awarded a Doctor Honoris Causa at the University of Nijmegen.

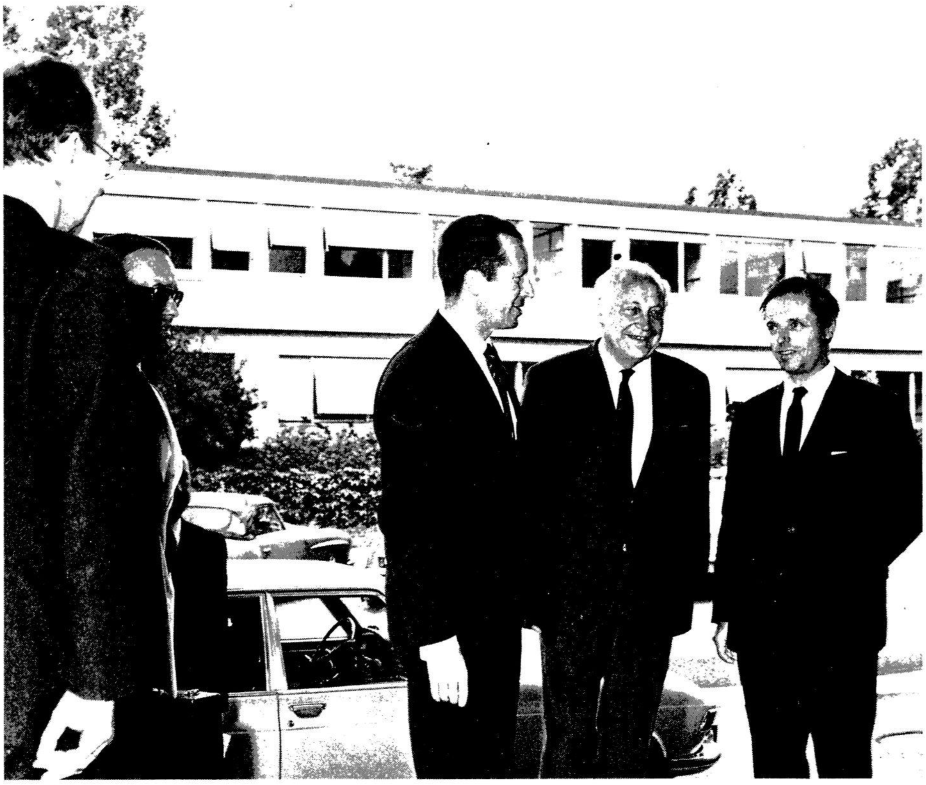
A. Blaauw, Director General of ESO, A. Hunter, Director General of the Royal Greenwich Observatory, and W.K. Jentschke, Director General of CERN Laboratory I, an introductory lecture was given by J.L. Greenstein of the Hale Observatory. His talk, full of verve and humour, set the tone for the whole conference.

A large number of subjects was tackled, including the study of the centre of our galaxy, globular clusters, the nearby galaxies, and extragalactic sources. Emphasis was laid on the Magellanic clouds which provide a fascinating subject for research in the southern hemisphere.

Besides the scientific matters, a subject was dealt with at the final session which had probably never been tackled before at an astronomers' conference — the philosophy of the use of telescopes. This aired the problems connected with time-sharing in large telescopes, bearing in mind the high operating costs, and clearly demonstrated the usefulness of seeking more and more efficient methods of utilisation.

Of special interest was a proposal to construct an array of radio telescopes in the Southern Hemisphere, similar to the one at Westerbork in the Netherlands. From the discussion at the conference, it was clear that such an instrument would be of the greatest value for the study of astrophysical objects in a way which is not now possible, complementing the new large optical telescopes.

After this review of the major questions raised by modern astronomy it is obvious that it will be possible with the new large European telescopes to carry out broad research programmes. The results are hardly likely to be ignored by CERN physicists, since modern astronomy appears to have closer and closer links with high energy physics.



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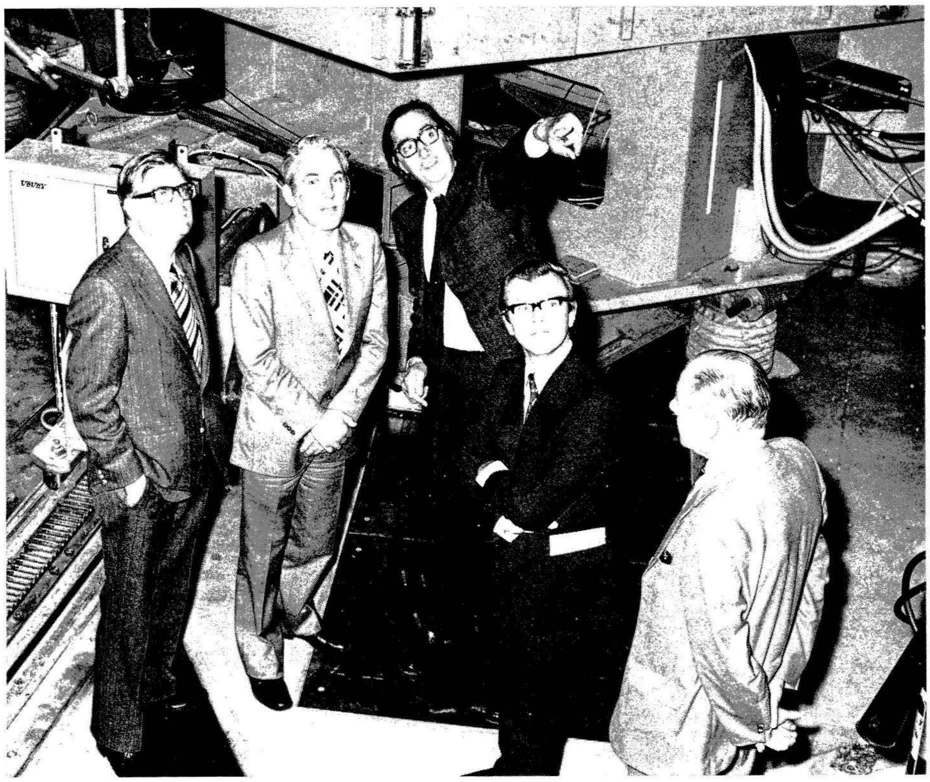

CERN 6.6.74

Not by physics alone doth man live . . .

1. The CERN rugby team who won the final of the Swiss Cup on 26 May, having already taken the Swiss league championship for 1973-74. It was a strong year for CERN rugby — the reserve team also won their championship and the junior team won all the matches in its category.

2. A team race around the CERN site has become an annual event. It consists of five stages of 1500, 1000, 800, 500 and 300 m and involved forty-five teams in this year's race held on 29 May. The photograph shows Professor Jentschke, Director General of CERN Laboratory I, firing the starting pistol in the race which was won by a team from Theory Division who, with 12 minutes 5 seconds, comfortably beat the track record.

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2. *CERN 443.5.74*

Around the Laboratories

BERKELEY
Restructuring the physics programme

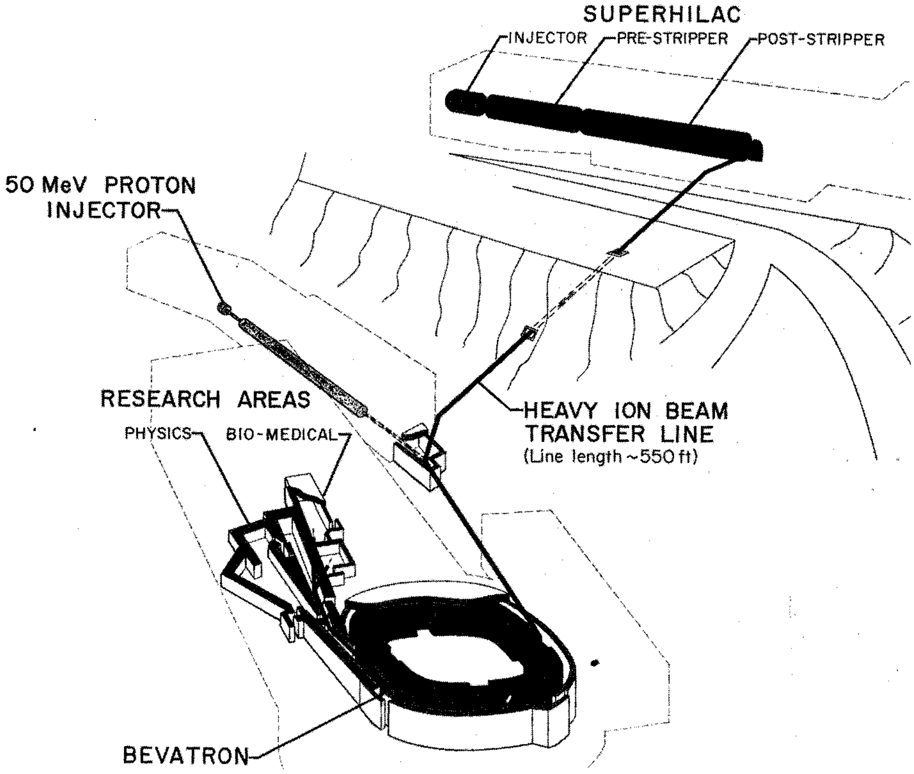
The Lawrence Berkeley Laboratory is reorganizing its programme in order to retain this world famous centre at the forefront of research. The major research facility for twenty years has been the 6 GeV Bevatron which has supported high energy physics of very high quality. Its best known results are probably those of the late 1950s when, with the first use of large bubble chambers, it identified a flood of new particles (resonances) which revolutionized our interpretation of the strong interaction. By now, however, the energy range that the Bevatron can cover makes it a largely obsolescent machine for high energy physics which is therefore taking second place. It is absorbing less than a half of the Bevatron operating time and this will fall still further in the coming fiscal year (FY 1975 which starts on 1 July).

Another well-known item of the programme which will not be sustained is the development of electron ring accelerators. It has proved extremely difficult to realize the initial promise of ERAs and, at least for the immediate future, this work at Berkeley is being put under wraps. This is organizationally necessary since it is now clear that the ERA technique will not yield a high energy accelerator and the development can therefore not continue under the high energy budget. It may emerge again for heavy ion or atomic spectroscopy reasons when another budget banner catches up with it. However, there is a lot of new work in accelerator physics to keep the Laboratory occupied.

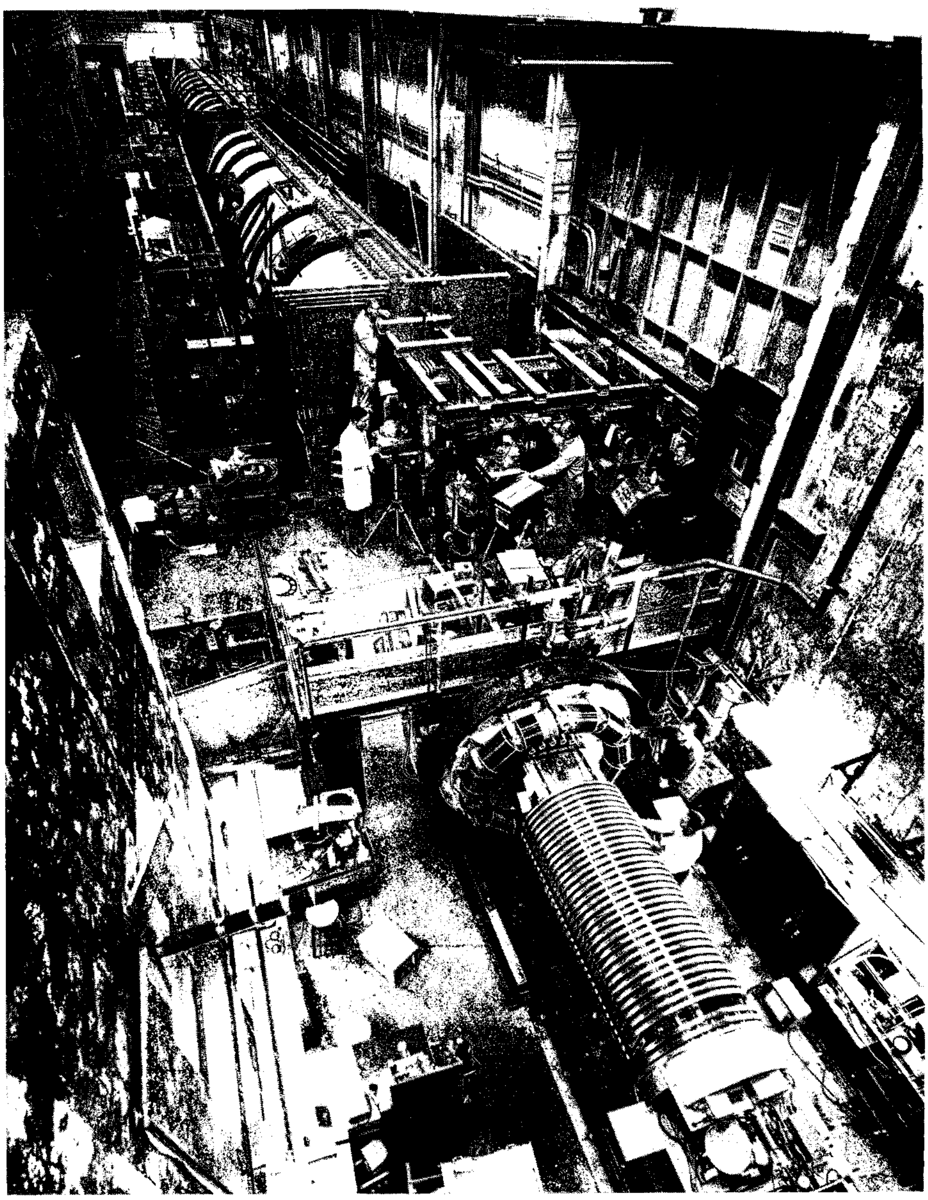
There is the collaboration in the PEP storage ring project which will be constructed at the Stanford Linear Accelerator Centre if it is funded. In addition to participation in the design of PEP Stage I (the electron-positron ring), where effort will increase in FY 1975, Berkeley is making a major contribution in preparation for Stage II (the proton ring) by confronting the problems associated with superconducting machines. A start is being made on the detailed design and construction of a small superconducting synchrotron/storage ring called ESCAR. All these topics have been covered in the report on the Accelerator Conference earlier in this issue, so we will concentrate here on the two major programmes at the Laboratory where effort is expanding dramatically — heavy ion research and energy and environment research.

Berkeley is building up facilities for heavy ion research which will be by far the finest in the world. There is the 88 inch cyclotron capable of accelerating 2×10^{14} helium ions to 33 MeV per nucleon through to 10^{10} argon ions to 4 MeV/u, the Superhilac capable of accelerating, for example, 10^{14} argon ions to 8.5 MeV/u eventually through to 10^{11} uranium ions to 8.5 MeV/u, the Bevatron capable of accelerating, for example, 10^{5} neon ions to energies between 250 MeV/u and 2.5 GeV/u (it is hoped to reduce the lower limit to 100 MeV/u so as to reduce the energy gap between Superhilac and the Bevatron) and, finally, the Bevalac project which will extend the ion types which the Bevatron can accelerate and greatly increase the beam intensities.

The Superhilac was described in vol. 11, page 75. It is a linear accelerator with a pre- and a post-stripper linac fed by two injectors — a 750 kV injector for ions from lithium to argon, and a 2.5 MV injector for ions from argon to uranium. It is a considerably revamped version of the previous Hilac machine and was completed in April 1972. Bringing it into reliable



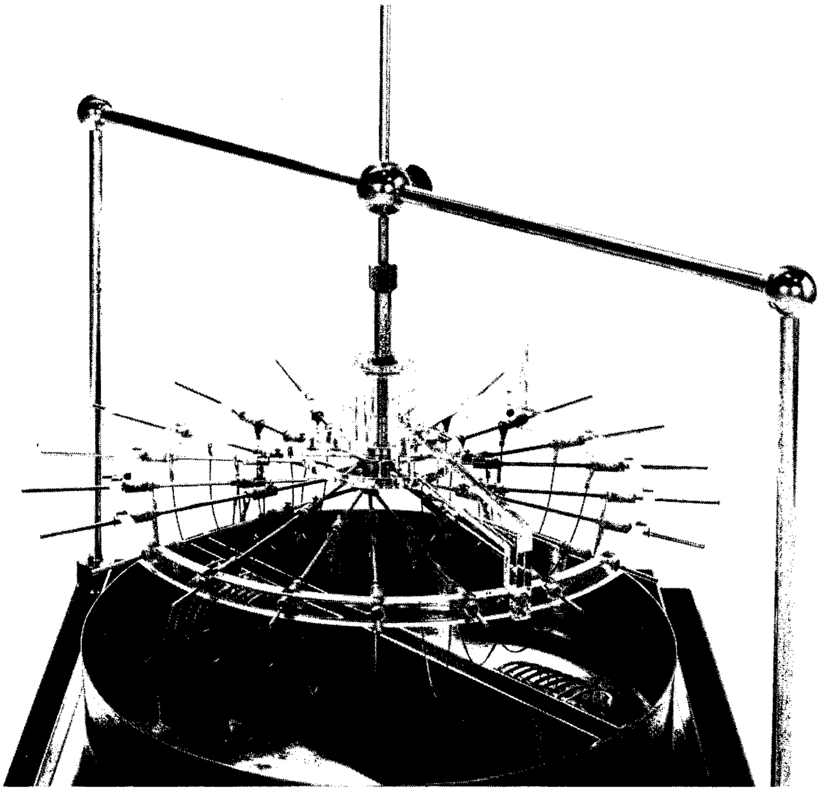
The high energy heavy ion facility at Berkeley known as the Bevalac. The linear accelerator, Superhilac, can provide a wide variety of heavy ion beams of high intensity which can be transported down the Berkeley hill for injection into the Bevatron and acceleration to GeV energies. Research with heavy ions has become the biggest component of the LBL programme.



Superhilac viewed from the injection end. The lighter ions are fed in from a 750 kV injector which is out of the photograph to the right. The heavier ions are fed in from the 2.5 MV injector visible at the bottom of the photograph. Accelerated xenon ions were achieved in April.

A small engine using loops of Nitinol, the metal alloy which memorises its annealed shape, attached to the spokes of a wheel. In operation, the loops dip into the circular bath which is divided into warm and cold water compartiments. In the warm water the loops push out against the rim to try to regain their memorised straight shape. In the cold water they relax and, because the axis is off centre, the wheel rotates converting heat energy into mechanical energy. This novel device is being worked on in the context of the Berkeley solar energy programme.

(Photos LBL)



operation has proved more difficult than was anticipated. Development of the machine's capabilities is working steadily up the periodic table. In April, xenon was accelerated quite reliably but as yet with low intensities. To accelerate metallic ions a sputter ion source and oven will be installed and work will begin on the acceleration of calcium ions. Mercury, lead and bismuth are of particular interest and ions as high as uranium are hoped for in 1975.

Better instrumentation and computer control is needed to make the operating conditions really reproducible and to improve the reliability of the machine. This is not an easy task because it is necessary to pick out a particular charge state and to follow those ions throughout the acceleration cycle. In the first quarter of this year Superhilac provided beam for research for 66 % of the scheduled operating time accelerating oxygen 18, argon 40, titanium 48, vanadium 51 and krypton 84. It fed ions to eleven experimental groups.

The Bevatron first demonstrated its abilities to accelerate heavy ions in 1971 using as injector the 20 MeV proton linac. In May, it ran with oxygen and carbon ions in a heavy ion programme including fragmentation work, a study of the excited states of carbon 12 and biomedical research on the effects of heavy ions in tissue. A new biomedical experimental area has just been brought into operation and is easily distinguished from its physics neighbours by the fact that it is as clean as an operating theatre. High energy physics experiments, for example, using a streamer chamber or a unique stopped positive kaon beam, continue to take data.

At the beginning of August it is intended to link the Superhilac with the Bevatron forming the Bevalac. This will result in a spectacular increase in heavy ion intensities (for example, neon passing from 10^5 ions per pulse towards 10^{10} ions per pulse) and will extend the ion types as far as krypton. The Superhilac will inject into the Bevatron via an ion transfer line which passes down the Berkeley hill between the two machines. Initial operation of the transfer will be without computer control which will only be brought into action early 1975. Since the Superhilac operates at the rate of 40 pulses per second, it will effectively be permanently on-call to inject into the Bevatron which pulses once every 6 s and thus the Superhilac experimental programme will be hardly disturbed at all when the systems are operating efficiently.

The Bevalac is a national facility for heavy ion research and well over 50 % of the users will come from outside the Laboratory. A Bevalac Users Association has been set up and has about 400 members. An indication of the breadth of the research programme can be seen from the number of disciplines involved: about half the members are from biology and medicine; the other half are from nuclear chemistry, nuclear physics, cosmic ray physics and particle physics. Heavy ion research has become the largest single programme in the Laboratory.

One tantalising prospect is that the Bevalac might be able to get at the 'abnormal nuclear states' recently discussed by T.D. Lee and C. Wick. They have deduced that a much denser form of nuclear matter could exist and that we could get at it by throwing, for example, uranium at uranium with an energy of 1 GeV per nucleon. It could possibly be produced by lighter elements and there will no doubt be efforts to look for such nuclear states even with the foreseeable Bevalac ions. To accelerate much heavier ions, perhaps up to lead, would require a better vacuum than the 2×10^{-7} torr that the ancient vacuum vessel of the Bevatron can provide. An inner liner with its own pumping system to achieve 10^{-9} torr has been proposed and might be incorporated in the machine in FY 1976.

A High Energy Heavy Ion Summer Study will be held at Berkeley from 15-26 July 1974 under the sponsorship of LBL and the Bevalac Users Association. Its purpose is to investigate those areas of atomic, nuclear, particle and astrophysics that can be studied with beams of relativistic nuclei (typically 1 to 2 GeV/nucleon) such as will be available from the Bevalac. Invited participants include — J. Bjorken, Z. Fraenkel, A. Goldhaber, W. Greiner, G. Harp, A. Kerman, G. Raisbeck, J. Truran and H. Vary. Further information can be obtained from L. Schroeder, Bevalac Users Association, Building 50, Lawrence Berkeley Laboratory, Berkeley, California 94720, USA.

The second activity which the Lawrence Berkeley Laboratory is expanding considerably is the energy and environment programme. We described its modest beginnings and rapid growth in vol. 13, page 303. That growth has continued and in the President's proposed budget for fiscal year 1975 almost a fifth of the total Berkeley operation and construction money goes to this programme which is carried out in a new Energy and Environment Division under J.M. Hollander.

The steep rise in available money is mainly accounted for by the new interest in energy which was accentuated by the crisis at the end of 1973. It is likely that as much as $ 2000 million will be spent on energy research and development in the USA in FY 1975. Only in America could a programme of this scale be turned on so fast.

Berkeley can draw money from the AEC for this work under various headings, since the AEC was authorized in 1971 to work on energy needs. Still more of their projects may be funded if the federal reorganization involving the AEC takes place. An Energy Research and Development Administration may be established and Berkeley would probably become an ERDA Laboratory. We pick out a few topics from different sections of the programme.

There is work on the development of the necessary technology to use the largely untapped resources of geothermal energy. For example, a 10 MW pilot plant is to be built in Nevada. Brine at a temperature of about 140°C is the source of heat but rather than boiling it off, which would cause environmental problems because of the disposal of the salt, it is heat exchanged with a secondary fluid which is used to drive turbines and generate power. The brine can then be reinjected into the ground.

A fascinating outcome of work on solar energy is a novel heat engine using a metal with unique properties. It is a niobium-titanium alloy known as Nitinol which manifests abrupt physical change when passing a threshold temperature. Below this temperature, which can be varied from below the freezing point to above the boiling point of water by varying the alloy composition, it is pliable like soft copper. Above this temperature it springs back to a 'memorised' shape. It could therefore be used in environments where small temperature differences exist (for example, produced by solar energy on the roof of a building, waste heat in industrial plant, thermal gradients at different depths in the oceans, etc.) to convert heat energy into mechanical energy. A small engine, invented by R. Banks, has been built demonstrating the principle. Loops are formed of Nitinol wire which has been annealed as straight lengths. The loops are arranged on the spokes of a wheel. The wheel has its centre off-set from the crankshaft and from the centre of a circular bath divided across its diameter into warm and cold water sections into which the loops dangle. In the warm water they try to regain their straight shape and push against the rim. On the opposite side, in the cold water, no such force exists and the wheel therefore rotates. With a 23 °K temperature difference, the engine runs at 65 rpm with an output of 0.2 W. It has completed over 13 million revolutions with no sign of lessening performance. A 10 W version is being completed, a 2 kW engine is being designed and even MW engines are under study. Much remains to be done to make the conversion from heat to mechanical energy an efficient process but if this can be mastered the possibilities are enormous.

Work on thermonuclear fusion is concentrating on theoretical studies and on the development of neutral beams to feed both fuel and energy into plasmas confined in magnetic fields. The usual beams of charged particles cannot easily penetrate the fields. Neutral 'currents' equivalent to 10 to 15 A of charged particles have been achieved.

Topics under the heading of advanced instrumentation for environmental monitoring were dealt with in our article in October 1973. They include X-ray fluorescence analysis, isotope Zeeman effect atomic absorption, electron spectroscopy for chemical analysis, etc. . .

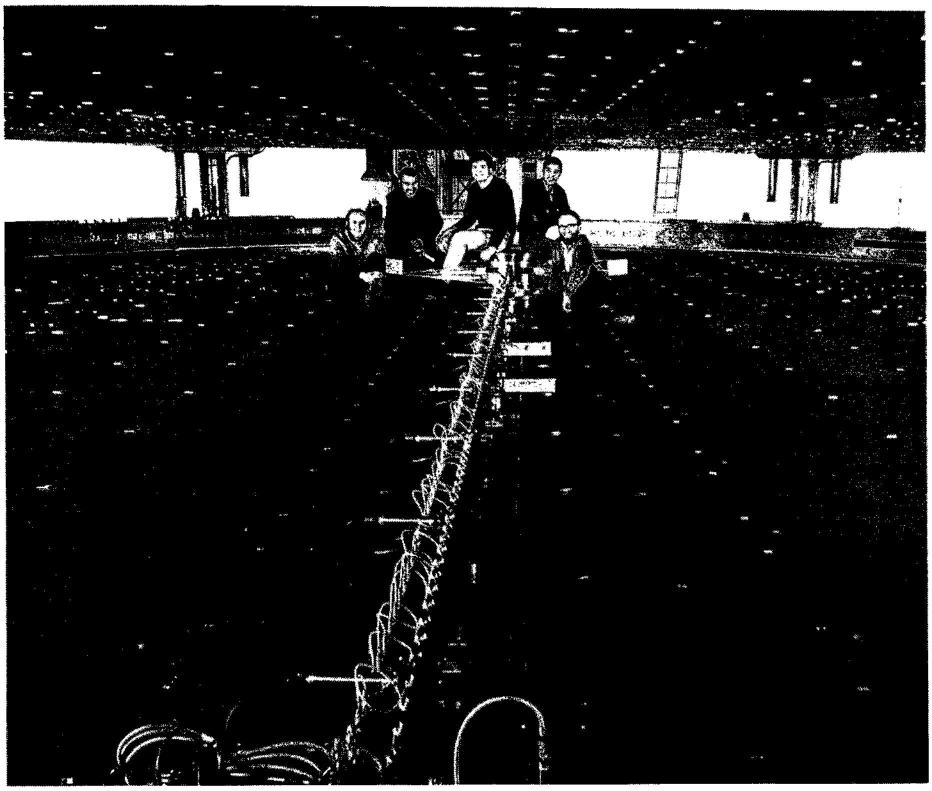
Since the San Francisco area is one of the most worrying of earthquake zones, it is not surprising that techniques for earthquake prediction is also on the Berkeley research list. Various seismic parameters, such as the electrical resistivity, have been observed to change several days before an earthquake and optimum ways of detecting such changes are under study.

It will be obvious from the above paragraphs that there is great interest, variety and 'relevance' in this new research programme at the Lawrence Berkeley Laboratory.

TRIUMF
Nearing first operation

After a difficult year in 1973, the TRIUMF cyclotron project at Vancouver now looks well on the way to starting its physics programme by the end of this year. Four Canadian Universities (Alberta, British Columbia, Simon Fraser and Victoria) administer the construction and operation of this sector-focused cyclotron to provide beams of energy up to 500 MeV. Most of the funds are provided by the Canadian government. It is an ambitious project with novel

Inside the huge vacuum tank of the TRIUMF cyclotron, the magnet group (left to right N. Rehlinger, A. Otter, D. Evans, K. Poon and E.G. Auld) pose behind the long arm which carried part of the magnetic field survey system. The system has been in relentless use for a year in the process of achieving the desired field configuration.



technical features and it is not surprising that construction has run into difficulties which have delayed first operation by about a year. In addition, money has been thin on the ground and it has not been possible to bring adequate numbers of people and adequate support facilities to bear where they were needed to maintain the schedule.

The cyclotron was described in vol. 8, page 136. It will accelerate negative hydrogen ions so as to achieve high extraction efficiency by using the field in the six sector magnet to bend out the protons which are released when the electrons are stripped off the ions. Beams will be fed to experiments in two experimental areas. Proton and neutron (polarized or unpolarized), pion and muon beams will be available.

The major problem of the past year has been to achieve the required accuracy of the field configuration in the assembled magnet. The field has to be accurate to one part in 10^4 with tolerances of less than a gauss in B_z and less than 0.5 gauss in B_r. The peak field value in the aperture is 0.6 T but, though this is comparatively low, the yoke configuration leads to fluxes as high as 2.8 T so that the steel is locally heavily saturated. Completely satisfactory results were obtained with a tenth-scale model of the magnet but, when the magnet itself was assembled, fields as far off the design figures as 200 gauss were measured. The permeability of the steel for the full-scale magnet differed from that of the model, possibly because the thinner sections of the model had been slightly cold-worked during manufacture.

A lengthy programme of field measurement and magnet shimming has therefore been carried out to bring the field configuration within the range that can be adjusted by trim coils. The measurements used a series of carefully spaced small coils carried on beams (one for the radial and the other for the vertical planes) which were flipped through 180° in the field and their output signal integrated. Steel shims were added and in some places steel was cut away to approach the desired field configuration.

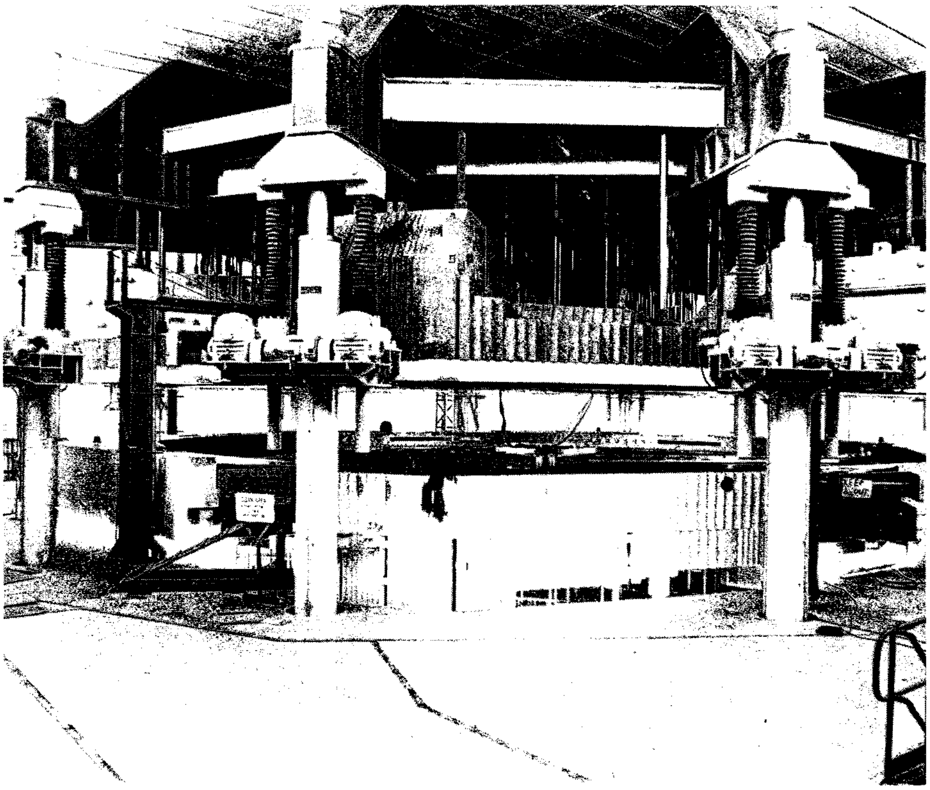
Through to September 1973, conventional calculations were used but the interdependence of the magnetic field variables made it necessary to turn to sophisticated matrix type calculations to estimate the required shimming. Measurement data was collected by an on-line computer and a lot of time on an IBM was needed to handle the multi-parameter calculations which gave the final shim predictions in an iterative procedure. On 17 April the required field was achieved.

Work on the other systems has been continuing in parallel. The ion source has provided negative hydrogen ion beams of 100 μA intensity and the injection beam-line (using electrostatic bending and focusing) conveyed them with good transmission efficiency (75 %) to the injection axis of the cyclotron. It remains to install the last elements to take the beam vertically into the central region of the machine. A polarised ion-source has been developed and has given beams of over 300 nA in prototype form with polarizations of 85 %. The final version arrived in February and is now installed and being tested. It then needs to be linked to the injection beam-line.

The r.f. accelerating system has completed its tests in air and has been cleaned and baked out. Installation in the vacuum tank began in May. The careful cleaning was necessary because the stainless steel resonators have a surface area greater than that of the vacuum tank itself and their outgassing rate will obviously influence the final pressure. The tank, like a huge shoe polish tin 17 m in diameter and 0.5 m high, was tested to 10^{-7} torr before installation in the magnet. Cryopumps and turbo-molecular pumps are installed.

Work on installing the two beam-lines into the experimental areas has started. Two stripping foils can be positioned at varying radii so as to provide simultaneous beams whose energy and intensity can be adjusted independently. Thin carbon foils are used to strip off the two electrons. The electrons dissipate most of their energy in the foils but the targets can probably handle beams up to 100 μA and require changing only once per week. A target changing system without need to enter the vacuum chamber has been developed.

The main advantages of TRIUMF in the physics it will be able to do are related to its ability to provide simultaneous proton beams at different energies and to vary the energies over



A view of the assembled cyclotron with the top half in the raised position. Note the sector arrangement of magnet blocks, the forest of tie rods which support the vacuum tank and the magnet survey equipment in place.

(Photos TRIUMF)

a range from about 200 to 500 MeV. The duty cycle, as seen by most detectors, is 100 %. The r.f. system operating at 23 MHz, does impose a 44 ns pulse structure on the extracted beam and this can be used for time of flight measurements using fast detectors such as plastic scintillators. Also, polarized proton beams are likely to be available at TRIUMF before they come into action elsewhere and will enable some unique experiments to be done.

An experiments evaluation Committee has discussed over fifty proposals and preparations for the first experiments are under way. The extracted beam intensity will be limited to 1 μA in the initial months of operation and experiments are lined up to use the first low intensity proton beams and (possibly a few months later) the first meson beams.

Covering the energy range from 200 to 500 MeV, an Alberta/Manitoba team will study proton-nucleus scattering on a series of light nuclei (hydrogen, helium, ...). They will begin with sodium-iodide detectors and this study will later continue using a high resolution magnetic spectrometer. Variable energy neutron beams from a liquid deuterium target covering the range 200 to 500 MeV will provide experimental possibilities not available anywhere else. They will be used in experiments by Canadian and UK physicists (the BASQUE collaboration mentioned in the May issue page 173) to study nucleon-nucleon interactions eventually in triple scattering experiments using the superconducting coil described last month.

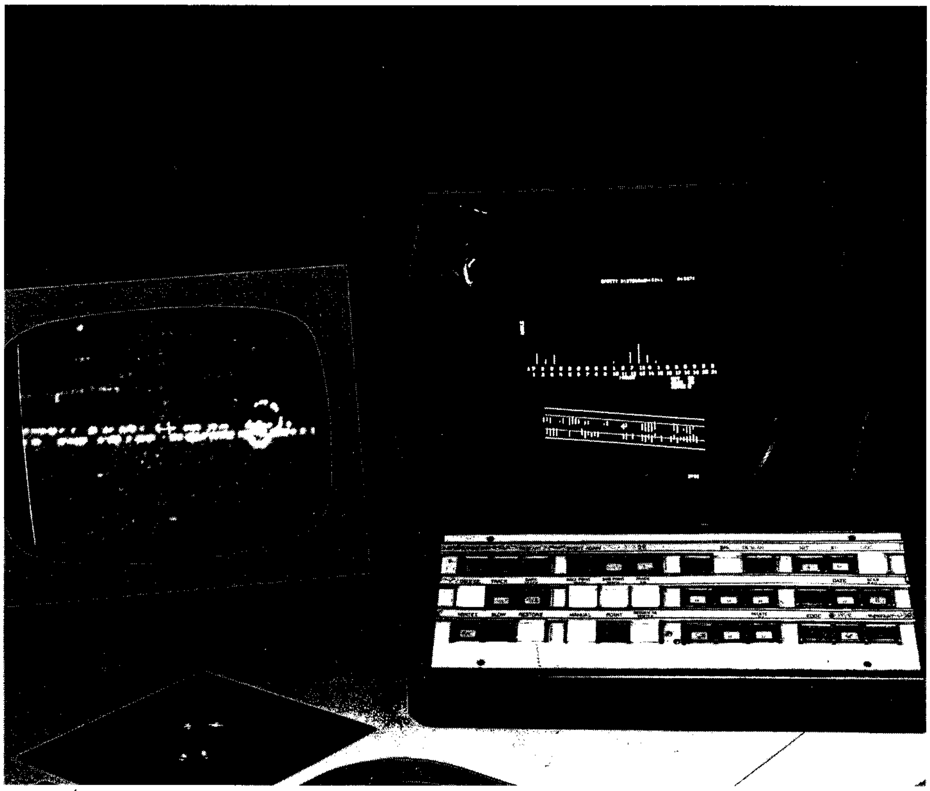
A large scattering chamber will be used by a Simon Fraser team to look at heavy fragments emerging from nuclei bombarded with protons. This will extend to studies of the fission of light and medium nuclei induced by protons and by pions. On the fission theme, later in the programme a Chalk River team intend to examine whether it is possible to produce interesting quantities of fissile material by the bombardment of thorium. This idea was often discussed in connection with the ING proposal for a linear accelerator many years ago.

Following on from the excellent work at 185 MeV on the Uppsala synchro-cyclotron, an Alberta/British Columbia/Victoria team will take to higher energies the study of positive pion production in proton-proton and proton-nucleus reactions using polarised and unpolarised beams. The positive pion beams subsequently available at TRIUMF are likely to be of higher flux and of better momentum definition than elsewhere since the pion production is prolific between 400 and 500 MeV. At the moment, however, TRIUMF lacks the facilities for a good pion scattering experiment.

A British Columbia/Montreal team will use negative pions from 50 to 200 MeV onto a hydrogen target to investigate the interaction giving a gamma and a neutron. This interaction has been used, for example, as a check on time reversal invariance and there is interest in pushing the accuracy of the data still further. A large sodium iodide crystal (45 cm diameter, 50 cm long) will be used to give good resolution in the observation of the high energy gamma so as to avoid confusion with the lower energy gammas from neutral pion decay. A Montreal team will later use the same detector to study rare decays of the pion (such as the positive pion decaying direct to a positron) which could give important new information on the weak interaction. Another British Columbia pion experiment will look at radioactive capture in light nuclei such as lithium.

Two experiments will use muon beams. A Victoria/British Columbia/Washington team plan a series of mesic X-ray studies beginning with a study of the influence of the chemical environment (which affects the available energy levels) on muon capture. Related work has been done at Dubna, Berkeley and CERN but the high duty cycle at TRIUMF should enable more thorough work to be done. A Berkeley/British Columbia/Victoria team will look at depolarization of the positive muon in a variety of materials studying the chemistry and physics of condensed matter. The work began at Berkeley but again the TRIUMF duty cycle will help. Later in the programme an experiment involving scientists from Tokyo will use negative muons for a series of solid-state studies probably beginning with a look at the hyperfine fine splitting in muonic bismuth atoms.

It is hoped that TRIUMF will accelerate protons for the first time in October and that the experimental programme will begin soon afterwards.



Display screens showing the Oxford PEPR in action sorting out two closely spaced tracks on film from the CERN 2 m bubble chamber. The screen on the left shows the two lines of bubbles recorded on the film. The screen on the right shows what PEPR has made of it. As a measure of the scale, the two 'peaks' marked above the two parallel lines of figures at the centre of the screen are about 100 μm apart. The limit of the resolution of the device is 25 to 30 μm which is close to the normal bubble diameter.

(Photo Oxford)

OXFORD
Computer scanning

An international conference on image processing with CRTs and vidicons, in high energy physics and other applications (Oxford Conference on Computer Scanning), was held from 2-5 April in the Department of Nuclear Physics of the University of Oxford. It attracted about 130 people, about four-fifths of them being from high energy physics Laboratories.

Nothing really new has emerged from the work of recent years on scanning and measuring machines for bubble chamber film. The various machines have now reached maturity, where routine operation and measurement of a hundred thousand or more events per year are commonplace. There have, of course, been refinements on existing types of device (in particular, on the PEPR and POLLY systems which have moved close together in their methods of operation) — but no fundamental new ideas. The CERN ERASME system is conceptually a step forward in the degree to which it enables on-line operator participation in the measuring process. It is however an expensive system and is not the answer to the prayer of small bubble chamber teams in individual Universities.

The attempt to achieve fully automatic scanning and measuring of tracks on film has been almost completely abandoned. The human eye has proved an invaluable asset. This was entertainingly affirmed, to the joy of mankind, in an after-dinner discussion entitled 'Are girls necessary?' The unaided measuring system and its computer can still only sort out particle interactions when fed with rather special track configurations.

Despite some degree of disillusionment regarding uses in the high energy physics field, where the systems seem to be close to the end of the road in terms of development, it is important to note that, by comparison with a few years ago, they are now handling much higher quantities of film which often record events of higher complexity and, generally, carry out the measurement, with higher efficiency. Direct filmless read-out using vidicons is an interesting development in the spark chamber field which may prove to be 'the future', taking over from the CRT devices just as CRTs have taken over from the mechanical devices, such as the HPDs. In addition, it is very exciting to see how the effort in high energy physics to 'provide the computer with an eye' is now reaping benefits in completely different fields.

Examples are: Oxford is using its PEPR machine for some hours a day to scan rainfall charts from the Meteorological Office. The charts, recording rainfall over many years at 150 different locations throughout the UK, are first filmed. PEPR then reads the charts and, via the computer, gives the data in assimilable form. Many years of work would be required to read the charts in any conventional way.

Harwell are studying an application to test for distortion on railway lines. Traces from a fairly simple device attached to trains might be rapidly scanned and give early warning of any growing distortions. Edinburgh Medical Research Council and MIT are developing a system for blood analysis doing rapid chromosome counts and are also looking at the possibility of rapid scanning of cells for cancer; screening tests might be greatly simplified by this technique. Chelsea College of the University of London are studying the automatic analysis of film of muscle fibre (muscular dystrophy), goblet cells and asbestos fibres in dust (various consequences of pollution).

Several other medical applications, replacing the human scanner peering through a microscope, seem conceptually possible but the patterns seen by the measuring machine are very different from those encountered in high energy physics. Much work will be needed to teach the computer to recognize what it is seeing. Other topics mentioned ranged from the stars to the Venetian lagoons!

The Conference summary was given by D. Hodges, who said that this was the first conference to bring high energy physicists and other physicists in the field of computer scanning together and the range of topics covered was consequently wide. It was clear that there were common interests and that the mixing of disciplines could be fruitful. For high energy physicists, the social relevance of these contacts needed no underlining. However, the thought with which he closed the Conference was just how expensive is image processing!

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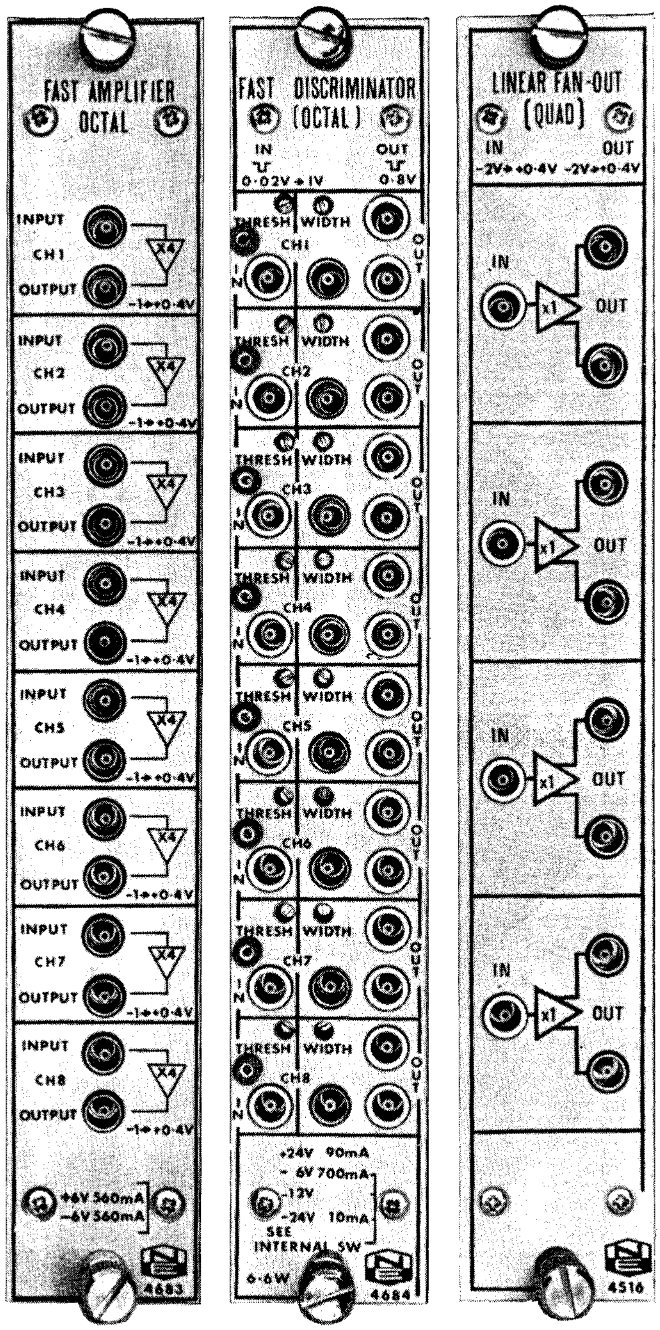

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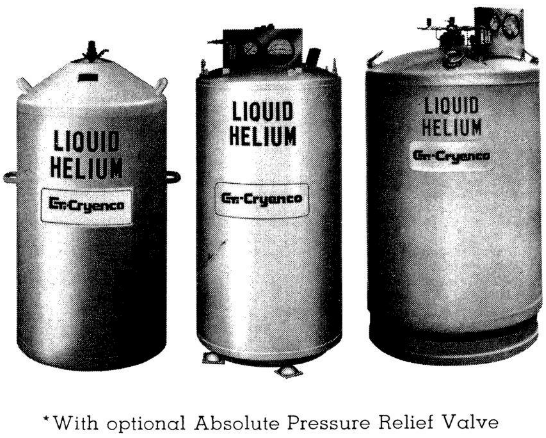

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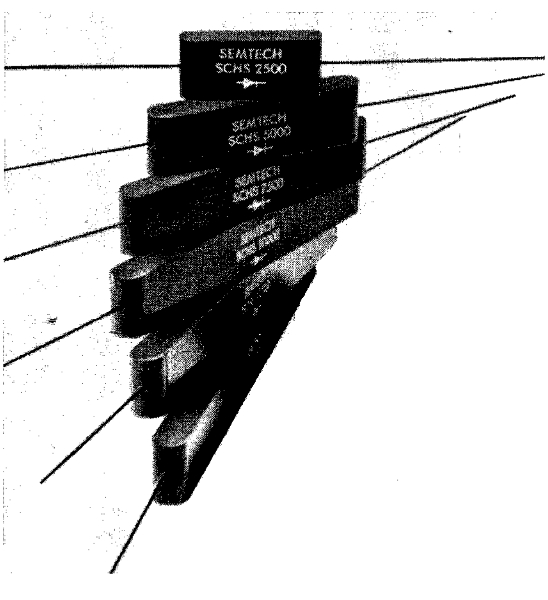

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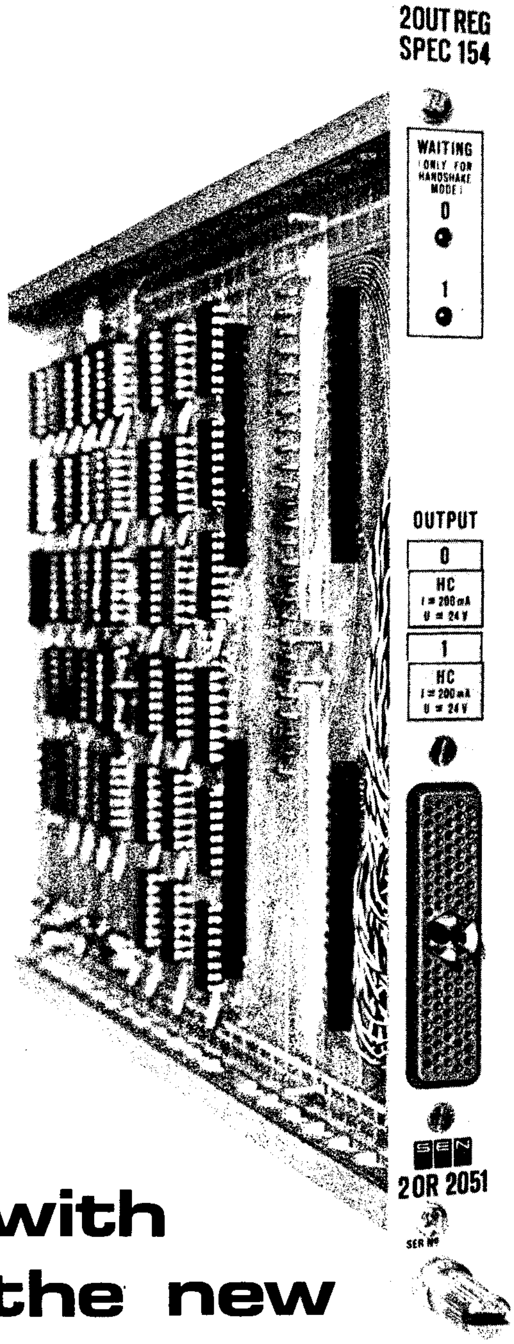

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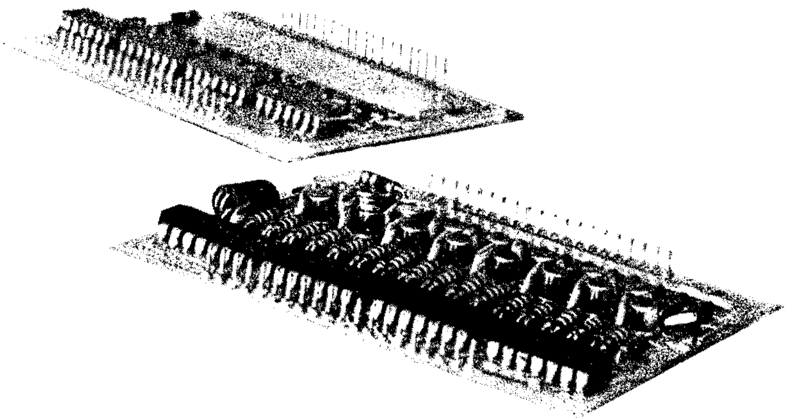

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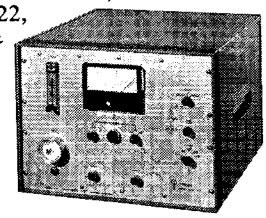

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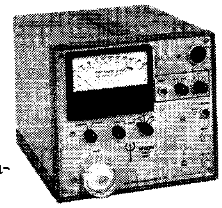

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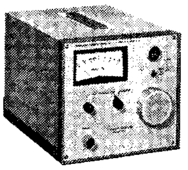

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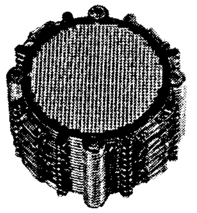

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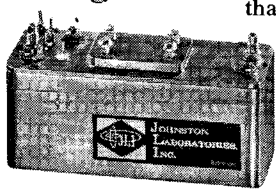

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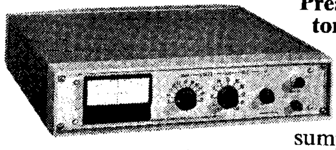

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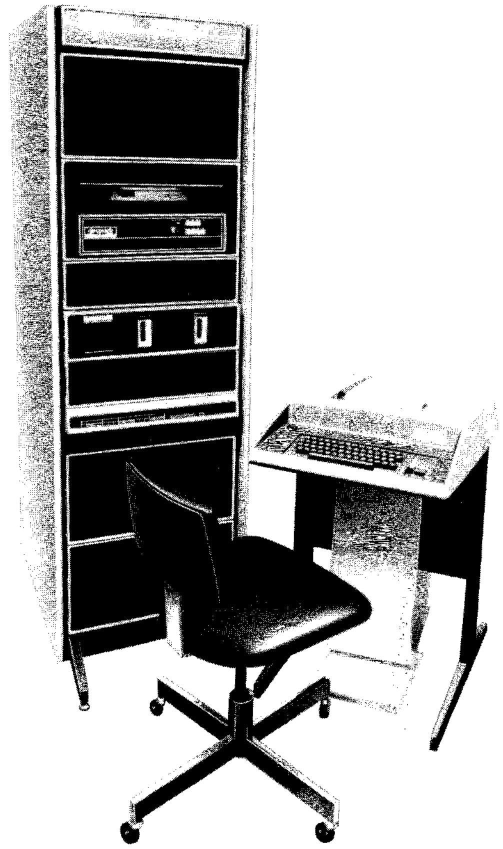

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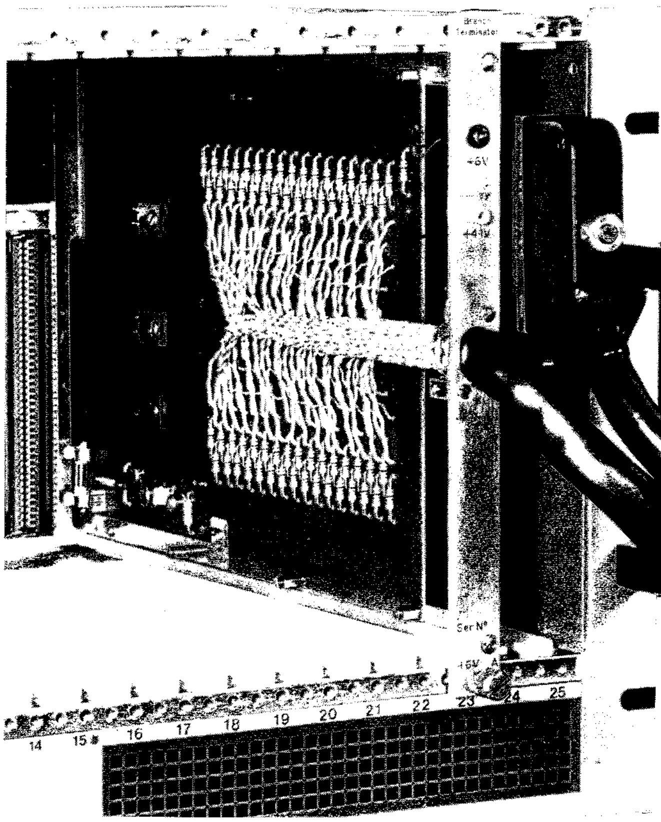

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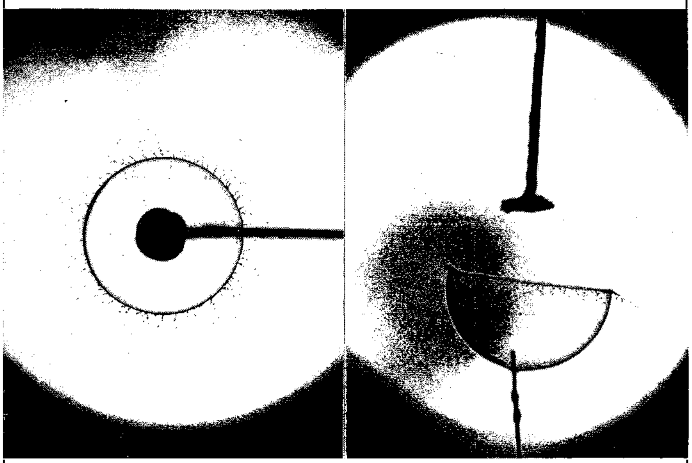

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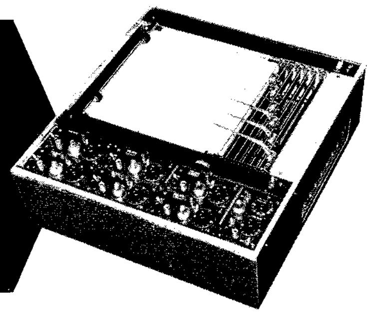

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RESPONSE.................................. 1.8 Sec. (X-axis), 1 Sec. (Y-axis)
ACCURACY .... ±0.4% (X-axis), ±0.3% (Y-axis)
RESOLUTION .... ±0.15% (X-axis), ±0.1% (Y-axis)
CHART FEEDING SPEED
(IN CASE T-Y RECORD) .... 600, 300, 100, 50, 20mm/min. hr 10 ranges
ACCURACY (OF CHART FEED)... ±1%
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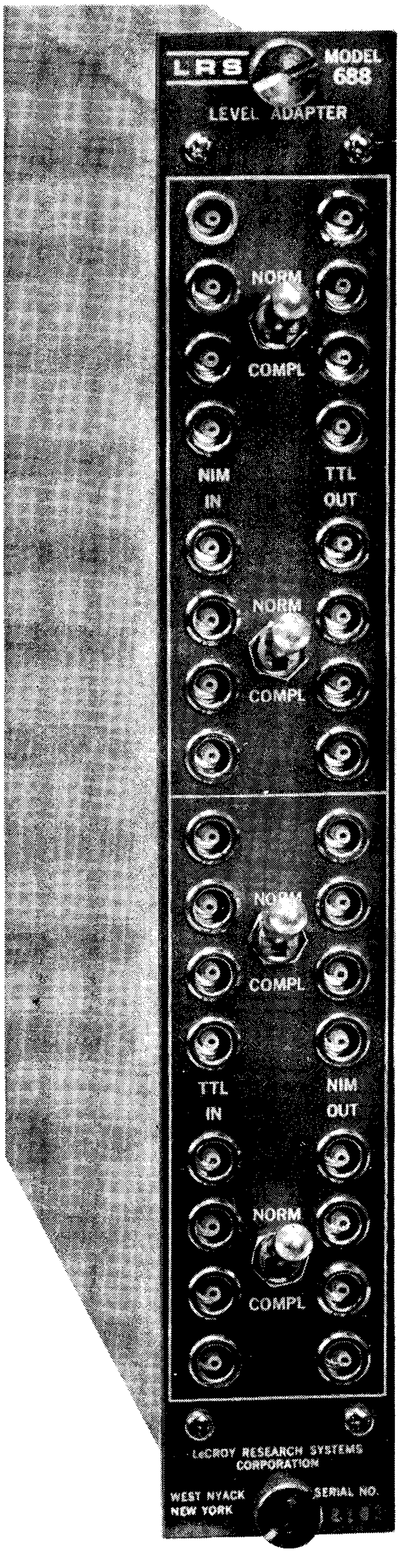

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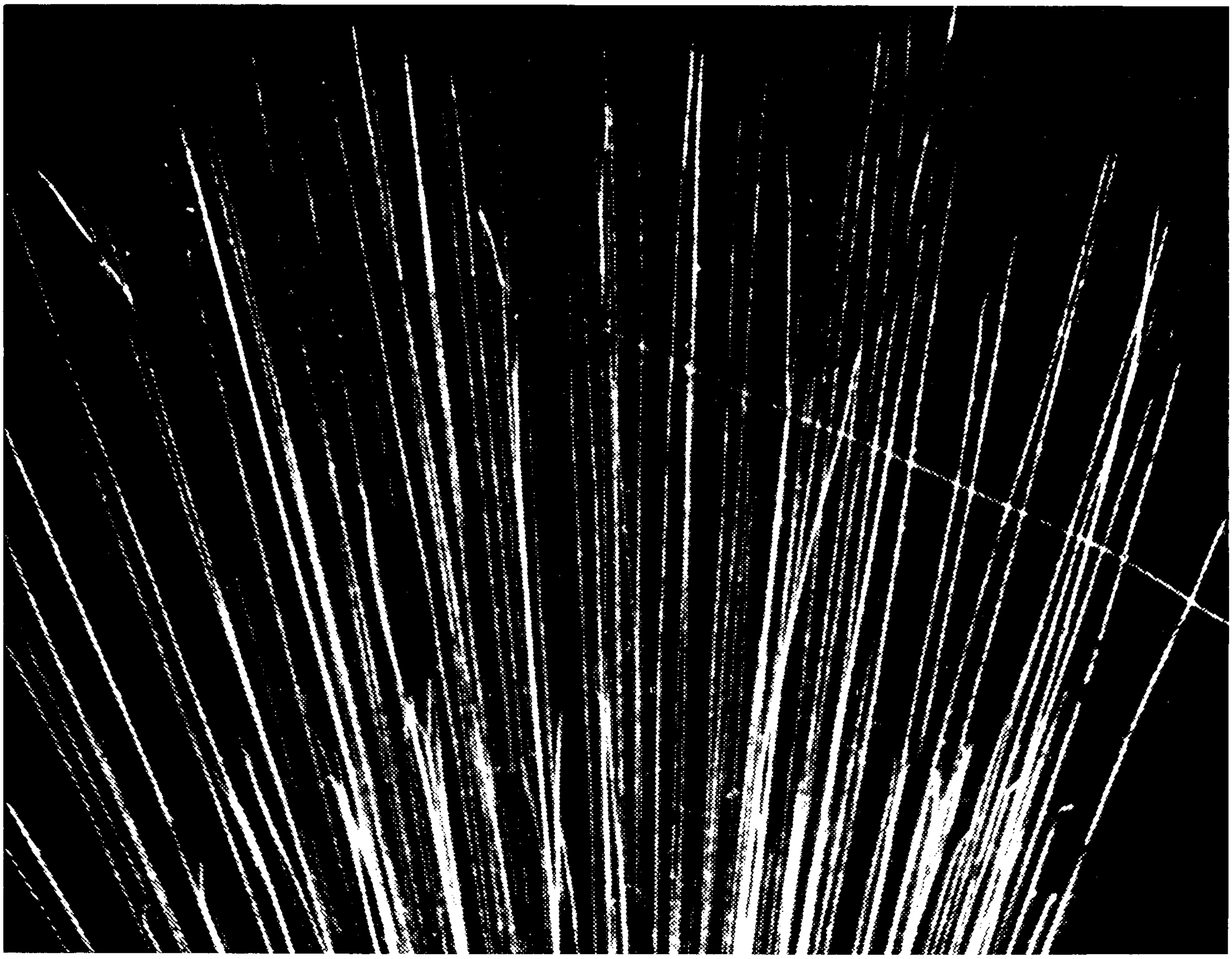

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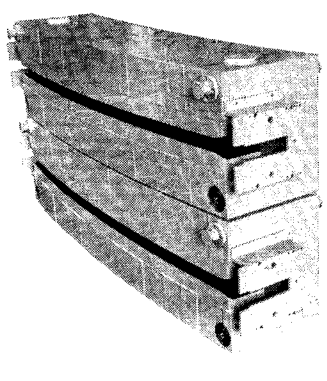

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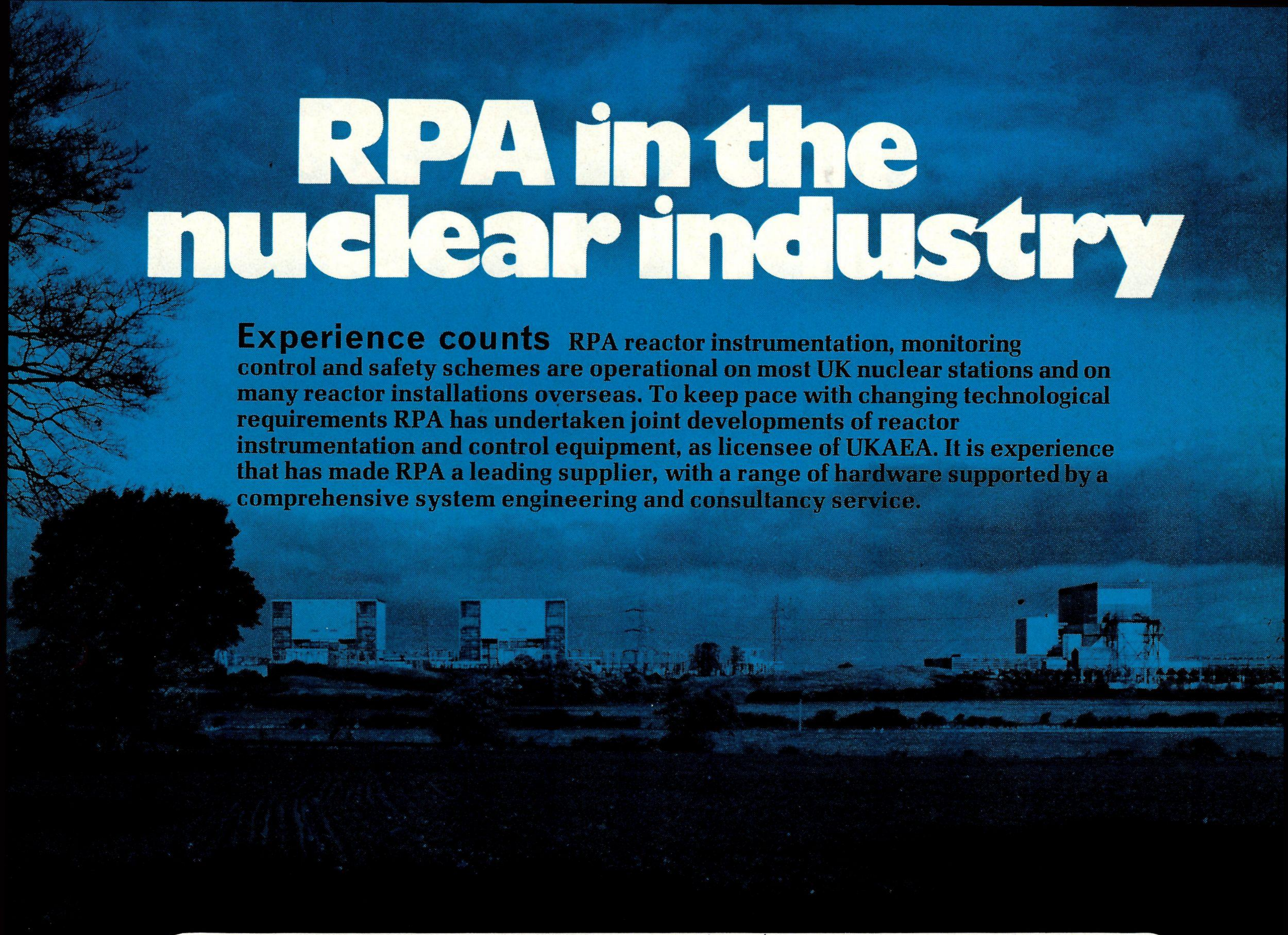

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