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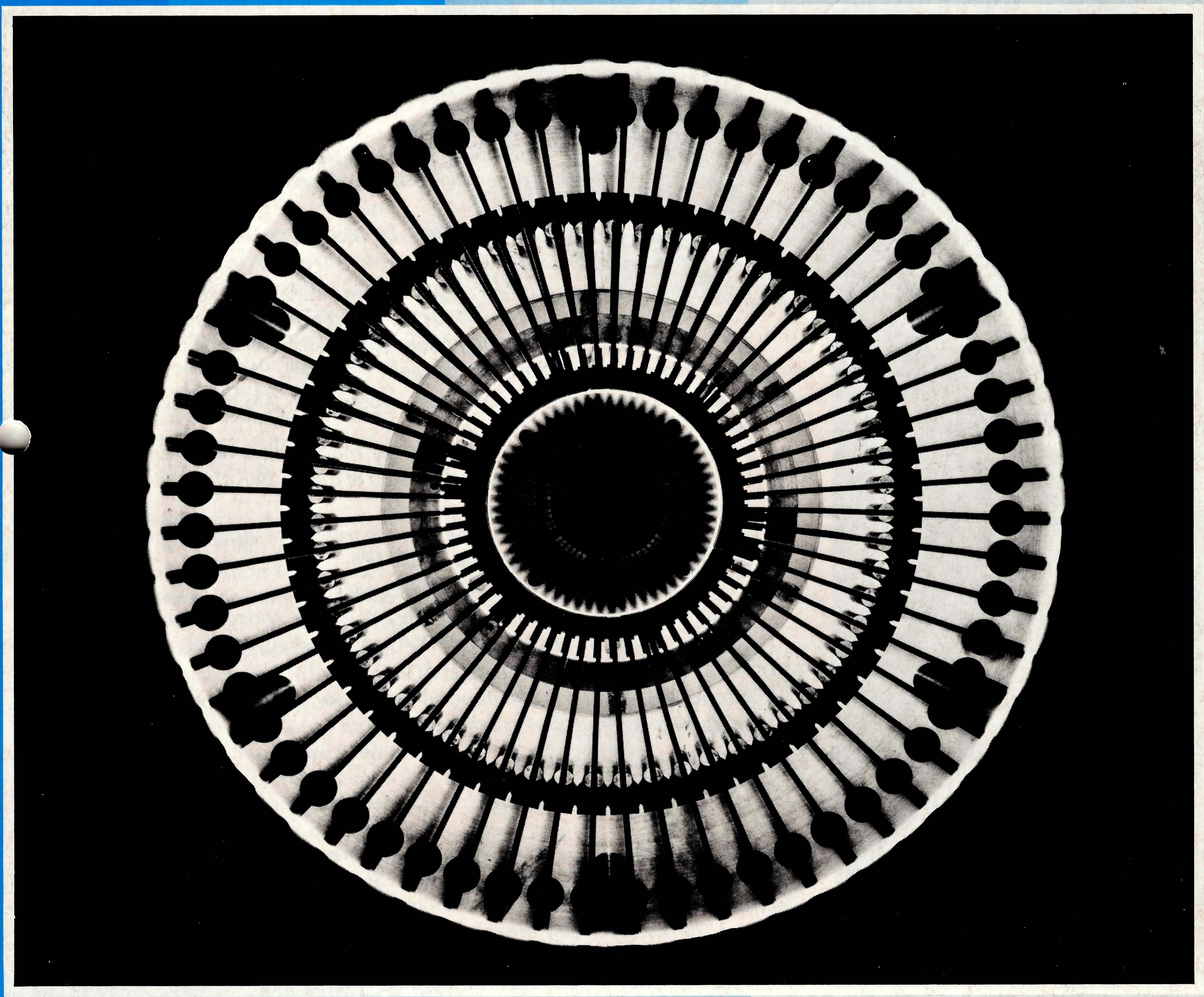

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Contents

Cover photograph: The coil of a beta spectrometer installed at the heavy ion linear accelerator, Unilac, by a Darmstadt/GSI collaboration. It is used to look for electrons and positrons emerging from heavy ion reactions in a target placed on the axis. The detector can measure these particles within the energy range 10 keV to 2.6 MeV. Because of its segmented form, it is referred to as the 'orange' beta spectrometer. (Photo GSI Darmstadt)

And then there were three

1. The toroidal magnets of the CalTech/Fermilab/Northwestern/Rockefeller team which was the first to see trimuon events.

2. A trimuon event from the detector, NEULAND, of the Harvard / Wisconsin / Pennsylvania / Fermilab / Rutgers collaboration which has six events to its credit.

(Photos Fermilab)

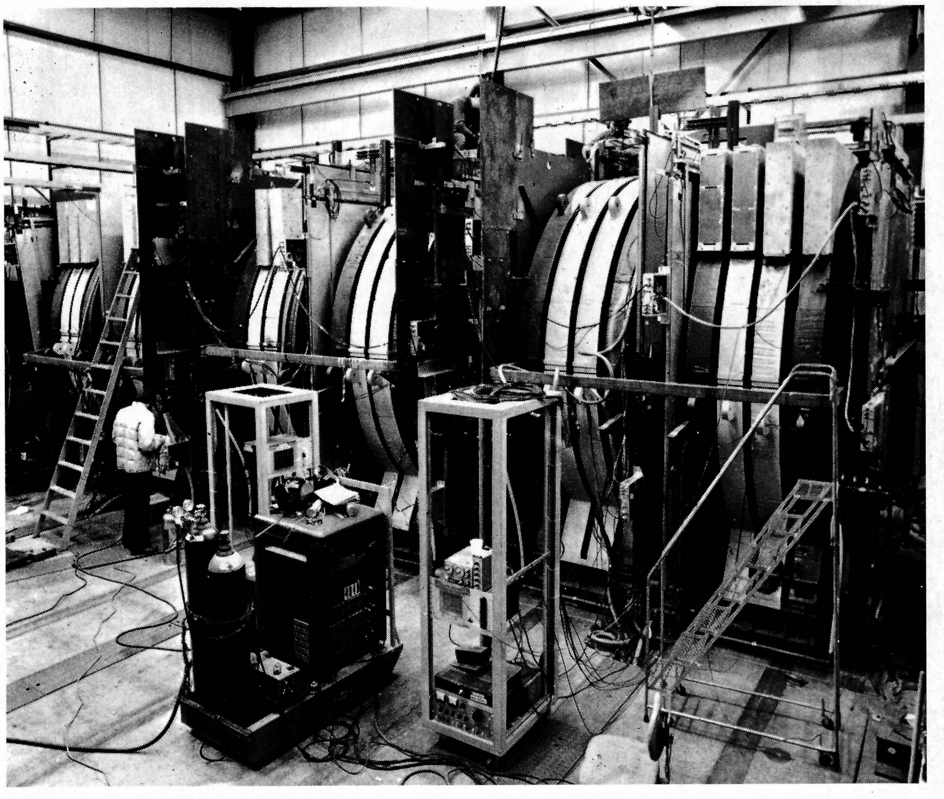
The discovery of dimuon events (two muons emerging from high energy collisions of neutrinos and antineutrinos with nucleons) has been one of the highlights of high energy physics in recent years. They were first seen at Fermilab in 1974 and two collaborations there, using large electronic detection systems, now have many examples of dimuon events. They are being joined by the collaboration using the CERN neutrino detector at the SPS, where the quality of the neutrino beams and the structure of the huge detector are making it possible to amass large quantities of data which should lead to a more thorough study of the phenomenon than has been possible up to now.

The origin of the dimuon events is probably tied up with the production of charmed particles in the neutrino interactions. The characteristics of almost all the observed events are consistent with such an interpretation.

The new discovery is that trimuon events (where three muons emerge from a high energy neutrino collision) also exist. The evidence so far is thin on the ground but convincing. Trimuon events seem to occur at the rate of a few percent compared to the dimuon events.

The first news of trimuon production came from the CalTech / Fermilab / Rockefeller collaboration led by Barry Barish which was measuring neutrino and antineutrino total cross sections with their extended detection system (see November issue 1976). In the sample data first analysed, events were selected where at least one muon was seen to traverse the spectrometer magnet, while additional muons were identified by spark chambers embedded in the steel of the detector. They saw two trimuon events from neutrino interactions.

One possibility which had to be eliminated at the outset was that of contamination due to background, 'non-prompt' trimuon production in



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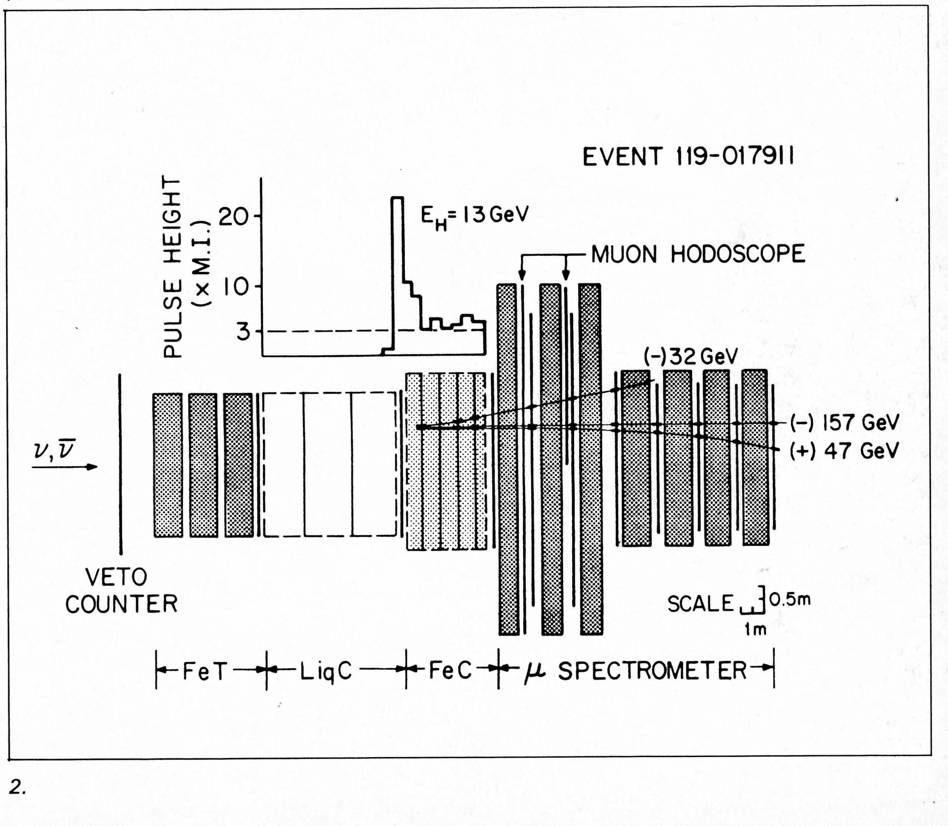

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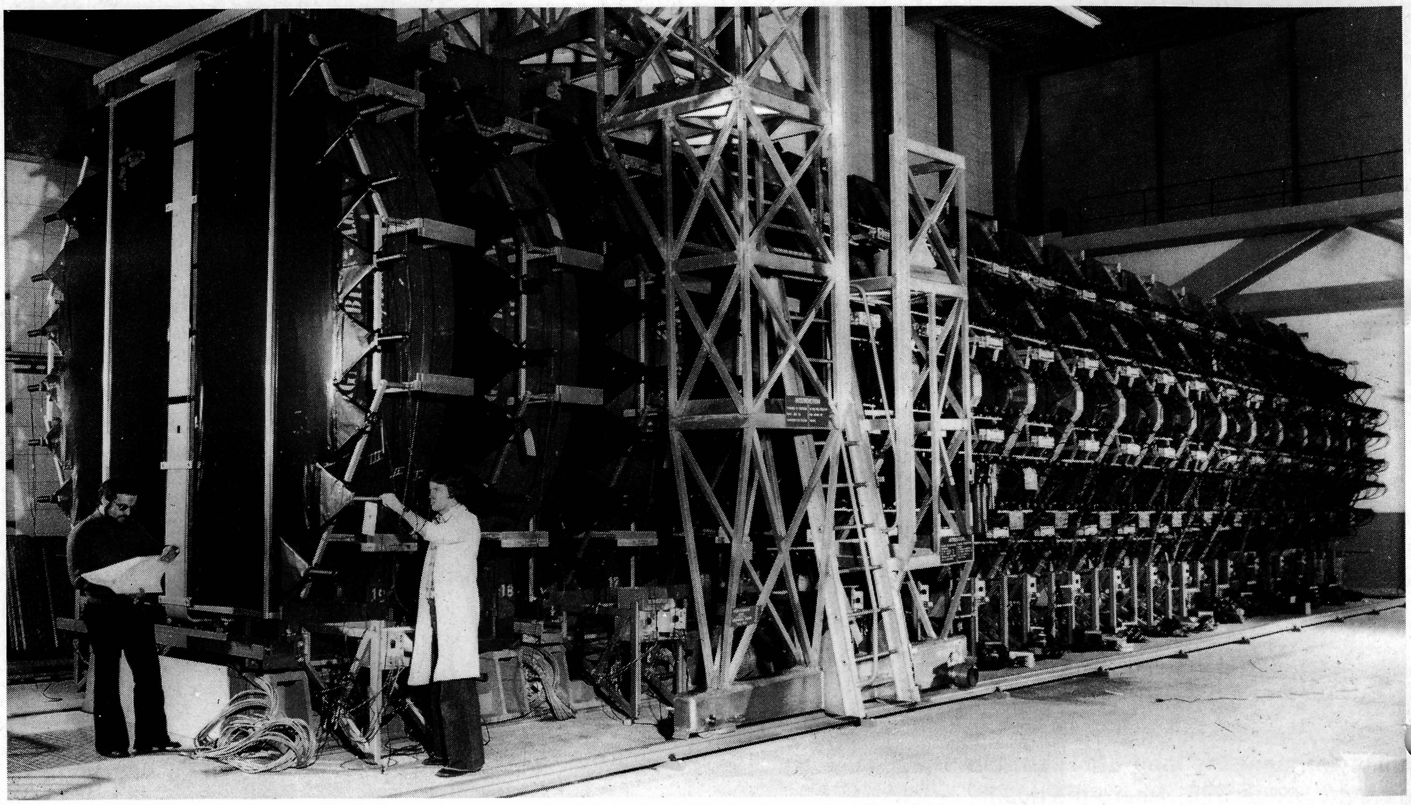


The huge detection system of the CERN / Dortmund / Heidelberg / Saclay collaboration at the SPS which is ideally suited to the detection of trimuon events.

(Photo CERN 1.10.76)

which a third muon appears as a result of pion or kaon decay along with normal dimuon production. Barish's group maintains that even just their two trimuon events are in excess of the number which would be expected as a background effect.

Both events have one energetic muon together with two muons of lower kinetic energy and the group surmise that this is possibly characteristic of low mass muon pairs emanating from meson decay, or from virtual photons, or from the decay of new hadrons. Their inclination is therefore to assign a hadronic origin to the trimuon events with charmed particles very much in mind.

Meanwhile the Fermilab / Harvard / Pennsylvania / Rutgers / Wisconsin collaboration, led by Dave Cline, A.K. Mann and Carlo Rubbia, using their new large angle neutrino detector, NEULAND, at Fermilab (also described in the November 1976 issue) has come up with six examples of trimuon final states from neutrino interactions, with the momenta and charges of almost all the muons firmly established. In four of the six events, all the muons have momenta greater than or equal to 10 GeV/c, while the angle between any two muons is less than five degrees.

Again the possibility of the three muons coming from 'normal' dimuon events in association with pion or kaon decay is quickly discounted, while estimates also eliminate other candidate mechanisms such as direct muon production at the hadron vertex, charm-anticharm production by a neutrino in a weak charged current interaction with subsequent semileptonic decay of both charmed particles, sequential semileptonic decays of new hadrons or weak neutral current decay of a charmed hadron.

Although the group thinks that in some cases a few events may be attributed to some of these effects, none of these mechanisms seems likely to be responsible for all the observed events. Instead, they propose that the three muons come from some new lepton states. Their idea is that a massive new lepton is first formed which decays into a muon, an antineutrino and another new lepton which, although still fairly massive, is a bit lighter than the first one. This second new lepton decays in turn into two muons and a neutrino.

At CERN, analysis of the first data collected at the SPS by the CERN / Dortmund / Heidelberg / Saclay collaboration, led by Jack Steinberger, has started. They already have over a hundred dimuon events, two candidates for trimuon events from neutrino interactions and the first candidate for a trimuon event from an antineutrino interaction.

With the total number of observed trimuon events seen anywhere in the world only just reaching double figures, statistics can hardly be said to be good, but speculation is rife as to possible explanations of this new phenomenon. The question of hadronic versus leptonic origin is the chief cause of head scratching. Hadronic would most likely contribute more to the knowledge of charmed particles. Leptonic would most likely add more evidence for the existence of new heavy leptons beyond that which has been seen at Stanford and DESY at the electron-positron storage rings.

USA Accelerator Conference

On 16-18 March over 600 accelerator physicists and engineers, together with many colleagues from related industries, gathered in Chicago for the 1977 Particle Accelerator Conference. This is the USA national conference (the international conference is scheduled for Serpukhov in July) but attracts many participants from other countries.

It was an intense three days, relieved on 17 March by a touch of local colour — the fortuitous coincidence with the Chicago St. Patrick's Day parade. Tens of thousands of sporters of the green marched in the all-afternoon procession and everyone of them seemed to finish up in the Tipperary bar at the Pick Congress Hotel where the conference was held.

One feature of the national conference, which distinguishes it from the international, is emphasis on practical applications of accelerator technology and on applications in other fields of science as well as in high energy physics. Thus there were papers on medical applications, neutron sources, synchrotron radiation sources, ion implantation, heavy ion facilities, spallation breeders and particularly on the possible use of high energy heavy ion beams in producing inertial confinement fusion.

This last topic prompted a large number of contributions to the conference, was the subject of an evening's panel discussion and was the major talking point in the corridors. Whether it proves to be a mirage, or too difficult to achieve with acceptable investment, remains to be seen but the subject of fusion as a source of energy is too important not to be pursued by every route which shows some promise.

The task is to build systems which can deliver power to a deuterium-tritium pellet so that it implodes reaching density and temperature conditions in which fusion reactions are sustained. A heavy ion system would need to deposit 600 TW of power and 10 MJ total energy, delivered in a tailored pulse giving some 60 % of the energy in about 10 ns using at least two, and probably more, beams. (For a much fuller discussion see the September issue 1976.)

Several heavy ion accelerator systems to meet these requirements are being promoted. Three of them have been under study for some time. Al Maschke of Brookhaven, Ron Martin and R. Arnold of Argonne have storage ring schemes using uranium and hydrogen iodide ions respectively. Dennis Keefe from Berkeley has a linear induction accelerator scheme (with a conventional linac first stage) for uranium ions. New schemes have come from C.L. Olson of Sandia Laboratories using the collective ion technique (see February issue 1971) and from Lee Teng of Fermilab using 'conventional' techniques of linac and synchrotron.

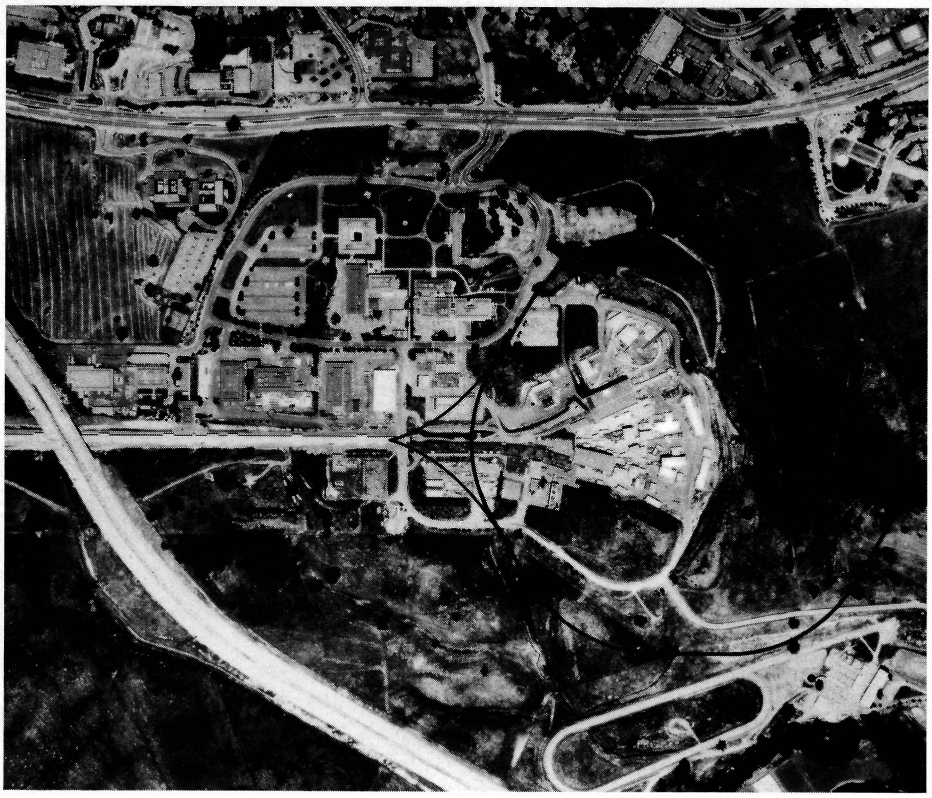
An idea of the scale of the problem can be grasped from the parameters Lee Teng's scheme — 2000 A beams of singly charged uranium ions accelerated to 150 GeV in ten bunches (extracted simultaneously by ten extraction systems so that the ten bunches bombard the pellet at the same time). The heavy ion energy would need to be delivered to the target in a peak pulse some 10 ns long. These are extremely difficult requirements to meet but a great deal of the accelerator technology involved in the various proposed schemes has already been mastered.

Experiments are now needed to look at some of the unknowns such as the charge exchange cross sections and the ability to bunch high intensity beams to pulse lengths in the 10 ns range rather than the 10 μs range we are used to. A first test on bunching was done at the Brookhaven AGS by Al Maschke, Gordon Danby, John Keane and Edward Gill. They applied the r.f. at 400 kV/turn and saw the proton beam bunch in about eight turns with an instantaneous current of 1.6 A. There was no sign of instabilities.

The ERDA programmes hope to demonstrate implosion fusion within the next few years using laser, electron and heavy ion beams. There was an announcement from Los Alamos at the beginning of March to the effect that fusion had been obtained using the world's largest carbon dioxide laser. This type is more efficient than neodymium glass lasers, can operate at higher repetition rates and is easily scaled up for large systems. It had been expected, however, that the gas lasers, with their longer wavelengths, would have difficulty in achieving the right profile for energy deposition in the target. The Los Alamos tests which began in October 1976 used a two beam bombardment of a deuterium-tritium pellet, delivering 200 J in 1 ns, and culminated in the observation of the characteristic 14 MeV neutrons from the fusion reaction. An eight beam system is scheduled for completion in 1978 and a 'breakeven' reactor, High Energy Gas Laser Facility (HEGLF), is under design for completion in 1981. To get things in proportion again, a 1000 MW generating plant would probably need 1 MJ on target in less than 1 ns.

It is interesting to note that the other major route to fusion, the magnetic confinement schemes, are also calling on accelerator technology. For example, the TFTR (Tokamak Fusion Test Reactor) project at Princeton, which is led by Paul Reardon from Fermilab and where many accelerator faces are to be seen, will have four neutral beams as an additional source of energy injection into the plasma.

To sum up the heavy ion accelerators for fusion discussions — a number of fundamental uncertainties remain (for example, the charge exchange cross sections which dictate everything downstream must come out good, problems with the reactor



Location of the PEP 18 GeV electron-positron storage ring on the site at Stanford. The 22 GeV linac, coming in from the left will provide the particles for injection. The break-in to the switchyard for the injection tunnels will start in the Summer.

(Photo SLAC)

vessel — God's own 'hostile environment' — must be solved, etc...). Even if these uncertainties are cleared satisfactorily, the scale, and probably the cost, of a reactor will be great. Nevertheless Glenn Kuswa, at the end of his review talk, extended his neck so far as to say that if fusion is ever going to be a source of energy for mankind, the heavy ion route is the one most likely to work.

One fusion scheme aside from the main discussions is being promoted by Bogdan Maglich. In a device known as MIGMA (now at version IV) he is shooting for fusion of two helium 3 ions. The device attempts to achieve the necessary fusion rates by injecting ion beams and arranging the field environment in which they move so that particles, during many orbits, traverse an interaction region many times. The effective ion concentration in this region is then very high. The idea is being pursued by the Fusion Energy Corporation and their work was illustrated after the Maglich talk by the longest five minute film on record.

The papers on accelerators for high energy physics concentrated on future projects. The newcomers on the scene were also welcomed — John Adams gave a talk on the start-up of the CERN SPS and Tetsuji Nishikawa on the start-up of the KEK synchrotron. At present the 18 GeV electron-positron storage ring, PEP, at Stanford and a 1000 GeV superconducting ring, Energy Doubler / Saver, at Fermilab are in the early stages of construction. 200 GeV proton-proton storage rings, ISABELLE, at Brookhaven and an 8 GeV electron-positron storage ring, CESR at Cornell are at advanced stages of preparation.

Progress on PEP was reported by project leader John Rees. The storage ring, 2200 m in circumference, has been designed to give peak luminosity, 10^{32} per cm^2 per s, at 15 GeV and usable luminosity, 10^{31}, up to 18 GeV. The normal dependence of luminosity on energy (inversely as E^4) has been reduced to E^2 by using the full aperture, by tune control and by use of a wiggler triplet of bending magnets. To achieve the design luminosity requires 50 mA per beam, 2.5×10^{12} particles, with three bunches per beam intersecting in six long straight sections. Five straights, with 19 m available for experimental equipment, will eventually be assigned to physics, and the sixth reserved for machine development.

The filling time from the 22 GeV electron linac is only a few minutes while the beam lifetimes with a vacuum of 10^{-8} torr should be several hours. The r.f. power will be supplied by 24 units of 5 cells with π - mode coupled structures driven in pairs by 12 klystrons. Klystron development has so far produced a tube giving 55 % efficiency.

Since the design first emerged in 1974, there have been two major changes. The separated function lattice is now symmetric around the half way point in a machine arc. Also the number of quadrupoles has been doubled to reduce the phase shift per cell. This may also make it possible to push the peak energy, with acceptable luminosity, above 20 GeV.

Excavation of the ring tunnel is scheduled to start in May. Site work and roads will begin a month later. The break-in to the switchyard of the 22 GeV electron linac for the injection tunnels will take place late-Summer during a long shutdown of the linac for the installation of the Mark II magnetic detector in the SPEAR storage ring. PEP is scheduled for completion between September 1979 and April 1980 (depending on the rate of funding) with a total project cost of $ 78 million.

The Energy Doubler / Saver project at Fermilab was reported by Phil Livdahl. It aims to thread a ring of superconducting magnets under the existing 500 GeV ring of conventional magnets. This will enable the peak energy to be taken to 1000 GeV (1 TeV) and, by making use of the low power consumption of the superconducting system, cut the electricity cost per year from the present figure of over $ 7 million by up to $ 5 million.

At the time of the Conference, prototype superconducting dipoles, 22 foot long, were being made at the rate of about one per week and had reached number 24. This rhythm is now being pushed towards one per day in the 'magnet factory' refurbished for the mass production of superconducting magnets. After training, all the magnets have reached the field of 4.5 T required for 1 TeV operation but they are not yet of adequate field quality for installation in a synchrotron ring. The measured field inhomogeneities can be correlated with known mechanical imperfections in the construction. More work is needed to ensure the necessary coil positioning

Cross section of a superconducting bending magnet for the Energy Doubler/Saver project at Fermilab. Note the shape of the vacuum vessel which increases vertical aperture to help ejection in the vertical direction. Over 700 magnets about 6 m long are needed to complete the 1000 GeV ring.

Test installation of two prototype superconducting magnets for the Doubler in the ring of the 500 GeV proton synchrotron. The Doubler magnets will be threaded through the support stands of the conventional magnets.

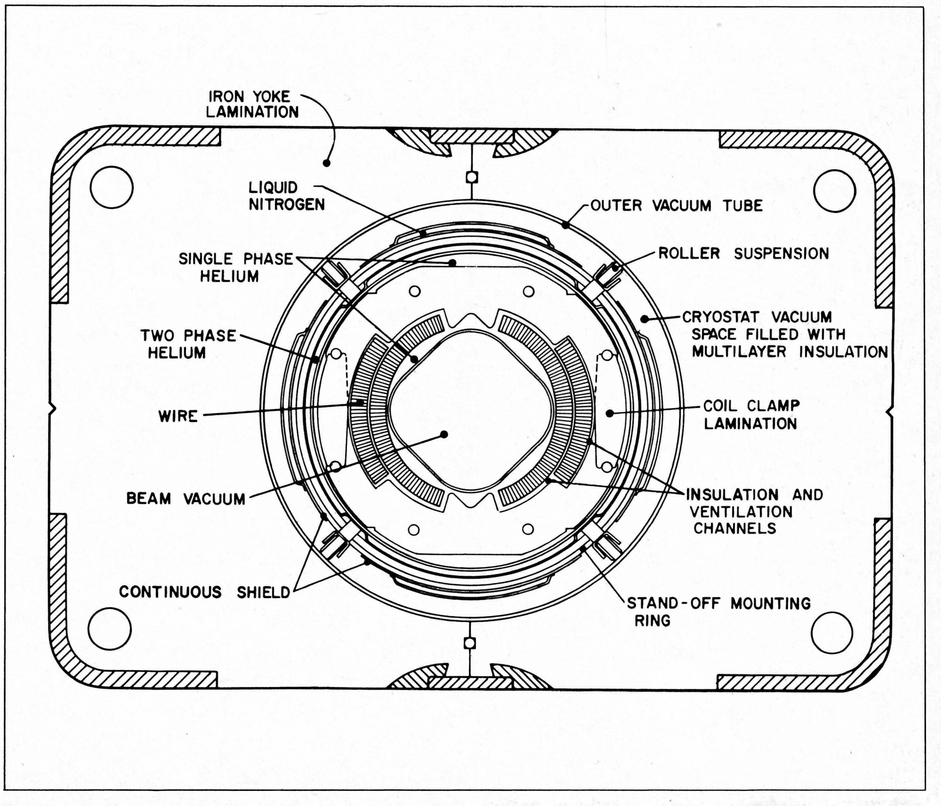
(Photos Fermilab)

precision and mechanical stability. The magnets which have been built so far will be used, and are needed, in the experimental area beam lines where the field quality requirement is not so severe.

A main purpose of the prototype construction which has been achieved, was to develop the necessary techniques to ensure that the magnets can be mass-produced (about 750 are needed) at a reasonable price. The cross section of the latest version of the dipole can be seen in the figure. It has thicker collars, to clamp the coils more firmly, and hence a larger cryostat. The vacuum chamber has been changed to a squared type without increase in cost and with a gain in vertical aperture which will be useful for the necessary vertical ejection. Magnets have been operated in strings of two (pulsed for five hours at 4.5 T) and a string of four will be put together soon. These tests are taking place near the first completed satellite refrigerator which is working well.

The Doubler project is being treated as 'Research and Development' up to the stage of circulating beam in the Doubler and $35 million have been estimated for this stage given a rapid rate of funding. During his Congressional Sub-Committee testimony on 3 March, Fermilab Director Bob Wilson, urged an increase in the Doubler money to $20 million for Fiscal Year 1978 rather than the $10 million which is assigned in the President's budget. To exploit the Doubler to the maximum is anticipated to involve a total project cost of $100 million.

Beams in the Doubler ring could be used in collision with beams in the existing ring (which can be run d.c. as a storage ring at 200 GeV). Construction of the 1 km link with the 8 GeV Booster, to enable beams to be injected into the Main Ring in the opposite direction, will begin soon. The breakthrough to the Booster building is likely to take place during the August shutdown.



A half cell of the ISABELLE storage rings assembled for tests in the old Cosmotron building. It consists of two superconducting dipoles and a superconducting quadrupole. On the left is a model tunnel section which will be extended to cover the half cell completely.

(Photo BNL)

The other colliding beam scheme using cooled antiprotons (see March issue, page 54) is also en route with the hope that cooling experiments can begin in the test ring at the end of this year. In addition the experimental areas are being converted for higher energy beams under the masterplan that Fermilab shall be a place of TeV physics in a few years time.

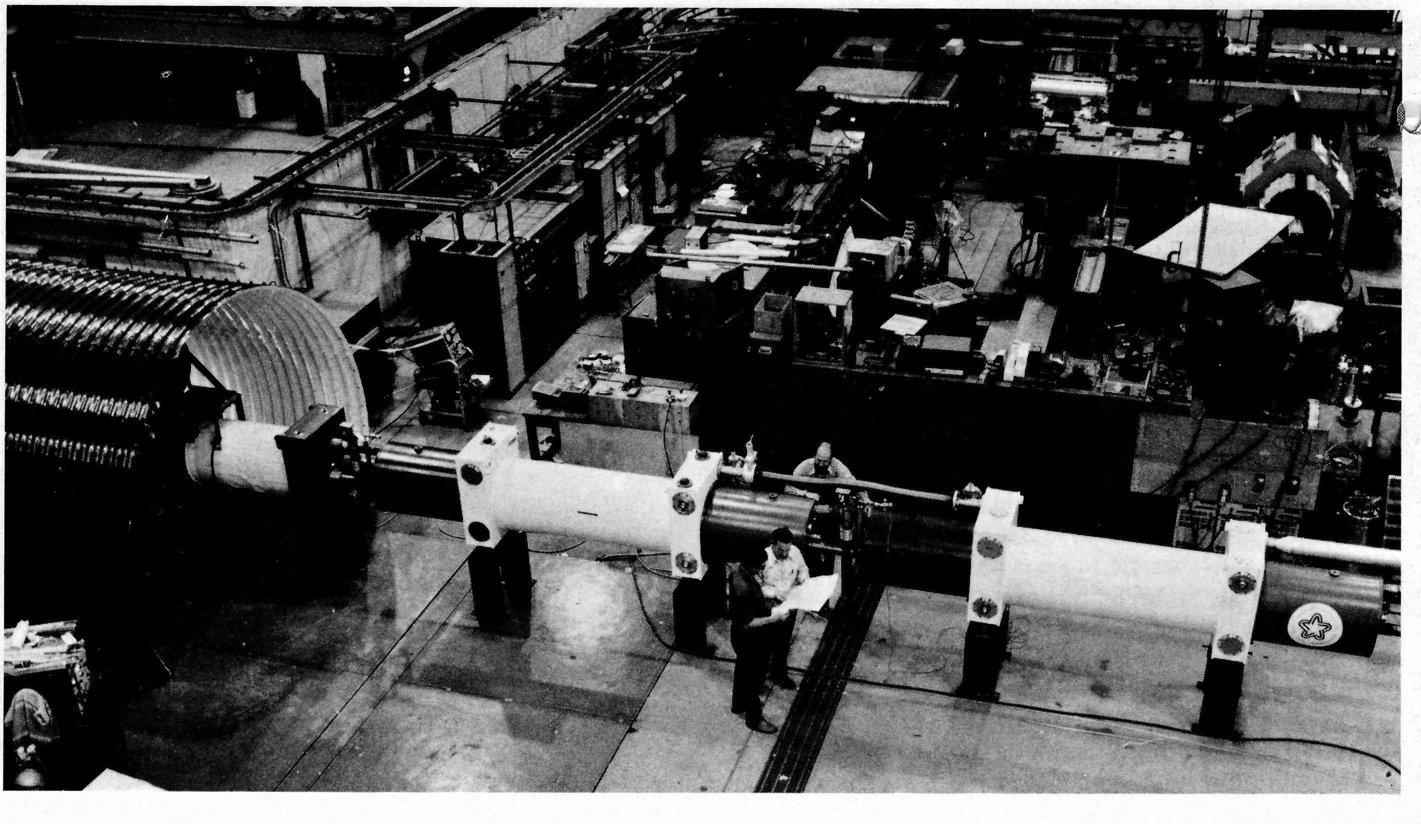
Preparations for the ISABELLE 200 GeV proton-proton storage rings were reported by project leader Jim Sanford. There has been a second allocation of C, P and D (Construction, Planning and Design) money to firm up the details of the project, whose total cost is estimated at $ 173 million with a five year construction time and, generally, there is more optimism that the project will go ahead. One factor in this is the confidence which exists in the superconducting magnet design for ISABELLE. Another is that ISABELLE protagonists now have a stronger voice in political circles in Washington.

The machine design has now moved to having six long straight sections. Injection into the two 2.6 km circumference rings from the AGS will be at 30 GeV. The filling time will be a few minutes (e.g. a hundred pulses at 5×10^{12} protons per pulse to build up currents of 10 A per beam) and the anticipated luminosity is 10^{32} to 10^{33} per cm^2 per s. A new detailed proposal will be presented soon.

The design requirement is for dipoles, 4.25 m long with a 12 cm coil aperture, able to give fields of 4 T. The results from the prototypes indicated that 5 T is probably feasible corresponding to energies of 250 GeV. Mark V prototype dipole was tested early this year. It exceeded the 4 T field on its first quench and was at 4.9 T on the ninth quench. Field quality was very good. The construction technique, with its excellent mechanical constraints on the coil, is achieving the magnet performance which is required. The cooling of the coils with forced convection of high pressure gaseous helium, adopted last year, is working well and is now definitely incorporated into the design. Coils are now being wound for the Mark VII dipole.

Mark V and Mark II are incorporated with a superconducting quadrupole in an assembled half cell of the ISABELLE lattice which is now undergoing tests in a model section of the tunnel built in the old Cosmotron hall. A full cell will be assembled later this year using industrially produced coils and collaboration with industry is being developed.

It is intriguing to see the different approaches of Brookhaven and Fermilab to the problem of superconducting dipole manufacture on a large scale. The approaches can be simplified as follows: Brookhaven



have worried first about magnet quality and their 'hand built' magnets are performing well. They are confronting the problems of manufacture by industry. Fermilab worried first about a design which could be manufactured rapidly and cheaply by industry. This they have achieved. They are now confronting the problems of magnet quality within the confines of this design.

Several ISABELLE Workshops will be held at Brookhaven from 18-29 July. After an introductory session and Laboratory tours there will be parallel sessions on specific topics such as operational problems, physics objectives and detector developments. More information can be obtained from Jim Sanford (Building 902, Brookhaven National Laboratory, Upton, New York 11973).

The CESR, Cornell Electron Storage Ring, is a more modest project than the three we have just covered. The design of the 8 GeV electron-positron storage ring was described in CERN COURIER April 1976. The present status was described at the Conference by Maury Tigner, originator of the novel storage ring filling scheme.

Present plans are for a single experimental region where a luminosity of 10^{32} per cm^2 per s is expected. Experiments would investigate the energy region from 1.5 to 10 GeV per beam which is below the regions where PEP and PETRA (the ring under construction at DESY) will operate most efficiently. The National Science Foundation has requested money for CESR and if this is forthcoming in the next fiscal year it is hoped that the project could be completed in October 1979.

Heads were raised from immediate concerns by the splendid concluding talk of Leon Lederman whose wit flicks out like a whip no matter what subject he is covering. He could probably bring amusement to the composition of an income tax form. His subject was 'international collaboration on very big accelerators' in the wake of the 1975 New Orleans and 1976 Serpukhov meetings (see for example CERN COURIER June 1976). The idea of building a Very Big Accelerator, VBA, by a world-wide collaboration brings some Very Big Problems. But it is not the first time that the high energy physics community has pioneered international collaboration.

This long-term subject is being kept alive under the auspices of the IUPAP, Particles and Fields Division. A meeting of ICFA, Interregional Committee for Future Accelerators, under the Chairmanship of Bernard Gregory is scheduled for early Summer.

Closedown of NINA

Alick Ashmore

The 5 GeV electron synchrotron, NINA, at the Daresbury Laboratory was closed down at mid-day on 1 April 1977. The occasion was marked by a funeral party at which there were tributes from those who had known and loved her.

NINA came into operation on 2 December 1966, the culmination of an outstanding effort by Alec Merrison and his colleagues who had started to build the Laboratory just over three years earlier in green fields by the Bridgewater Canal in the parish of Daresbury in Cheshire, the birthplace of Lewis Carroll. In 1965, the Laboratory had been taken over by the newly formed Science Research Council from the National Institute for Research in Nuclear Science, a body much mourned by nuclear physicists. In November 1972, the Council decided that, as part of the price for the entry of the United Kingdom into the SPS programme at CERN, NINA should be closed within about five years. A lifetime of ten years is short for an accelerator but it is long enough for the experimental programme to bloom and it may be better to die with a bang than with a whimper.

Daresbury Laboratory was built to provide research facilities in high energy physics particularly for Universities in the Northern part of the country. Liverpool and Glasgow were the founder members and the establishment of the Laboratory led to an expansion of the small group at Manchester and the formation of new groups at Lancaster and Sheffield. These five Universities, along with the Laboratory itself, have provided the main body of NINA users. There has also been welcome participation from Orsay and Strasbourg in France and from Pisa and Frascati in Italy.

With the prospect of closure, the users have gradually turned their attention to the higher energies available elsewhere in Europe. Participation of NINA users in the

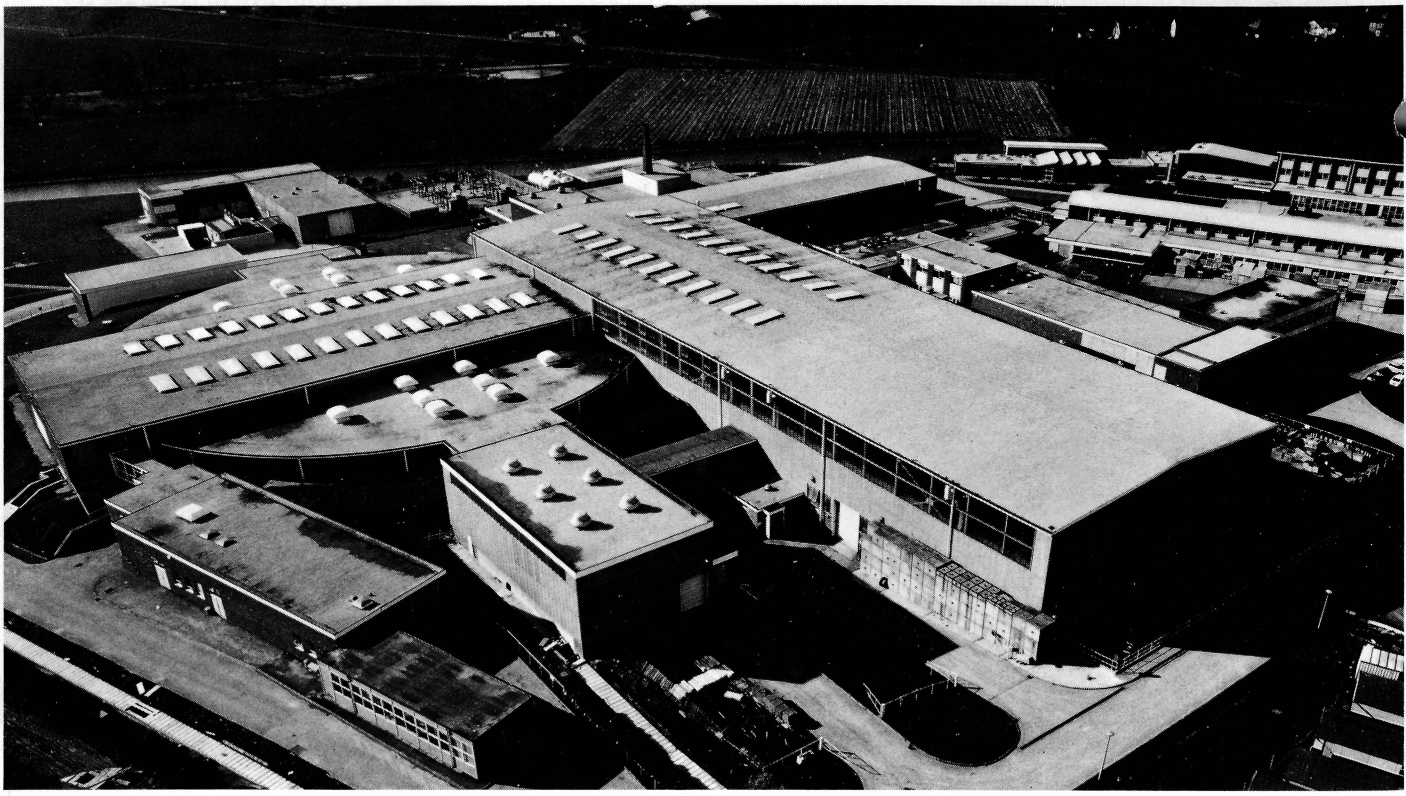
1. The site of the Daresbury Laboratory in April 1964 when the foundations for the ring of the electron synchrotron, NINA, were being prepared.

2. The site in March 1977 photographed from the top of the tower which will house a 30 MV tandem. The 2 GeV electron storage ring to be used as a source of synchrotron radiation will be installed in the NINA ring — the circular building on the left of the picture.

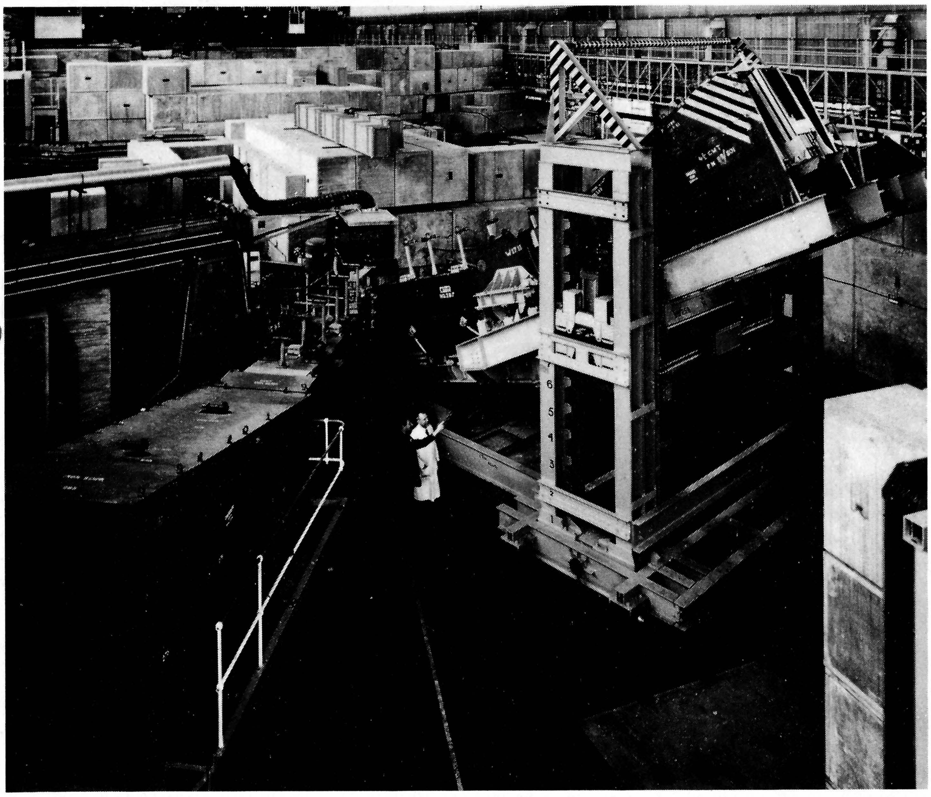
programme at CERN started in 1969 with the proton-antiproton experiment at the PS and proceeded to the ISR and the SPS. More recently, some have become involved in the JADE programme destined for PETRA at DESY. Thus, now supported through the Rutherford Laboratory, the NINA user community has not been lost along with their accelerator.

In 1970 the decision was taken to set up a Synchrotron Radiation Facility to exploit the intense radiation from NINA in the ultra violet and x-ray regions, following pioneering work of groups from Manchester and Reading. This Facility has attracted scientists from Universities and research centres from all over the United Kingdom and from Israel, Finland, Federal Republic of Germany, Canada and the USA.

A wide range of science has been covered concentrating on atomic, molecular and solid state physics but extending to crystallography and molecular biology. The Facility has also been used by the National Physical Laboratory for radiometry in the vacuum ultra violet region. The yield of scientific results has led to the approval of a 2 GeV electron storage ring dedicated to synchrotron radiation applications, which is now under construction at Daresbury to become one of its two major research facilities for the coming years.



The huge double arm spectrometer of the 'Mancaster' (Manchester/Lancaster) coincidence experiments which carried out a very thorough study of electroproduction. The hadron arm on the right of the picture has a total mass of about 250 tonnes and the section which can be moved vertically a mass of about 185 tonnes.



Looking back on the achievements with NINA, it seems that those who formulated the project were gifted with remarkable foresight. The choice of an electron machine was natural, since it was complementary to NIMROD, the 7 GeV proton synchrotron at Rutherford Laboratory. It also turned out that the choice of energy was fortunate since it directed attention to the study of photoproduction and electroproduction in and near the resonance region which has been the major scientific contribution from NINA. Furthermore, the synchrotron radiation spectrum peaked nicely for x-ray diffraction and scattering experiments.

During the lifetime of NINA, a series of progressively more sophisticated experiments was carried out with high energy photons and electrons. An important factor in this progression was the increasing abilities and reliability of the accelerator which, for the last few years, had an operating efficiency of about 90 %. The available beams were gradually improved — a polarised photon beam from an internal diamond target was commissioned early in 1973 and separated function extraction of electron beams from the end of 1974 gave both better quality and the possibility of sharing a high intensity electron beam with a tagged photon beam. The tagged photon beam has been a special feature of the NINA programme.

Magnetic spectrometers figured in the experimental programme from its early days including the massive 'Mancaster' (Manchester/Lancaster) double arm spectrometer for coincidence experiments in electroproduction, with the hadron arm movable in the vertical as well as the horizontal plane. The second version of this system, with increased acceptance for hadrons, was an impressive example of the big apparatus required for the study of minute particles. A polarised proton target, introduced by the Liverpool group in 1971, was subsequently modified for experiments with the polarisation direction in the scattering plane. Multiwire proportional chambers were developed in the Laboratory for the final stages of the NINA programme and for the SPS. A distinctive characteristic of the NINA programme was the use of the Laboratory's central computer for data acquisition with fast links to small computers on-line at the experiments.

Highlights include the pioneering experiment on rho-omega interference by the Daresbury WAPP group, the total cross section measurements by the Daresbury / Glasgow / Sheffield collaboration using a photon tagging system, the definitive experiments on pseudoscalar meson photoproduction by the Glasgow / Liverpool / Sheffield collaboration using a polarised photon beam and a polarised proton target. The thorough study of electroproduction by the Lancaster/ Manchester collaboration over many years has a natural successor in the European Muon Collaboration at the SPS and the study of multiparticle photoproduction by the LAMP collaboration (Daresbury / Lancaster / Sheffield), which collected 15 million triggers, has its successor in the electron / photon programme at the SPS.

There were also 'alarums and excursions', such as discrepancies in wide angle pair production, the possible existence of an isotensor component in the electromagnetic current and oscillations in the angular distribution of electrons elastically scattered from protons, all of which went away under further scrutiny.

The Theory Group, formed in 1969 under the leadership of A. Donnachie, had a major influence on the high energy physics programme. There is no doubt from this experience that the existence of a theory group in a

The tenth anniversary of the first operation of NINA was celebrated in December 1976. The photographs show —

1. Sir Sam Edwards, Chairman of the Science Research Council, with Bob Voss, one of the original NINA construction team and now project leader for the Nuclear Structure Facility at Daresbury.

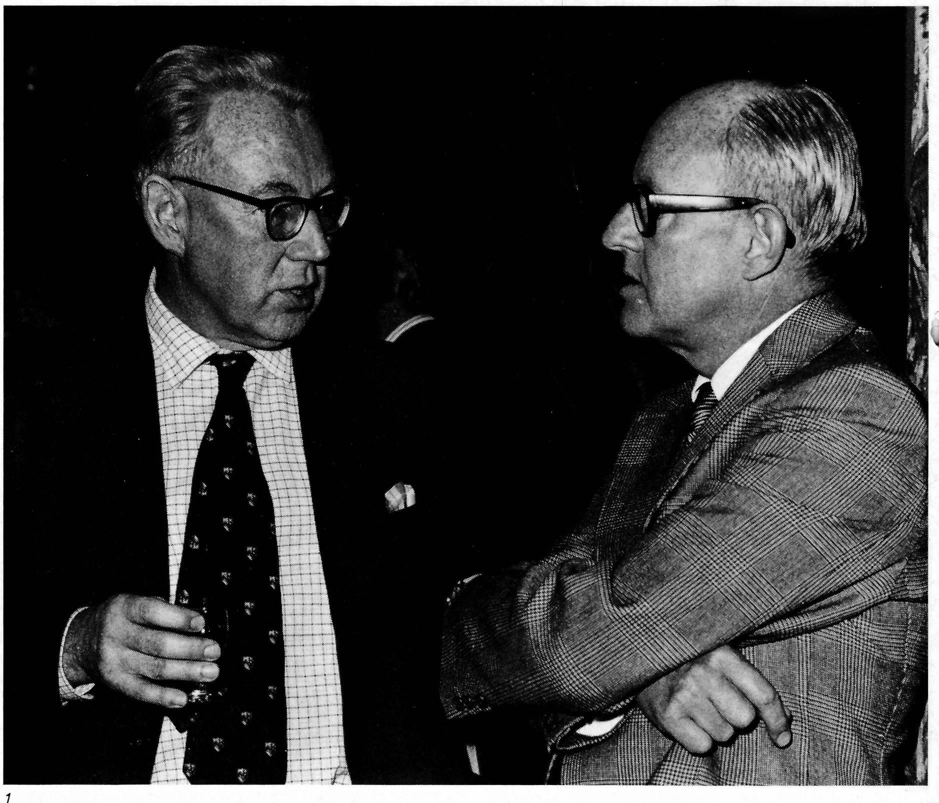
2. Mike Moore, one of the original NINA construction team and Head of Engineering Services Division at Daresbury until his retirement last June, with Sir James Mountford, formerly Vice-Chancellor of Liverpool University and a member of the Board of the National Institute for Research in Nuclear Science.

(Photos Daresbury)

National Laboratory supporting the work of the experimental teams has a value out of all proportion to its cost. It is in this spirit that the group has been reconstituted in support of the future research at the Laboratory.

The tenth anniversary of the first accelerated beam in NINA was celebrated in December 1976 by visitors, users and Laboratory staff associated with the construction and exploitation of NINA. A fascinating and attractive display was set up showing in words and pictures the history of NINA and her physics achievements. Under the chairmanship of J.R. Holt, short talks were given by J.M. Cassels on the pre-history, A.W. Merrison on NINA construction, A. Donnachie on the exploitation and A. Ashmore on the coming years at Daresbury. They brought out much of the interest and amusement in large scale scientific research and its personalities.

Daresbury is now in another construction phase but this time with the supporting base of an established Laboratory. The tower which will house the 30 MV tandem of the Nuclear Structure Facility looms large over the site and the foundations for the 600 MeV injector of the Synchrotron Radiation Source are being laid. Thus the Laboratory can look forward to a new physics era before long and can hope that it will be as productive as that which has now come to an end on the 5 GeV electron synchrotron, NINA.



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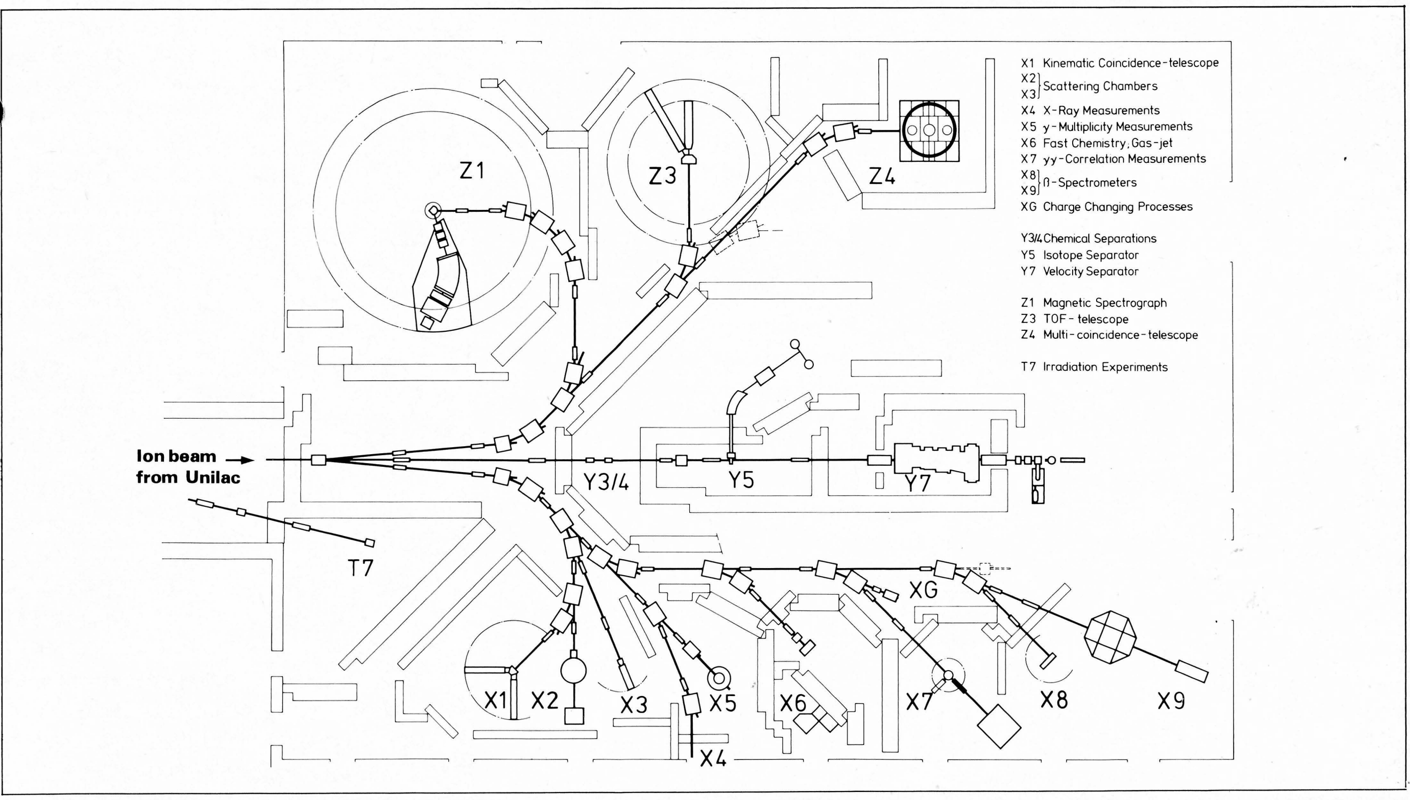
Around the Laboratories

DARMSTADT
Research at Unilac

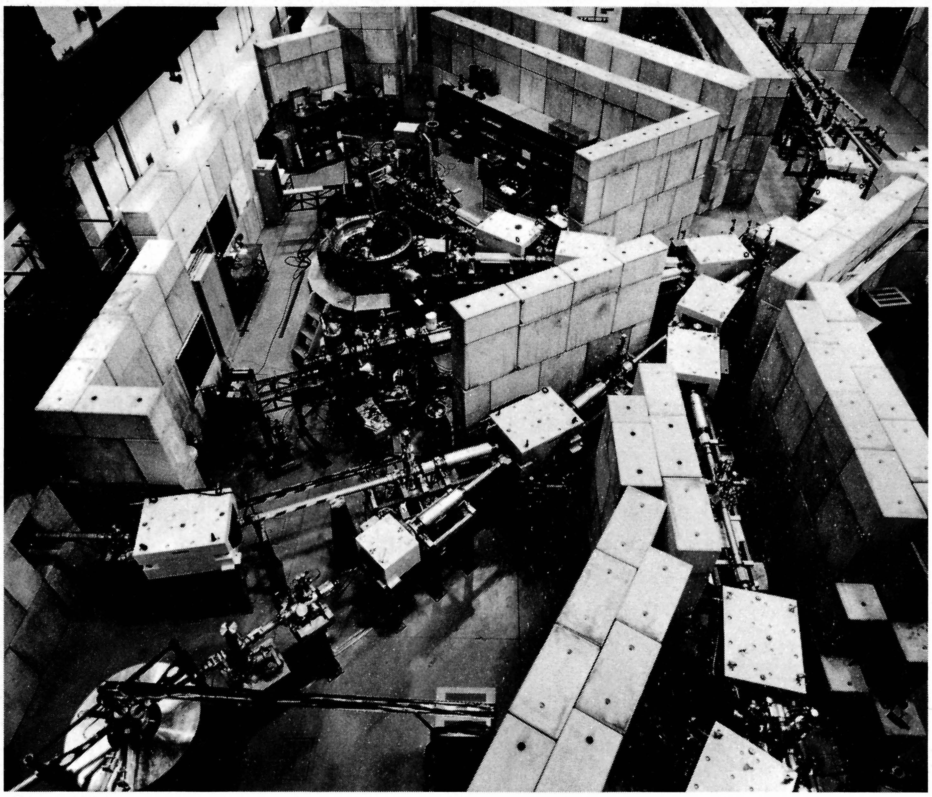
Recent months at the Unilac heavy ion linac of the Gesellschaft für Schwerionenforschung at Darmstadt have been characterized by a steady increase in the reliability of the machine. In December 1976 the highest energy operation to date was reached — 9.2 MeV/u ^{136}Xe — with thirteen single gap cavities in use. Energy settings in the range from 3 to 7.6 MeV/u are now available routinely. At the beginning of the year, a four week shutdown was used to replace the stem bellows of the outer drift tubes in the Wideröe structure by a type less sensitive to corrosion; leaks in the wall between the vacuum and the cooling water channels had caused many unscheduled maintenance hours.

In February a record number of hours for research in a single month were clocked up — 394 hours with beam on target plus 43 hours for machine studies. A relatively high percentage (at least 20%) of the total operating time is necessary for tuning up the machine, since frequent changes of ion species and energies are required. During recent weeks accelerated ions were ^{40}Ar, $^{84,\,86}$Kr, $^{129,\,139,\,136}$Xe, ^{58}Ni, ^{208}Pb and ^{238}U. Particle currents on the target ranged from 2×10^{10} per s for uranium to 10^{13} per s for argon. In the case of ^{136}Xe the enriched isotope was used and three charge states were accelerated simultaneously in the poststripper section giving a particle current on the target of 2×10^{12} per s.

The rather elaborate beam diagnostic system has proved to be very valuable in minimizing the tune up time of the machine and beam transport system. Out of the many devices for measuring current, profile, position, emittance, time structure and energy at many points along the beam path, the profile harp and a capacitive probe for observing the microstructure of the bunches have been particularly profitable. The d.c. beam delivered by the injector is density modulated by a 27 MHz buncher and focused into 27 MHz pulses during acceleration in the Wideröe prestripper section. Phase probes, delivering a bipolar signal of a beam micropulse, are installed along the beam line and allow a display of the bunch form and (particularly important) an energy measurement on-line with high precision (better than 10^{-3}). The energy spread is less than 1%. The time-of-flight technique is a routine tool for energy and phase matching between pre- and post-stripper accelerator sections during normal operation (even the energy loss in the gas or foil stripper is easily measured) as well as for tuning the Alvarez section and for adjusting the single gap cavities.



Plan of the target positions and beam lines in the experimental hall of the heavy ion accelerator, Unilac, at Darmstadt. (The equipment for Z1 is still being assembled.) The experimental programme is predominantly in the field of nuclear physics.



View inside the Unilac experimental area. The heavy ion beam enters top right and ions can be deviated to the detection systems on the left. By refering to the experimental area plan on the previous page, from bottom left upwards can be identified — X5 for gamma multiplicity measurements, X4 for X-ray measurements, X3 a scattering chamber for particle spectroscopy with time of flight and energy/energy loss spectrometers, X2 a multi-purpose scattering chamber and X1 a kinematic coincidence spectrometer with position sensitive particle detector telescopes.

A shutdown of two weeks is planned for the end of April to install a beam splitter, an arrangement of septum magnets providing three simultaneous beams in the main experimental area. At the same time, the first of four rebuncher helices for the beam lines of the experimental area should be available making it possible to restore the bunch structure at the target. Because all targets are at least 50 m from the accelerator, rebunching is indispensable for experiments using time-of-flight techniques.

From more than 100 submitted proposals for experiments, about 75% are in the field of nuclear physics while the remaining 25% are from other fields — predominantly atomic physics. Demands for beam time come about equally from outside users and from joint groups (including GSI users) while about 14% comes from GSI users alone. Outside users are mainly German Universities and research institutions such as Max-Planck-Institutes and the federally sponsored research centres. The Users Committee has accepted 49 proposals.

The initial phase of the experimental programme has involved testing of the detection systems and preliminary investigations. Fourteen target positions are available in the main experimental area and the equipment in operation includes helium-jet systems, tape systems and a fast rotating wheel (for the investigation of short half-lives), an on-line isotope separator, a velocity separator (allowing the separation of fusion products from the primary beam), a solenoid and an 'orange' beta spectrometer, time-of-flight telescopes combined with energy loss and energy detectors, a multi-coincidence spectrometer using position sensitive large area detectors, as well as instruments for a systematic programme of chemical separations and low level counting for the identification of spontaneously fissioning, alpha and beta active nuclei.

A number of reaction studies are under way with the emphasis on very heavy projectiles like ^{208}Pb and ^{238}U. Of particular interest is the radiation emitted from the highly excited states with high angular momentum which can be formed in heavy ion reactions. Present experiments aim to determine the number of gammas emitted in a reaction, which is a measure of the angular momentum of the emitting state, and to search for isomerism of such a state.

The first measurements with the velocity separator, built by a Giessen/GSI collaboration, showed that the primary beam can be suppressed by factors of, at least, 10^8 for xenon to 10^{12} for argon according to the velocity difference between projectiles and the evaporation residues of the original fusion products. These results make it possible to use sensitive detector systems directly at the focus of the separator.

A run with ^{136}Xe as projectile at energies between 5.2 and 5.6 MeV/u and ^{170}Er as target nucleus — one of the few reactions which is predicted to be favourable for the production of the elusive superheavy nuclei — has shown no evidence for the existence of such nuclei with half-lives for alpha decay and spontaneous fission between 1 μs and about one hour and a production cross section larger than 10^{-33} cm^2. A Mainz/GSI group had the same aim when irradiating a thick target of ^{238}U by ^{136}Xe (7.5 MeV/u); a dose rate of 6×10^{16} particles could be reached within 22 hours, at least a factor of 20 more than achieved before. To identify the radioactive species, radiochemical separations were performed, so that the reaction products could be devided in chemical groups. Looking for fission events and alpha spectra led to the conclusion that the production cross section for superheavies is smaller than 10^{-34} cm^2 if the half-life is assumed to be between 1 h and 100 days. This method should be sensitive to elements with Z between 108 and 118 or with Z around 126. The same procedure was applied to a uranium target irradiated by 7.4 MeV/u ^{238}U and no unexpected results were found. Direct reaction products were detected in the mass region between gold and fermium but the dose rate was only about 10^{13}.

In another experiment (Heidelberg/GSI) investigating the reaction ^{238}U + ^{238}U by measuring energy and energy loss, alpha spectra and fission events of the emerging particles indicated no formation of spontaneously fissioning nuclei. The experiment is giving data on the mass distribution of products formed in U + U by fission, transfer of nucleons between target and projectile, or combination of these processes.

To study nuclei far from stability, the GSI on-line isotope separator has started operation. This facility is similar to ISOLDE at CERN (see January/February issue of CERN COURIER).

A view of the on-line mass separator facility where the properties of short-lived nuclei far from stability, can be studied. The heavy ion beam from Unilac enters top left into the target and ion source system. The nuclei to be investigated emerge from the ion source into the experimental and control area on the right of the shielding wall where they are mass separated.

(Photos GSI Darmstadt)

Reaction products are stopped inside an ion source and, after re-ionisation, are separated according to their masses by a magnetic field. It is only by such a separation that identification and investigation of nuclei far from stability becomes possible in the bulk activity of evaporation residues from heavy ion reactions.

At present, experiments at the on-line separator are concentrating on searching for proton-rich nuclei around the doubly magic tin nucleus $^{100}_{50}$Sn. For example, by reactions of a beam of nickel ions (intensity 2×10^{11} ions/s, energy 5 MeV/u) on a nickel target, a proton-rich nucleus of barium is formed which can deexcite by emission of three protons and some neutrons to iodine isotopes. In an experiment at the beginning of March, the chain of iodine isotopes was extended to the nucleus ^{110}I (17 neutrons less than the stable ^{127}I) which has a half-life of 0.6 s. This nucleus is supposed to be the last bound isotope of iodine. Nuclei in this region are characterized not only by beta-delayed proton (or alpha) emission but also by alpha decay of their ground states which reflects the shell structure.

Unilac was described by James Ball of Oak Ridge at the recent USA Accelerator Conference as 'the most elegant' of the presently operating heavy ion facilities. It is developing an experimental programme to match the abilities of the accelerator.

ARGONNE: Intense Pulsed Neutron Source

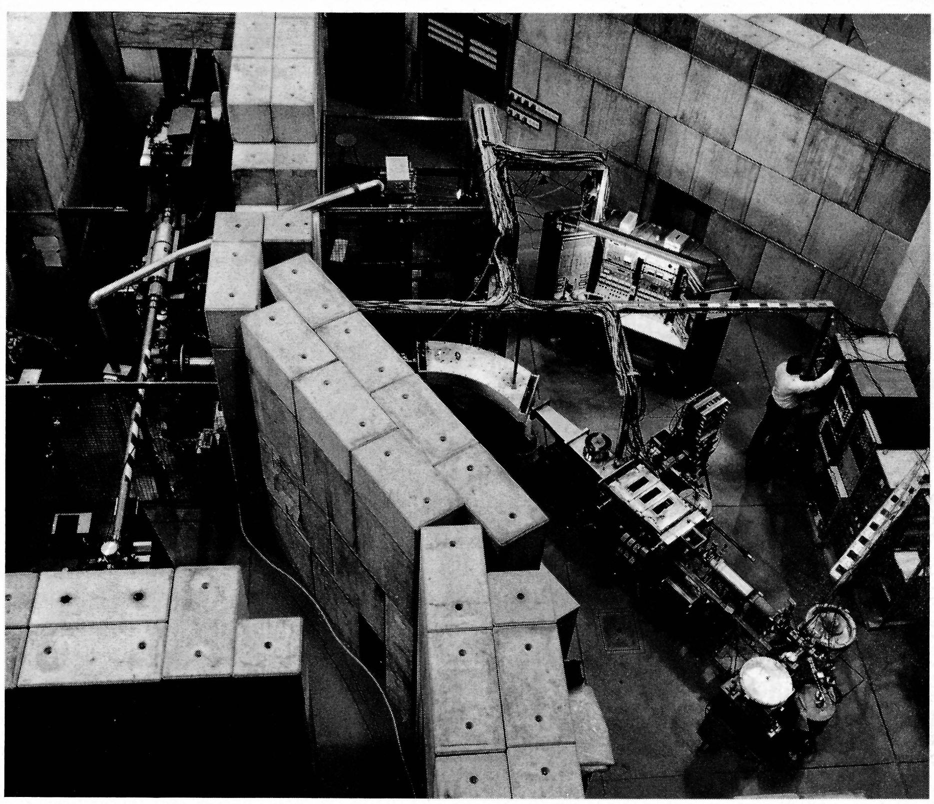
Whatever the Chinese might call it, 1977 looks like being the year of the pulsed neutron source. The US Energy Research and Development Administration (ERDA) has given Argonne National Laboratory Construction, Planning and Design (C, P and D) money to the tune of $400 000 to firm up the design of the proposed Intense Pulsed Neutron Source (IPNS). This follows hard on the heels of a provisional go-ahead, pending final allocation of UK research funds, to the Rutherford Laboratory's twin proposal for a Spallation Neutron Source (SNS) described in the May issue 1976.

The Argonne IPNS project is estimated to cost $52 million and its construction would follow the close-down of the ZGS proton synchrotron. Many of the buildings and components already in use at the ZGS would be used in the new machine, bringing considerable savings.

Shutdown of the ZGS is likely in 1979 and the new IPNS project could then be operational by 1983, offering chemists and biologists, as well as physicists, new facilities to study the structure of matter at the atomic and molecular levels.

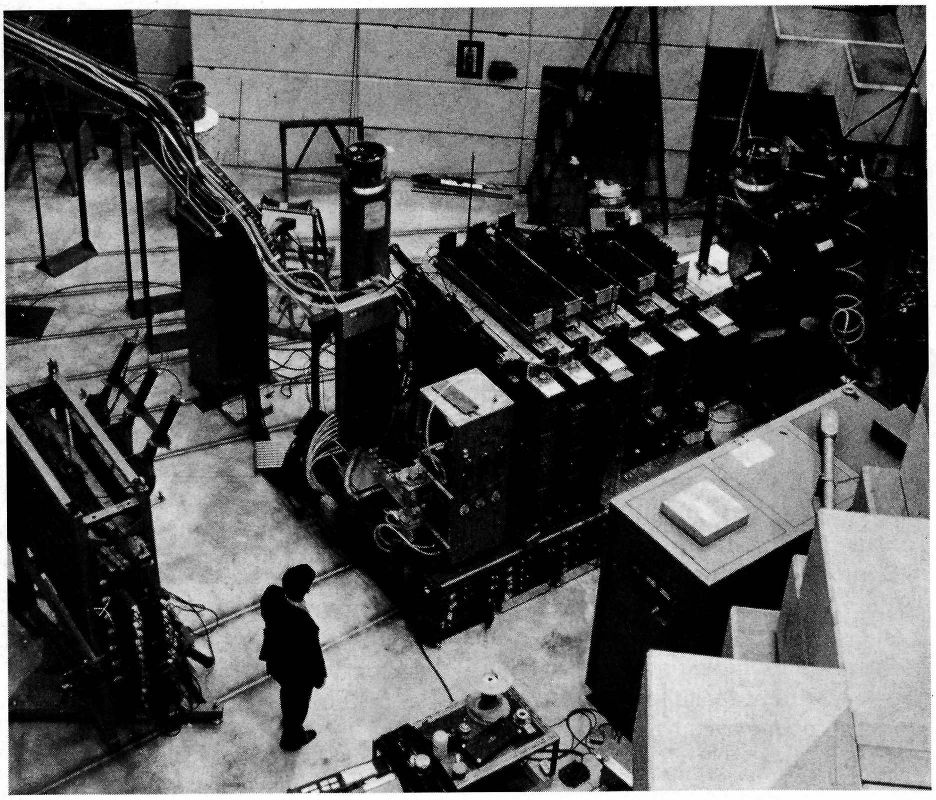
The design has an 800 MeV proton synchrotron firing intense beams into heavy metal targets to produce copious quantities of neutrons by spallation and would increase by a factor of ten the available fluxes of thermal neutrons. Fast neutrons would also be available to enable experiments to be carried out on the effects of neutron irradiation on reactor components and materials, which is of great importance for the future of fusion reactors.

The groundwork for IPNS was carried out using an experimental booster synchrotron at the Argonne ZGS to intensify the available proton beam. The successful results obtained with this booster led in turn to the design of a second prototype machine, several hundred times more powerful than the first, which will use the new ZGS 500 MeV Booster II synchrotron, shortly to become operational. This will provide 5×10^{12} protons per pulse



The carbon polarimeter used by the BASQUE collaboration at the TRIUMF cyclotron in their thorough study of the nucleon-nucleon interaction at intermediate energies. The polarimeter has twelve large multiwire proportional chambers. On the right can be seen the cylindrical outer vessel of a superconducting solenoid.

(Photo TRIUMF)



at 30 Hz and should give valuable input for the final design of the IPNS, which will operate at 60 Hz. Peak fluxes should be ten times greater than those obtainable with the 500 MeV Booster II machine.

TRIUMF: Polarised neutron beam

The ability to extract proton beams of continuously variable energy from 180 to 520 MeV is one of the most useful design features of the TRIUMF cyclotron. In conjunction with a polarised negative hydrogen ion source, providing external proton beams of about 78 % polarisation and 30 nA intensity, it provides a powerful facility for the study of nuclear reactions at intermediate energies. This capability has recently been extended by the commissioning of a secondary beam of monoenergetic polarised fast neutrons produced at 9° lab by the polarised proton beam bombarding a liquid deuterium target.

The neutron polarisation varies smoothly from 73 ± 9 % at 220 MeV to 38 ± 5 % at 495 MeV, while the intensity is typically 1.5×10^5 neutrons/s for a 7 cm × 9 cm spot. The energy spread of the 495 MeV beam was smaller than could be resolved by the time of flight technique (60 MeV) and much smaller than that observed for neutrons produced from a carbon target (about 200 MeV). Theoretically, the energy spread is estimated to be 11 MeV, due to the final state interaction between the two protons recoiling slowly in the lab system.

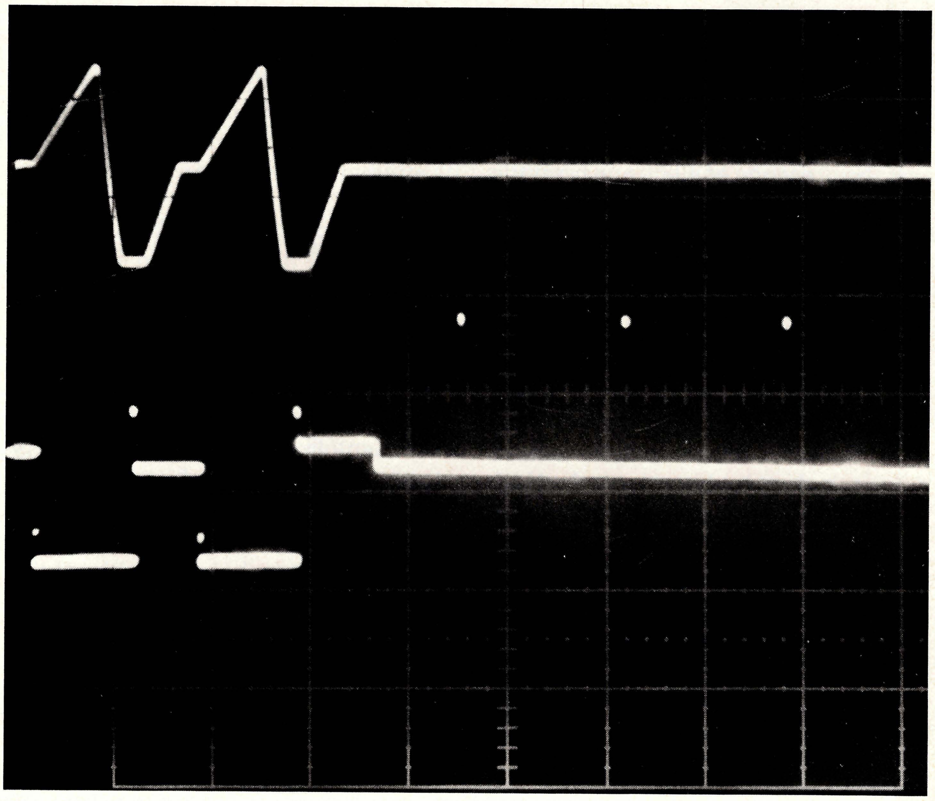
The optimum conditions for the polarised neutron beam were determined in a survey experiment by the BASQUE (Queen Mary / British Columbia / Surrey / Bedford / Victoria / UCLA) collaboration. To find the best production angle, neutrons from the 20 cm long liquid deuterium target were collimated by a 3.5 m long lead collimator into channels spaced at 3° intervals from 0° to 27°. To determine the initial and final spin directions giving the optimum neutron polarisation, the Wolfenstein transfer parameters were measured.

The proton spin direction could be controlled by reversal at the source and by precession in the transverse plane in a superconducting solenoid (described in the May issue 1974). The neutron spin direction could be precessed about vertical or horizontal axes by means of dipole magnets. The proton polarisation was monitored by proton-proton scattering in a polyethylene foil and the neutron polarisation (for a part of the experiment) by using a carbon polarimeter and (for the remainder) by neutron-proton scattering from a 50 cm long liquid hydrogen target. At the lower energies there is almost complete polarisation transfer from protons to neutrons.

The BASQUE group has already put the polarised neutron beam to good use in their study of spin dependent effects in neutron-proton scattering. So far the angular distribution of the Wolfenstein D_t parameter has been measured at three energies. The polarisation of the recoil protons is determined in a carbon polarimeter, the dominant feature on the experimental floor. This consists of a carbon scatterer, 6 cm thick, sandwiched between twelve large multiwire proportional chambers (the front six being 50×50 cm², the rear six 100×100 cm²) to determine the proton scattering angles. This polarimeter provides a reasonable analysing power (0.35 on average) with a high detection efficiency (roughly one proton in fourteen is scattered).

Further experiments are planned to measure other parameters in neutron-

On the left the SPS; on the right the SSR. These oscilloscope traces from a machine development run show, on the left, the normal pulses of the magnet cycle (above) and beam intensity (below) of the CERN 400 GeV proton synchrotron, the SPS. It has an intermediate flat top at 200 GeV which is normally used to send protons to the counter experiments in the West Hall. On the third pulse, a button is pressed to hold the magnet fields at the 200 GeV value and, on the right, the traces remain at constant values as the machine is converted into a Super Storage Ring.



proton scattering. The advantage of a monoenergetic polarised neutron beam here is that it makes possible a direct study of the neutron-proton scattering process, whereas previous studies have had to rely on subtracting proton-proton from proton-deuteron scattering data. The present experiments, therefore, yield more accurate results. Their importance is that they enable the isospin $T = 0$ nucleon-nucleon scattering amplitudes, which are relatively poorly known at present, to be determined with greater accuracy.

The other main thrust in the BASQUE group's general assault on the nucleon-nucleon interaction at intermediate energies has been directed at proton-proton scattering, which involves isospin $T = 1$ only. For this they have measured Wolfenstein parameters, to an accuracy of ± 0.02 at a number of forward angles at five energies between 209 and 515 MeV. These experiments utilised the polarised proton beam, the liquid hydrogen target, the carbon polarimeter and the spin-precession solenoid and dipole magnets. The results were in good agreement with existing data at 210 MeV. At higher energies it was possible to determine the phase shifts with significantly greater accuracy than before.

CERN
SPS practises as a storage ring

One of the potential future extensions of the research facilities at CERN is the use of the 400 GeV proton synchrotron for colliding beam physics. Proton-antiproton schemes have been in the news recently, in connection with the new possibilities opened by the beam cooling technique, and proton-electron schemes also have their strong advocates. The power requirements are such that the SPS can be operated d.c. (in storage ring mode) at energies up to 270 GeV. Before carrying any of these ideas much further, it is important to get some idea of how well the SPS can perform as a storage ring.

On 23 March the first test took place during a machine development run. The synchrotron was operated with its normal pulse — acceleration to 200 GeV, where a intermediate 'flat top' is introduced to send protons to the West Hall experiments, and then continued acceleration to 400 GeV, where the remaining protons are sent to the neutrino target. The intensity injected from the PS was kept low (about 10^{12} protons per pulse) to limit irradiation of the machine.

When a beam of healthy intensity was achieved, the normal pulse was interrupted and the magnet fields were held constant at the levels corresponding to a proton energy of 200 GeV. This was tried with the r.f. switched off, giving a stored unbunched beam and with the r.f. switched on at low voltage, giving a stored bunched beam. In both conditions the protons could be held with comparatively little loss of intensity for times in excess of an hour. The beam lifetime that could be calculated from these results was in good agreement with that the prediction from scattering of the protons on the residual gas molecules in the machine vacuum of 5×10^{-8} torr, which was believed to prevail.

After the run, a closer look at the average pressure indicated that it was actually 7×10^{-9} torr and, in this case, effects in addition to scattering must have been causing loss of beam. This was investigated a week later. First, the active beam damper was switched off and the lifetime climbed to nearly 7 hours. Secondly, a higher intensity beam was injected (4×10^{12} protons) and rapid initial loss of protons was observed, indicating that the cause of the loss was strongly dependent on the intensity.

Drawing on ISR experience, it looks as if the presence of electrons from the ionized gas is a likely source of the beam loss. There are no clearing electrodes to pull the electrons out as there are in the ISR and it is known that they can have a stronger effect than the scattering. Another pointer in this direction is that a bunched beam should show less intensity dependence (since the electrons have time to leak away between bunches). This was confirmed and even a 4×10^{12} beam had a lifetime of 2½ hours when bunched.

This first look at the Super Proton Synchrotron as a Super Storage Ring looks good. The performance is already not negligible and at least the dominant causes of the beam losses seem to be understood.

Meanwhile, not to be outdone by the newcomer, CERN's old machines were also showing their paces. During a machine development run on 31 March, Ring II of the ISR topped a 40 A current, for the first time. This followed a period of PS/ISR collaboration which achieved high longitudinal phase space density of the beam.

The ISR uses such runs to find the 'vacuum limit'. The current is increased until beam induced pressure bumps (see November issue 1972, page 361) cause the beam to blow up and be lost. This tells the vacuum people where their weakest points are in the rings. In the run at the end of March the current climbed to 41.1 A before blow up occurred. The beam conditions were not suitable for physics runs but it is, nevertheless, a milestone for the ISR to have doubled the 20 A design current.

From 14-21 September the second session of the Workshop on Future ISR Physics will be held at CERN. The first part, with some 40 participants, will be devoted to detailed studies relevant to the future possibilities at the ISR and the last three days will be discussion meetings for a larger audience. Physicists interested in contributing to the Workshop can communicate their field of interest to B.G. Pope at CERN.

New fire detection technique

Insurance company statistics show that some 30 per cent of all fires are of electrical origin, so that in an environment like a scientific laboratory where a great deal of electrical apparatus is in use, an efficient system of fire detection is necessary.

With electrical installations, the main problem is to detect the potential fire hazard well before insulation begins to deteriorate and the risk increases as short circuits occur. Existing methods of fire detection usually depend on the detection of smoke, flames or high temperatures, but in an electrical installation the insulating material could well have been damaged by the time the fire is detected.

A new method of fire detection has been developed at CERN by A.H. Pietersen after the damaging cable fire at the PS in 1975. It uses an easily detectable gas which is liberated at a low enough temperature to ensure that the insulating material does not have time to ignite. The ideal detection temperature is around 70°C, intermediate between the maximum operating temperature of the cable (50°C) and the temperature at which the insulating material smoulders (90°).

The CERN solution is to use 120µm diameter gelatin microcapsules containing liquid freon. When the internal vapour pressure exceeds the critical value as the temperature increases, the microcapsules burst, releasing the easily detectable freon. (The popping sound of the bursting capsules could also be picked up by a cheap microphone.) The microcapsules can either be scattered on cable arrays directly, or mixed with paint.

FERMILAB Multiparticle spectrometer workshop

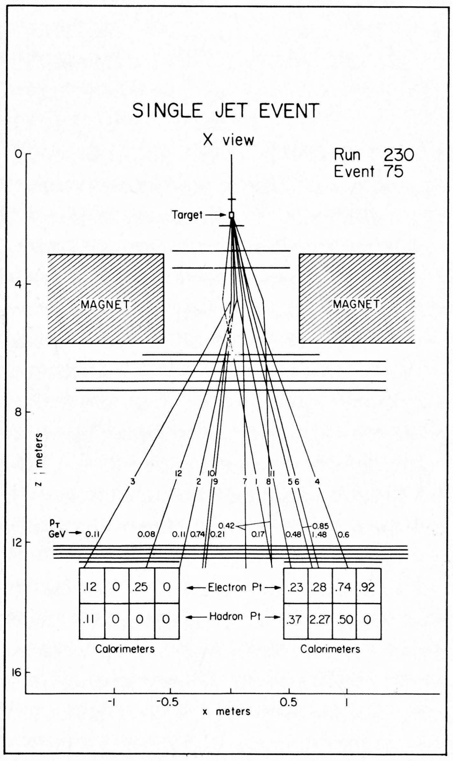
A Workshop on the Fermilab Multiparticle Spectrometer Facility (MPS) was held on 4-5 March. This facility, located in the Meson Area, was designed and built by a collaboration of physicists from Cal.Tech / Fermilab / UCLA / Illinois / Indiana. It has been used in an experiment on hadron jets and is now in operation, with a slightly modified configuration, for studies of several exclusive channels.

The Workshop convened to examine the physics potential of the MPS based on operating experience, to explore how well second generation experiments can utilize the capabilities of the present facility and to discuss possible improvements.

The spectrometer is built around a superconducting magnet with a 0.6 m high aperture and a maximum p_t kick of 750 MeV/c. Charged particles emerging from a hydrogen target upstream of the magnet at angles out to about 150 mrad are analysed by the magnet and track chambers. In the hadron jet configuration, the MPS is triggered by two large downstream calorimeters. Each module has a lead scintillator front section (for electromagnetic showers) and an iron scintillator back section (for hadron cascades). These calorimeters can trigger the apparatus on a jet, defined experimentally as a cluster of high p_t particles. Track chambers interspersed through the apparatus give charged particle trajectories while several large multicell atmospheric Cherenkov counters are used for mass identification of emerging particles.

There is also a cylindrical proportional wire chamber and a 24 segment

1. A single jet event recorded in the Fermilab multiparticle spectrometer (MPS). A Workshop was held in March to discuss the future use of this facility.
2. Beam intensity trace at the Fermilab synchrotron during double pulse extraction for neutrino experiments in the 15 foot bubble chamber. The 'staircase' pattern at A shows the increasing intensity during the injection of twelve pulses from the 8 GeV Booster. The intensity stays constant during acceleration and at B the first extraction takes place (7/12 of the beam) and at C, one second later, the remaining beam is extracted.



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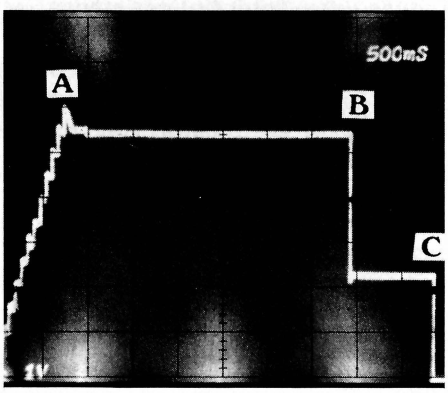

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barrel shower counter surrounding the hydrogen target. Chambers line the magnet to select highly asymmetric double pion scatters. Test runs on the latest experiment were in progress at the time of the Workshop and the new configuration appears to be working well.

The physics results from the MPS were reported at the Workshop. The experimenters showed evidence for a coplanar double jet structure and stated that the distribution in z (the fraction of jet momentum carried by individual charged particles) shows a striking similarity to that observed in lepton induced processes. The opposite side z distribution shows that the single particle (one high p_t particle trigger) and jet triggers balance transverse momentum in similar ways. This is expected in the quark picture but seems difficult to understand in the constituent interchange model. The experimenters report that the jet and single particle cross sections have a similar shape from 3 to 5 GeV/c but the jet cross section is over two orders of magnitude larger.

The particles in the jet naturally divide into three categories: (1) charged particles, comprising 57% of the jet momentum with a typical multiplicity of three into the calorimeter and a total observed event multiplicity of nine or above, (2) photons from neutral pion or other decays, comprising 30% of the jet momentum and (3) neutral hadrons. The possibility that the jet cross section is several orders of magnitude higher than the single particle cross section had been predicted in models which postulate that hadrons with large p_t come from the fragmentation of quarks in a hard collision between constituent quarks in the initial hadrons. No clear resonance signals are seen in the jet data.

Ideas for future experiments and improvements for the MPS are plentiful. Some of the topics discussed were charm searches, a study of multiparticle peripheral hadron reactions yielding forward neutral mesons, the use of nuclear targets, double V° physics (double kaons and double lambdas to high effective mass), and further study of hadron jets up to 400 GeV. Possible improvements for the MPS include replacing existing spark chambers with proportional wire chambers to increase the rate capability, larger aperture calorimeters and doubling the energy of the beam.

The meeting concluded with two rousing theoretical talks by Ed Berger (Argonne) and Steve Ellis (Washington) who challenged the Workshop participants with the many exciting physics possibilities they could envisage for the MPS or similar multiparticle detectors.

Double pulse test completed

A new mode of extracting beam from the Fermilab accelerator was tested on 4 March. It aimed to demonstrate the possibility of taking two neutrino experiment pictures in the 15 foot bubble chamber during each accelerator cycle with the chamber filled with a heavy neon-hydrogen mixture. This would substantially increase the number of neutrino events recorded without burning up the target (as can happen if all the beam is extracted at one time). It is, therefore, of great interest to the Laboratory's programme scheduling as well as to experimenters using the chamber.

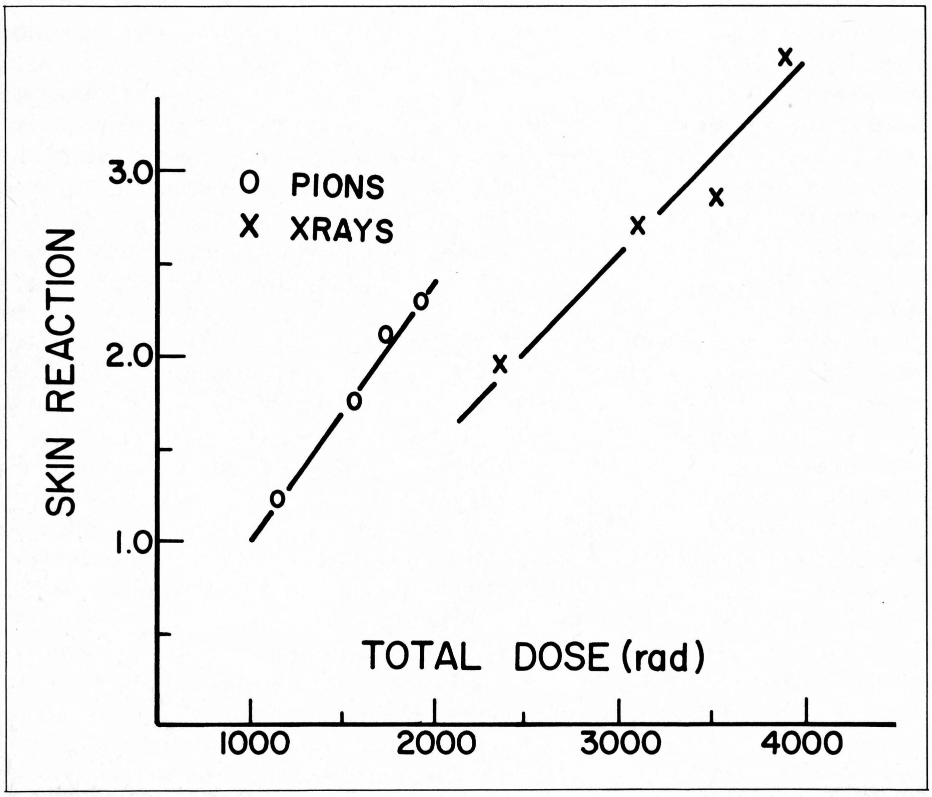
The new approach has been under discussion for some time. The 15 foot was double pulsed successfully with a hydrogen fill about a year ago. Tests of other component systems had been made over the preceding weeks. The focusing horn on the Neutrino Line was tested in the two pulse mode. The 15 foot was again checked for the capability of getting clear pictures on two expansions less than one second apart. The Switchyard Group developed hardware for removing the beam from one half of the Main Ring's four-mile circumference with one pulse of the fast extraction magnet and the other half with a second pulse at the end of the cycle.

All the systems were put together for a six-hour operating period on 4 March. Two thousand pictures were taken and the results were satisfactory.

Measurements of skin reaction, by the Los Alamos biomedical team, as a function of total dose on shallow skin tumours for pions and X-rays 43 days after finishing the treatment. This measurement indicates approximately 42 % greater biological effectiveness for pions than for X-rays.

The scanning range shifter in position beneath the LAMPF biomedical channel. The range shifter uses a liquid and bellows to move the pion range through the tumour volume.

(Photo Los Alamos)



LOS ALAMOS Pion biomedical programme

Since radiation therapy is used on over 50% of cancer patients, improvements in this procedure could significantly affect the overall picture of cancer treatment. COURIER readers are aware of the wide interest within the accelerator community in this subject and of the development of biomedical facilities at many accelerator laboratories.

The potential physical and biological advantages of negative pions have often been discussed (see, for example, the December issue 1976). Briefly, pions provide good localization of dose due to definite range, the Bragg peak in ionization loss, and the emission of short range nuclear fragments as a result of pion capture. Highly ionizing, or high linear energy transfer (LET), radiation also serves to reduce the intrinsic resistance of hypoxic cells commonly found in tumours. Clinical studies with pions have awaited the advent of meson factories, such as the 800 MeV proton linear accelerator, LAMPF, at Los Alamos, to supply therapeutically useful dose rates.

The small volume stopping pion distributions developed with early LAMPF operation at 10 μA were quite adequate for fundamental radiobiology studies and preliminary human biology studies. Developing, characterizing, and applying larger volume beams for therapeutic use were the chief goals in the programme when proton beams became available again in 1976.

The distribution of dose through tissue volume is controlled by beam focus and collimation in the transverse direction and in tissue depth by the beam energy. Recently, channel tunes for several volumes up to 8 × 10 × 7 cm^3 have been developed at 163 MeV/c and 206 MeV/c (the latter

The Chancellor of the Federal Republic of Germany, Helmut Schmidt, visited the DESY Laboratory on 11 March. He is seen here (left) in conversation with Helwig Schopper, Chairman of the DESY Directorate.

(Photo DESY)

momentum for tumours as deep as 28 cm). With 150 μA production beams from the linac, the dose rate in 50 cc can be as intense as 40 rad/min.

The distribution of peak dose in depth is determined by the pion beam energy spread. Wedge degraders at the channel intermediate focus can compress the stopping distribution to 1 cm rms width at 15 cm tissue depth. If required, the narrow peak can be spread in depth by using a scanning range shifter moved into position at the channel exit to yield any prescribed depth dose distribution with thicknesses ranging from about 3 to 14 cm.

Dosimetry is performed using thimble type ionization chambers with tissue-equivalent plastic walls filled with methane based tissue-equivalent gas. Measurements are made in a large phantom filled with water or tissue-equivalent liquid using a three dimensioned scanner. Additional microdosimetric measurements with spherical gas proportional counters and Si(Li) detectors are made to obtain LET distributions within the ionization peak, to allow better estimation of relative biological effectiveness (RBE).

Although most time on the biomedical channel is spent in tuning, dosimetry, and measurements on simpler biological systems, clinical studies with human patients is the last and most dramatic step toward therapeutic use of pion beams. Treatment began on four selected patients in 1974 and after the 'Great Shutdown' in 1975 eight more patients have participated. Tumours were treated in skin, subcutaneous tissue, muscle, oral cavity, chest wall, and lung.

The initial goal was to determine normal tissue tolerance, which is the limiting factor in delivering doses to kill tumours. Typically, a fractionated radiation schedule (15 fractions in 19 days) was used based on conventional dose-time relationships in clinical practice. Fractionated treatment in which a series of small doses are delivered permit differential repair and recovery of normal tissue while the tumour cells accumulate a lethal dose.

The initial pion skin doses were 60 % of the curative X-ray dose divided by a safety factor of two. Doses were gradually increased until definitive studies were performed on two patients having a combined total of 30 metastatic shallow skin nodules. To obtain a meaningful RBE the pion depth-dose curve was matched to the depth-dose distribution of the reference radiation (100 kVp X-rays) by using sufficient absorber above the skin to place the tail of the narrow pion peak in the tumour volume. Both the reference radiation and the pion beam were collimated in the transverse plane so that similar areas were irradiated. Peak pion dose rates were 10 to 15 rads/min. The nodules were randomly assigned to X-ray or pion irradiations at several total dose levels up to 1951 rads.

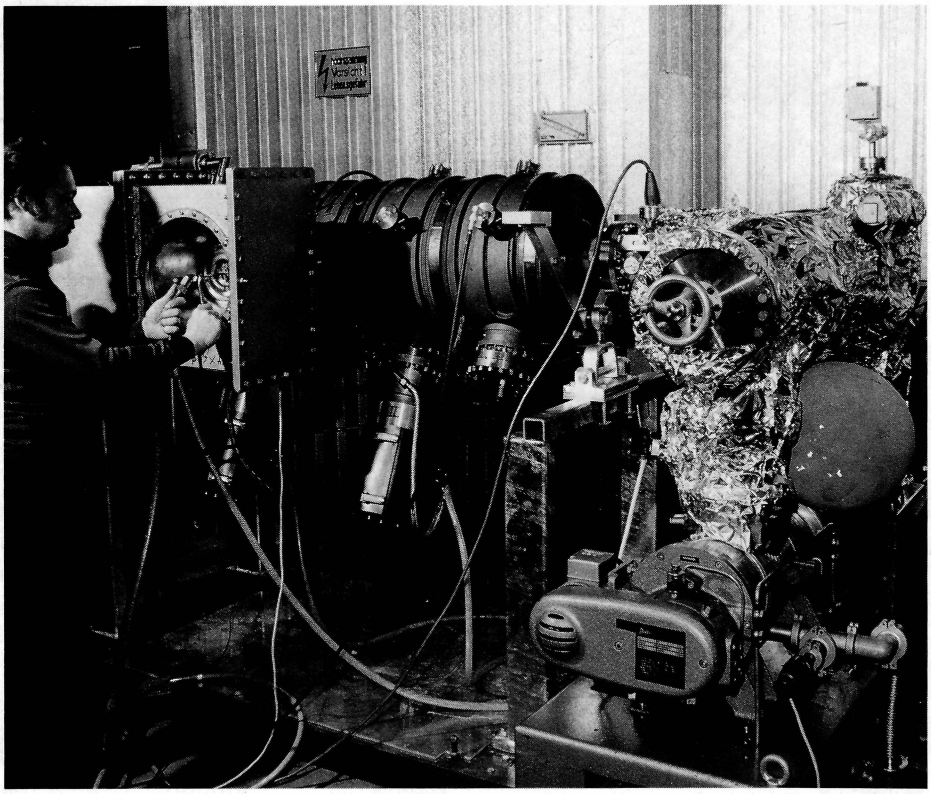
Skin reactions were periodically scored after irradiation using standard methods. The results for day 43, on which the greatest discrimination was observed, are shown in the graph. The RBE for acute skin effects is calculated to be between 1.40 and 1.44. No untoward effects have been noted up to 5½ months after the start of treatment, at which time all nodules (both pion and X-ray) had disappeared. Histological examination revealed no quantitative differences in the nodules irradiated in the two ways.

In late 1976, several larger tumours were irradiated with pions with volumes ranging from $4 \times 4 \times 4\ cm^3$ to $8 \times 10 \times 7\ cm^3$, the latter being obtained with the dynamic range shifter. The dose rate in the largest volume was 4.5 rads/min. The results of radiobiology and microdosimetry experiments were used to shape the pion-stopping distributions; in some cases the tumour volume and location were determined by ultrasound scans. All patients are currently under observation.

DESY
Distinguished visitor sees PETRA progress

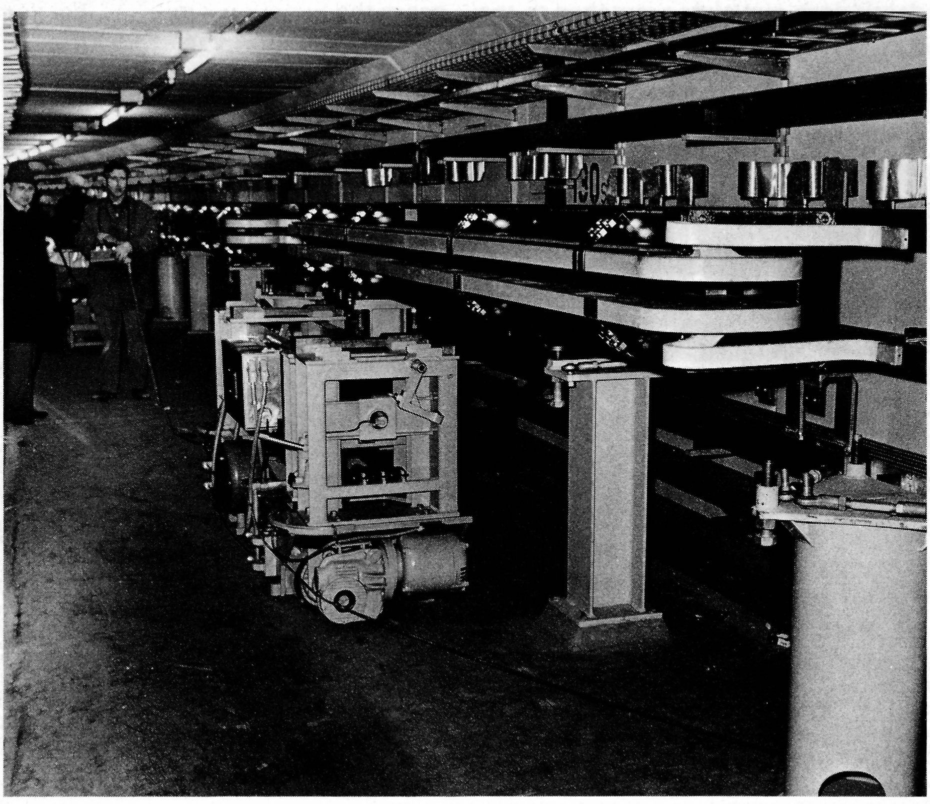
Helmut Schmidt, Chancellor of the Federal Republic of Germany, visited the DESY Laboratory on 11 March. He saw many changes since his last visit in 1969 when excavation for the DORIS storage ring had just started. This time he watched preparations for digging the last 24 m of the 2.3 km PETRA ring tunnel, which was completed three days after his visit. At the injection region the Chairman of the DESY Directorate, Herwig Schopper, told the Chancellor that positrons of 7.5 GeV have already travelled the first 100 m from the synchrotron towards

The first series-production radiofrequency accelerating cavity for the PETRA electron-positron storage ring at DESY has arrived on site. Below are tuning plungers on the second and fourth of the five cells. On the left the input coupler to the waveguide is receiving attention.



The first bending magnets in position in the PETRA tunnel. They are moved into place by the specially designed support vehicle in the foreground.

(Photos DESY)



PETRA and that all work at PETRA is on schedule.

Meanwhile, on 5 April, the seemingly complicated technique of accumulating positrons in DORIS in a single ring mode (only the two upper ring halves of DORIS are used) and ejecting single bunches back to the DESY synchrotron via the electron injection channel, has been very successfully tested.

At PETRA, the 2 × 19 GeV storage ring itself, one dipole per day is arriving on site since the beginning of March, and the same rate is now valid for quadrupoles and sextupoles. Magnetic measurements of the dipoles showed the integrated field to vary by less than $\pm 3 \times 10^{-4}$ with respect to the integral along the axis over a region 12 cm wide. Measured variations from magnet to magnet are also of the same magnitude.

The rather unusual joint programme for producing these C-shaped dipoles seems to be a great success. Special punching tools are made by a firm in West Hamburg; laminations are stamped by a Rendsburg firm from sheet steel produced in Bochum. The core builder, located East of Hamburg, combines roughly 3500 laminations on a stacking and welding fixture developed at DESY. The coils, supplied by a United States and a German firm are installed by DESY people who also wind the correction coils onto the backlegs of about a hundred dipoles.

The quadrupoles and sextupoles are made by U.K. firms out of steel from the same manufacturer who produces the steel for all the ring magnets and the big quadrupoles for the interaction regions. The first magnets have been installed in their final place in the ring tunnel where vacuum chambers will also soon be installed.

Integrated sputter ion pumps, which use the magnetic field of the bending magnets, provide the required pumping speed in the PETRA vacuum chambers. These pumps have been designed with two different anode cells of 32 and 17 mm diameters. The 32 mm cells can work as well at low magnetic fields as in the strong field of the dipoles. The 17 mm cells assure the required pumping speed for high energy operation, where the maximum degassing rates occur. A total number of 2300 pump units consisting of 15000 large and 65000 small cells will reach a pumping speed of 150000 l/s. Due to excellent cooperation with the Technical University of Aachen it is possible to develop and produce these pumps in about one year.

Another problem had to be solved in order to achieve this pumping speed in the beam region. PETRA requires smooth vacuum chambers due to the expected high bunch currents which can cause beam energy losses by excitation of r.f. parasitic modes in irregularities of the vacuum chamber. Therefore, the connecting slots in the wall between the beam space and the integrated pump have to be produced without significantly distorting the chamber smoothness.

Possible techniques such as milling, boring, punching and spark erosion were studied. This last has been prefered because of the possibility of perforating any slot shape. Long tools with copper electrodes having the shape of the wanted slots were constructed in cooperation with Lufthansa, who have used this technique for perforating complicated shapes in jet turbines. Several tests and modifications reduced the spark erosion time for a chamber from 6 to 1 ½ hours.

A thousand slots of 10 by 5 mm will connect the beam and the pump tunnel of each chamber, that means a total number of 250000 slots around PETRA. Thus a maximum pumping speed is achieved with a minimum distortion of the chamber smoothness. The chambers for the first PETRA octant are already perforated and series production for all the others is under way.

The first r.f. accelerating cavity was delivered to DESY at the beginning of March and tests started immediately to learn if the specifications developed with an aluminium model have been fulfilled. The final degassing rate of 4×10^{-12} torr l/s cm^2 has proved twice as good as specified, demonstrating that the firm is well acquainted with the technique of electron beam welding. All other test measurements on this first cavity have been in good agreement with specifications.

BROOKHAVEN
New energy record at AGS

Two recently proposed experiments at the 33 GeV Alternating Gradient Synchrotron at Brookhaven asked for very unusual machine performance — extraction of the protons at 5 GeV and at 800 MeV kinetic energies, far below the design energy. Since the AGS has never operated below about 20 GeV it was not certain that the various components could perform satisfactorily so far from their nominal setting. For 5 GeV the answer is a resounding yes, and for 800 MeV the answer is 'probably'.

A BNL / Princeton collaboration, led by T. Kycia and Val Fitch will use the 5 GeV beam to search for the H particle — a bound state of six quarks, recently predicted by a bag model calculation of R. Jaffe. The H would have the quantum numbers of two lambda particles and a mass near the two lambda threshold of 2230 MeV. The signature of the particle would be the two positive kaons produced in the reaction $pp \rightarrow H K^+K^+$. The kaons can be detected in a symmetric two arm spectrometer used in a recent charm search by the Princeton collaborators.

The experiment will use a hydrogen target and identify the H through a peak in the missing mass spectrum with a sensitivity of about 1 nb. The apparatus can stand about 5×10^8 protons / pulse which was more than the secondary beam line could supply. Extracting at 5 GeV, however, gives a sufficient flux of protons with the further advantage of no pion contamination. Also the duty cycle can be increased between 40 % and 80 % and the power cost is very small. AGS studies have demonstrated that a satisfactory flat top can be maintained at 5 GeV and that Coulomb scattering from an internal target will deliver more than enough flux. The experiment is scheduled for this Summer.

A Harvard / Pennsylvania / Wisconsin / Brookhaven collaboration led by L. Sulak and H.H. Williams will search for neutrino oscillations with their present detector. The experiment will look for electron-type neutrinos in a beam of low energy muon-type neutrinos. The muon-type will be produced in the decay of pions from the $\Delta(1238)$ resonance, the preponderant channel for the interaction of 800 MeV (1.5 GeV/c momentum) protons. The interest in low energy is primarily because the sensitivity is proportional to the length of the neutrino flight path and inversely proportional to the neutrino energy.

A further consideration is that the electron-type neutrino background is lower if the protons are below threshold for kaon production. A repetition rate of one pulse every 1.3 s and a low power cost also help make the experiment feasible. Two brief AGS periods have been devoted to tests for this experiment. Thus far, three turn extraction with 60 % efficiency has been achieved but work on extraction at high intensity and on beam transport still needs to be done. The experimenters plan a one week test of the experiment in Summer.

The AGS, with its increasing intensity and reliability, is still a versatile accelerator.

People and things

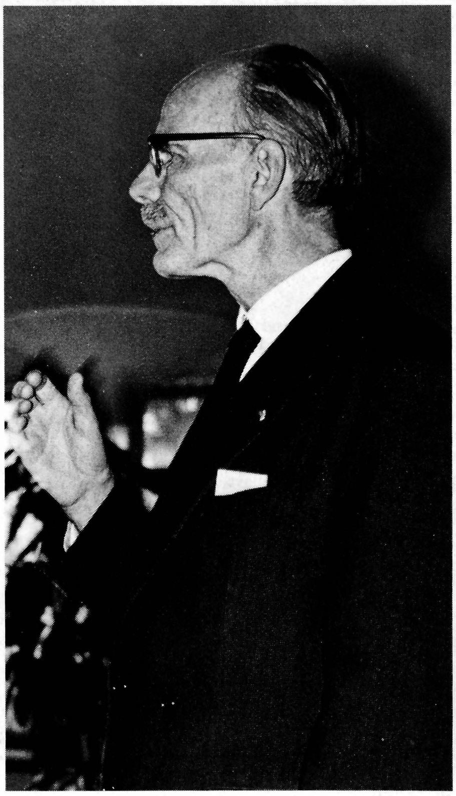
Future accelerators in Europe

The ECFA Committee for Accelerator Studies is calling a Discussion Meeting on Regional Accelerator Projects on 24 May at CERN. It will hear reports on the physics interest of higher energies, on projects for higher energy proton facilities in the USA (Brookhaven ISABELLE storage rings, Fermilab Energy Doubler) and the European studies concerning higher energy colliding proton beams and colliding electron-positron beams. The Discussion Meeting will immediately precede a Plenary ECFA Meeting in the CERN Council Chamber on 25 May. (This is an open meeting.) The main point on the agenda is the preliminary formulation of a recommendation concerning the future facilities for particle physics research in Europe.

On People

Pierre Auger has become a Member of the French Academy of Sciences following an initiative by President Giscard d'Estaing to extend and revitalize the Academy. The Academy previously had 80 Members from all the science disciplines and new Members were appointed only on the death of an existing Member. The number is being increased to about 130 and many younger scientists are being brought in. There is also a clearer distinction between the disciplines than before. Pierre Auger was Godfather to CERN when he was Director of Natural Science at UNESCO in CERN's formative years.

Herbert Coblans, first Head of the Scientific Information Service at CERN and an internationally recognized library expert, died on 18 March. After an extensive professional career, including direction of the UNESCO Library in 1949/50, Dr. Coblans joined CERN in October 1954, where he established the Library and Scientific Information Service. Ten years later, he left for the United Kingdom, where he worked for ASLIB on a number of library research and development projects. Even after his retirement in 1969, he continued to be active in international projects where he was involved in the setting up of international information services in nuclear and agricultural sciences (INIS and AGRIS) as well as the standardization work of UNESCO (UNISIST).



1. Pierre Auger
2. Marian Danysz

On 30 March, Marian Danysz received the degree of Doctor Honoris Causa at the University of Warsaw. Professor Danysz has just retired from the University. He is well known for his discovery in 1952, together with J. Pniewski, of a hypernucleus in a nuclear emulsion experiment. This work opened up the new field of hypernuclear physics.

Gordon Fraser has joined the editorial team on CERN COURIER succeeding Michel Darbin. He received his Ph D in particle physics at Imperial College London in 1967 and has since been involved in research and in science journalism. For the past year and a half he worked as Information Officer at Rutherford Laboratory. With Gordon's arrival we hope to strengthen particularly the particle physics coverage of the journal.

CERN at the Fair

Visitors to the world's largest industrial fair, the Hanover Fair in the Federal Republic of Germany, were able to get a glimpse of CERN on show there from 20 to 28 April. In the section dedicated to Research and Technology, the CERN stand displayed some of the interesting technical developments resulting from pure research and thus repeated, on a smaller scale, what had been done in 1974 when a Meeting on Technology Arising from High Energy Physics was held at CERN (see April issue 1974).

The very sophisticated SPS Control Computer system formed the heart of the CERN stand. Demonstrating its highly flexible control facilities and colourful displays, it controlled a number of exhibits such as a liquid dispenser (originally designed as a precise dosing system for chemicals used in the development of bubble chamber film) used at the Fair to mix drinks for thirsty visitors. Also on show was a fire early warning system using gas-filled microcapsules which burst when overheated so that the popping sound and the released gas give an alarm. In an improved type of condensation cryopump, the losses due to thermal radiation have been so reduced that one charge of liquid helium at 4.2 K provides autonomy for about 200 days.

Another exhibit was the laser alignment system which helped in the precise positioning of the SPS *magnets. Other items were a quick-release coupling mechanism for vacuum systems (suitable for remote handling in radioactive environments) and the production of high quality grids by chemical or electrochemical machining (such as used in precise collimators) in a wide variety of materials, ranging from plastic film to the hardest of refractory metals. The numerous visitors could also inform themselves about CERN in general — its aims and facilities and its role as one of the world's largest international organization engaged in pure research which brings benefits also in practical fields.*

TRIUMF muon decay experiment

An experiment, by a British Columbia / Montreal / Victoria team, has recently been completed at the TRIUMF cyclotron on the elusive decay of the muon into an electron and a gamma, which has been much in the news recently (see March issue page 51). Four weeks of beam time were used in February and March and the analysis of the data has started. The equipment consisted of two large sodium-iodide crystals which were placed opposite each other with a stopping target between. A pion beam was used because insufficient stop-rate was obtained with a muon beam but, unfortunately, the use of pions increases the accidental background considerably. Coincidences between the two detectors were recorded and the energy of the particles in each detector will be used to identify the muon decay.

There were a large number of events observed which had low energy electrons and gammas indicating that two neutrinos had also emerged from the muon decay. These are being used as a check on the geometrical efficiency of the system and will also be an interesting by-product. At present the search for events continues and a final result is not yet available. However, so far, no obvious candidates for the decay have been observed at a sensitivity which is better than the existing published limit of 2×10^{-8}.

Meeting on HEP finance in UK

Finance was very much on people's minds at the latest UK High Energy Physics Users' Meeting, held at the Rutherford Laboratory, on 14 March. Just a few days after that meeting, the Science Research Council, which is the channel of finance for pure research in the UK, was itself convening to fix the allocation of funds for the next few years. The outcome of the Council meeting was much as had been expected, which does not mean that particle physicists were satisfied. In the general cutback of government expenditure in the UK, high energy physics has suffered proportionally more than other areas of pure research and a sudden reversal of this trend was not anticipated.

Conference at SIN

From 29 August to 2 September the 7th International Conference on High Energy and Nuclear Structure will be held at SIN, (Schweizerisches Institut für Nuklearforschung), near Zurich. Participation is limited to 400 people. For further information contact Mrs. E. Huber, SIN, CH - 5234 Villigen.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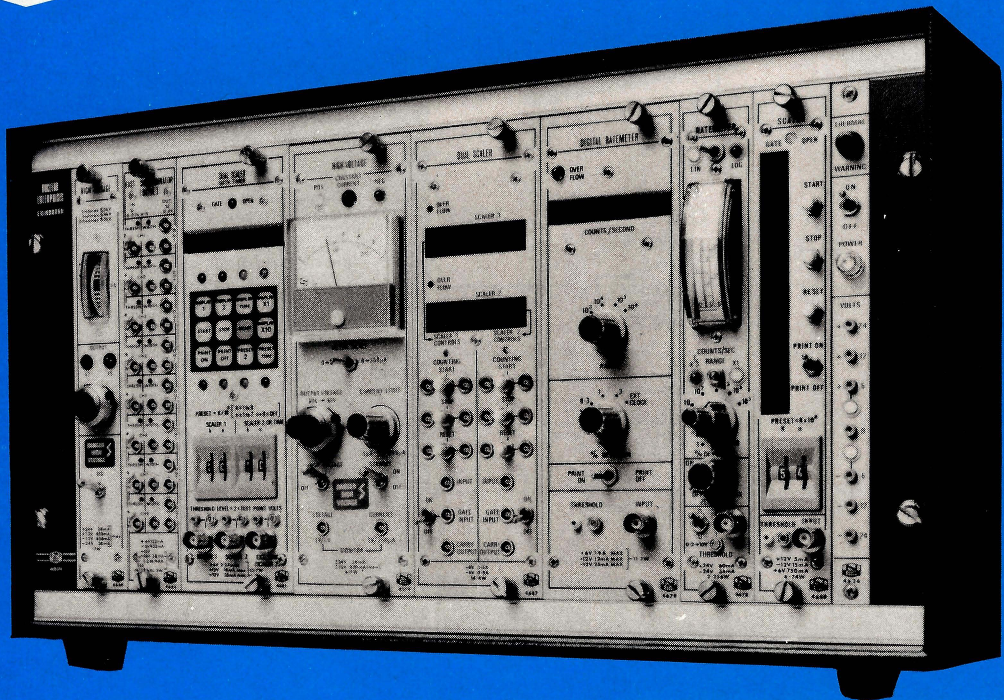

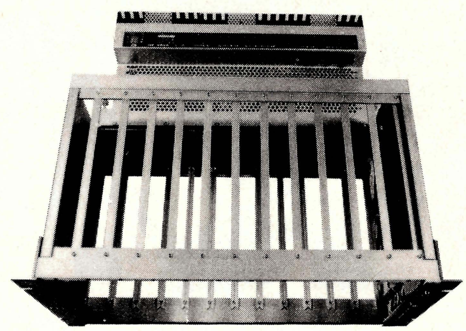

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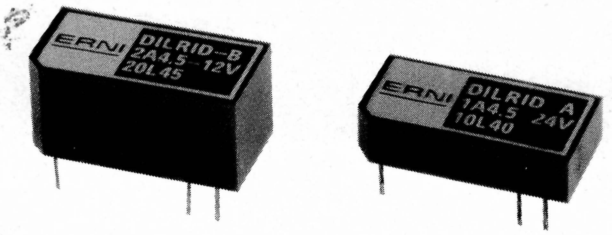

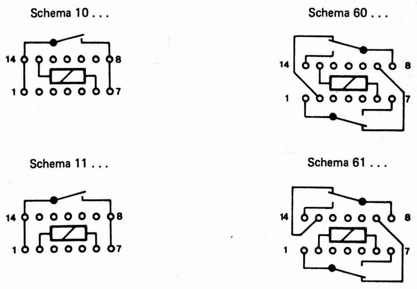

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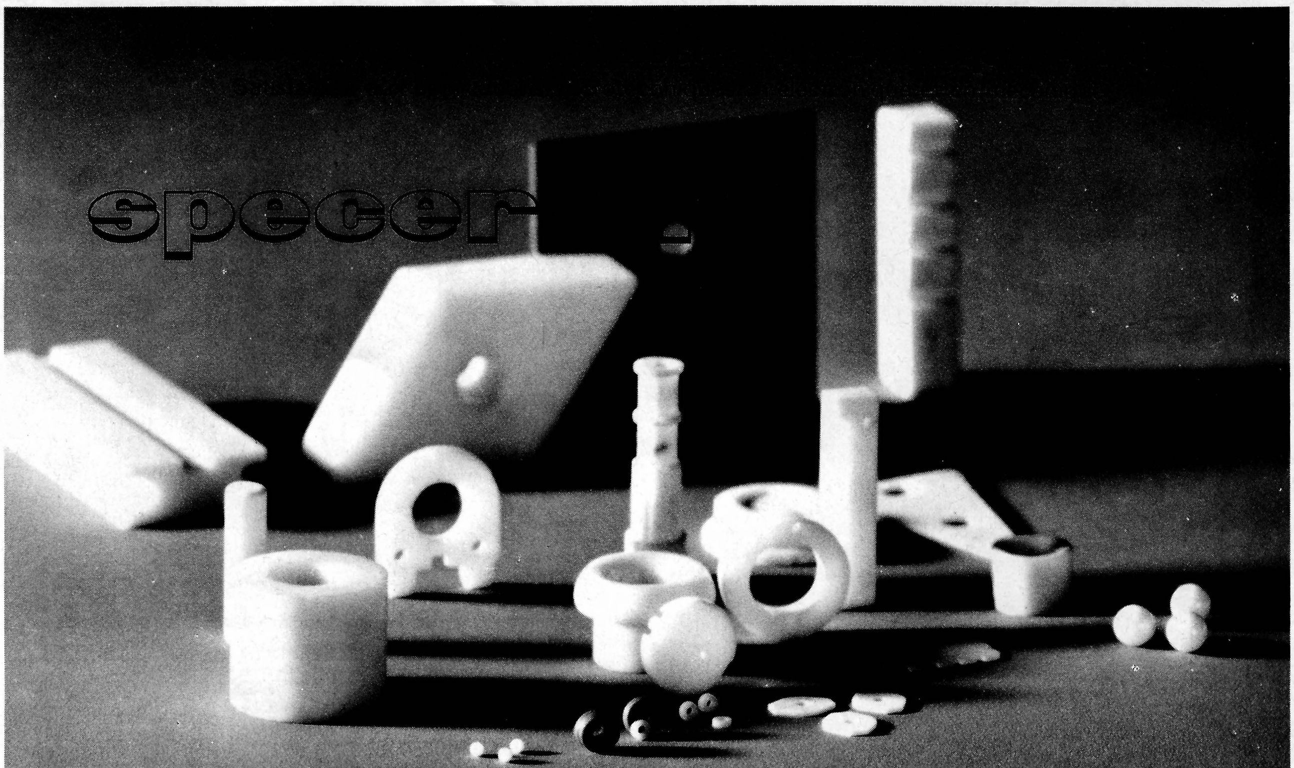

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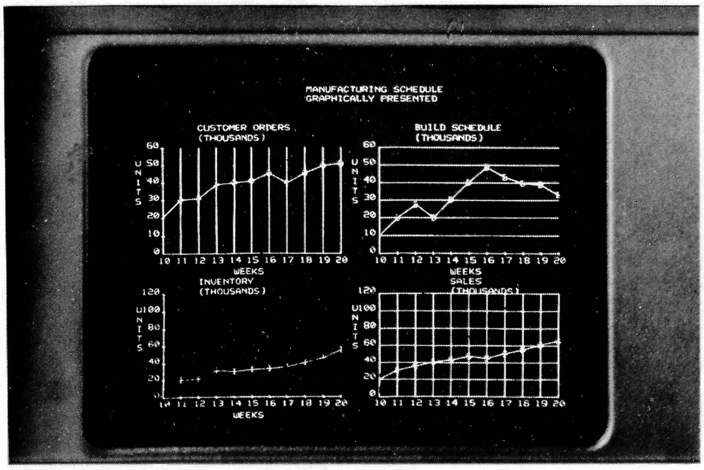

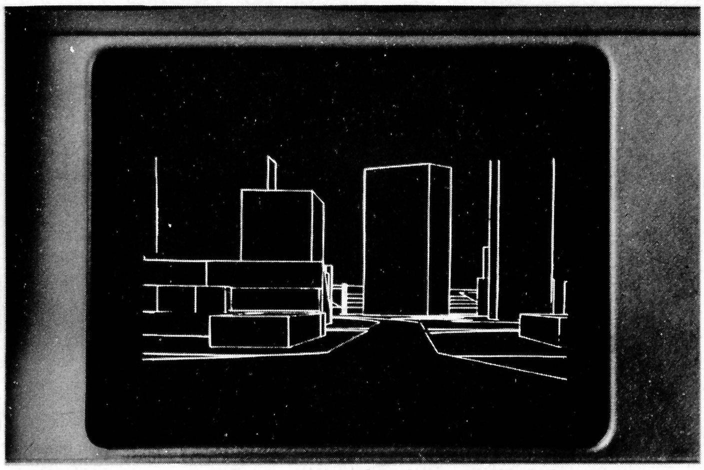

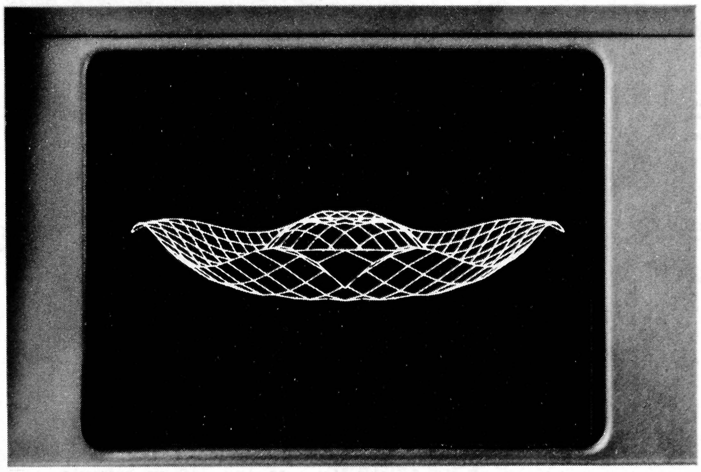

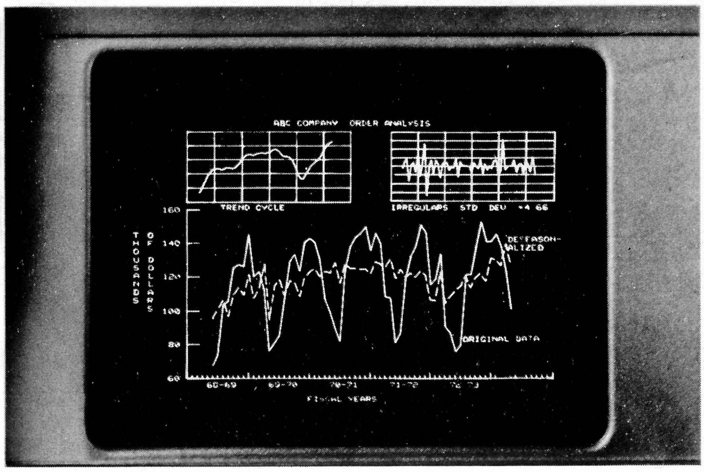

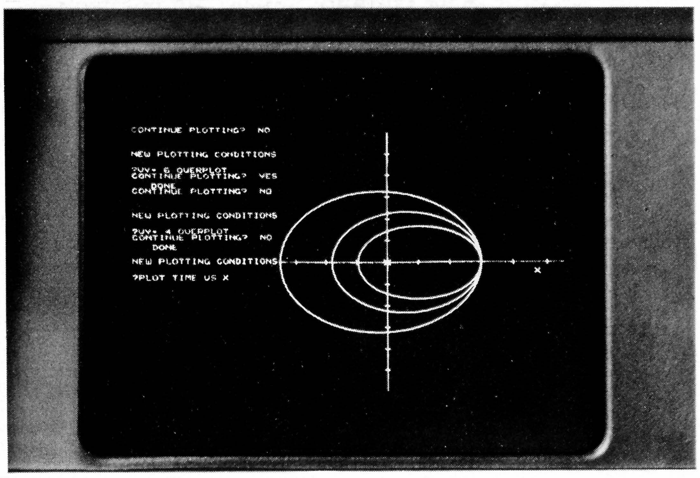

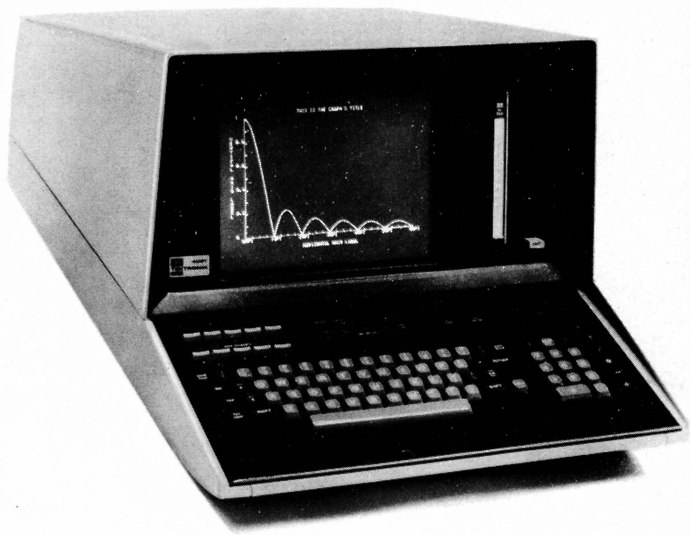

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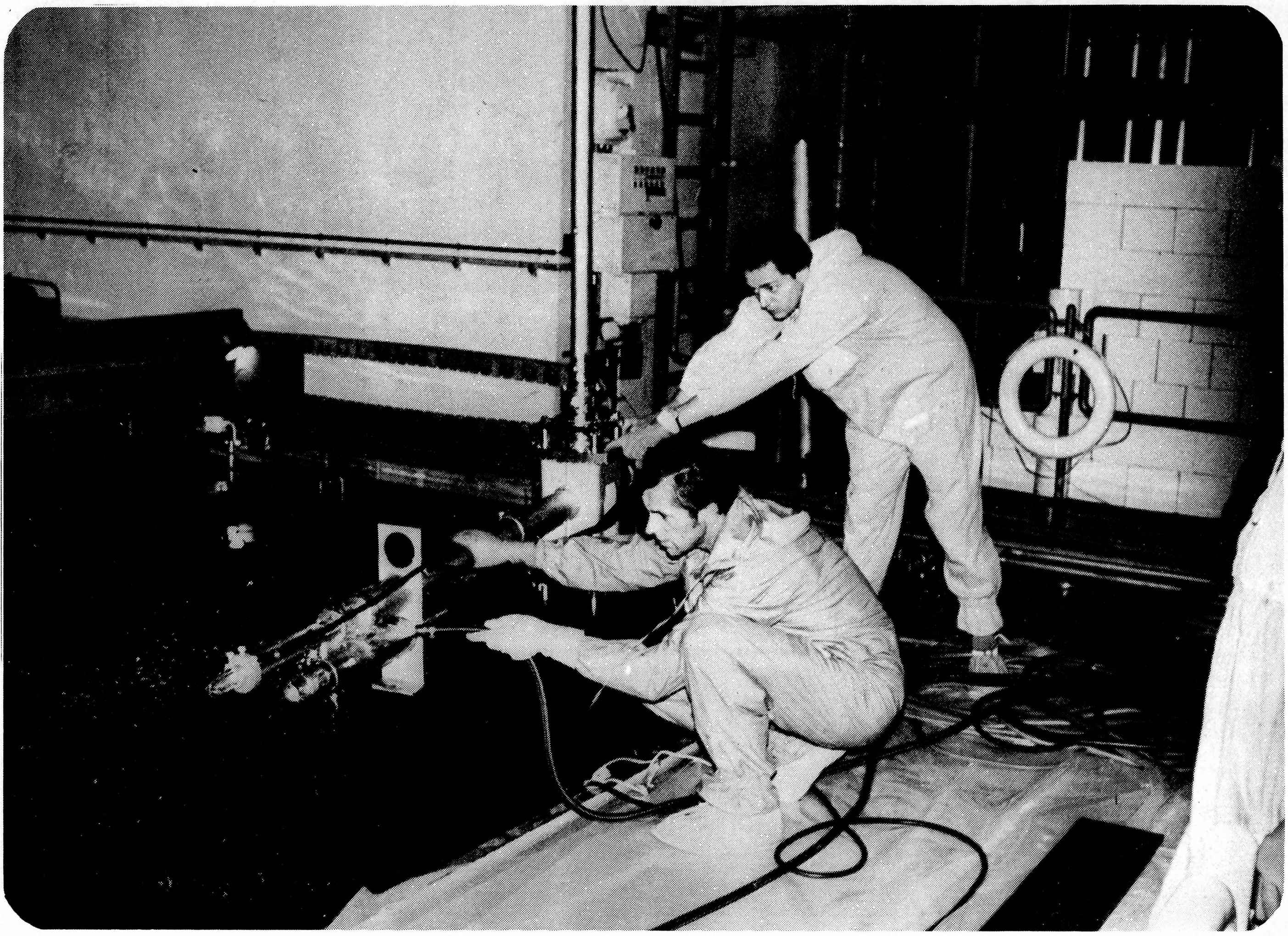

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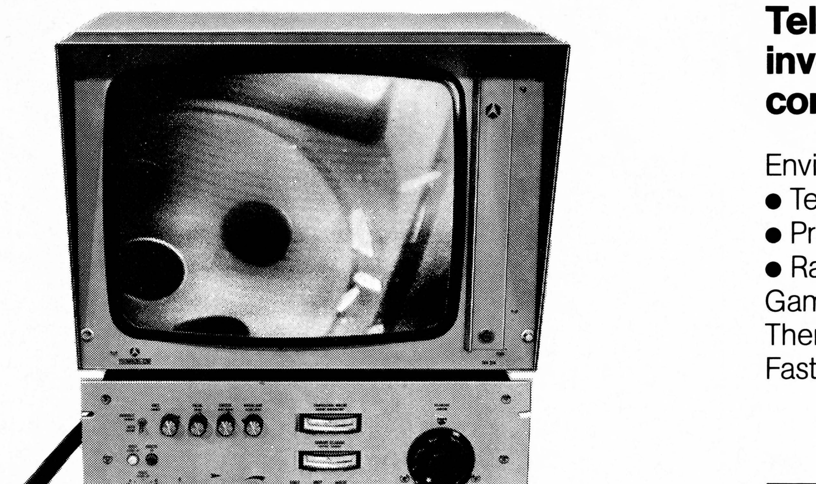

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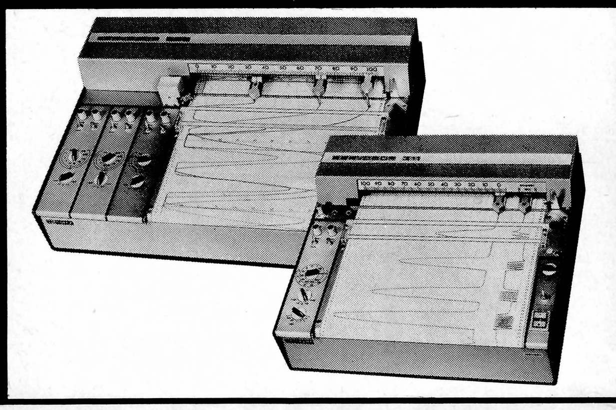

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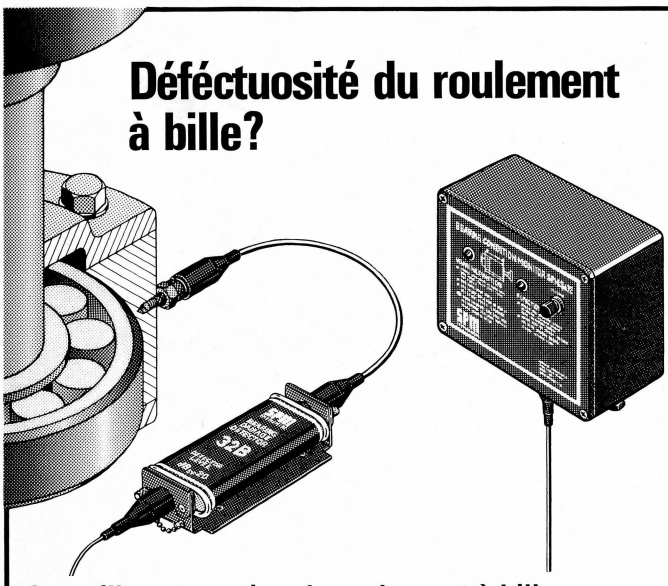

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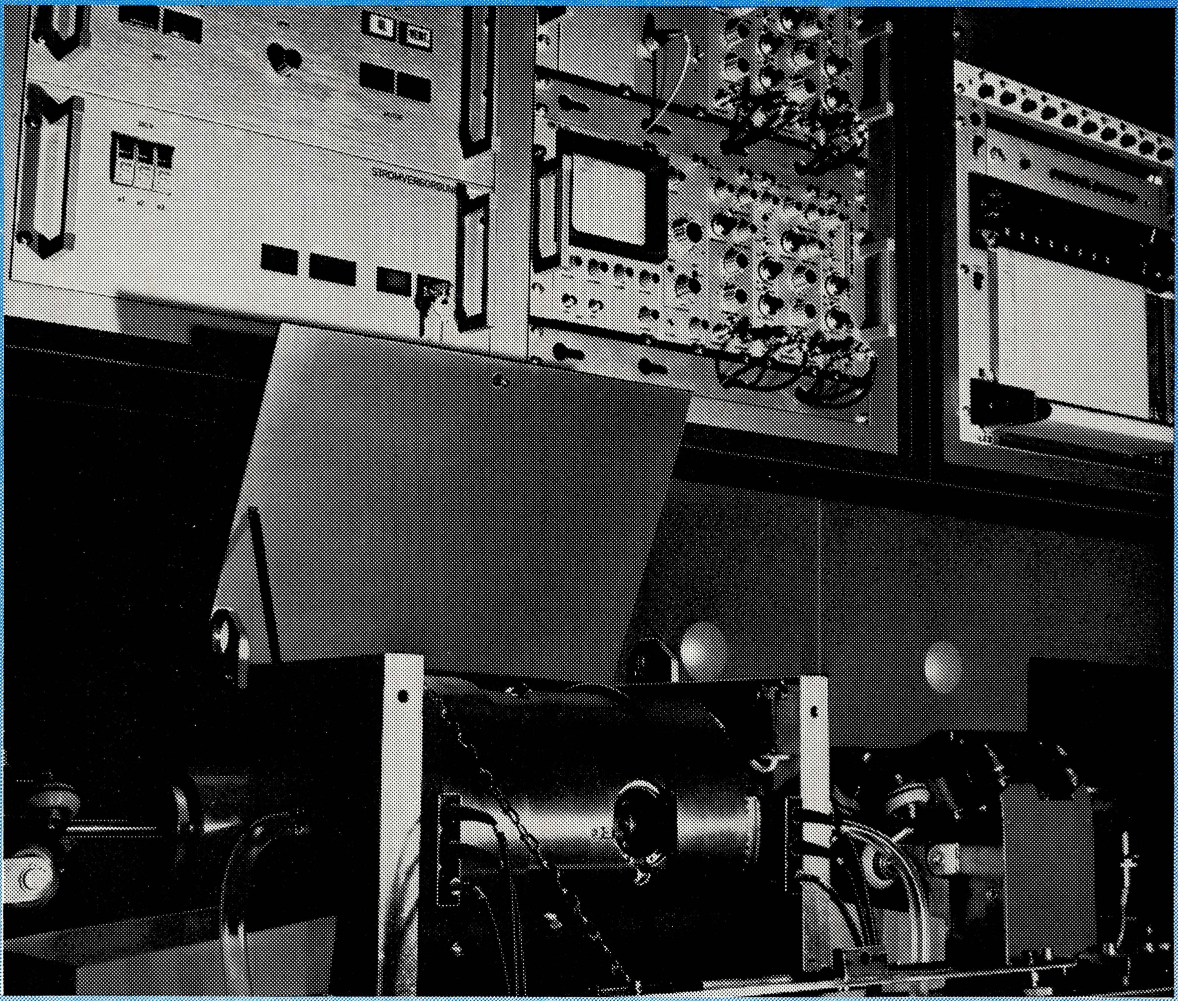

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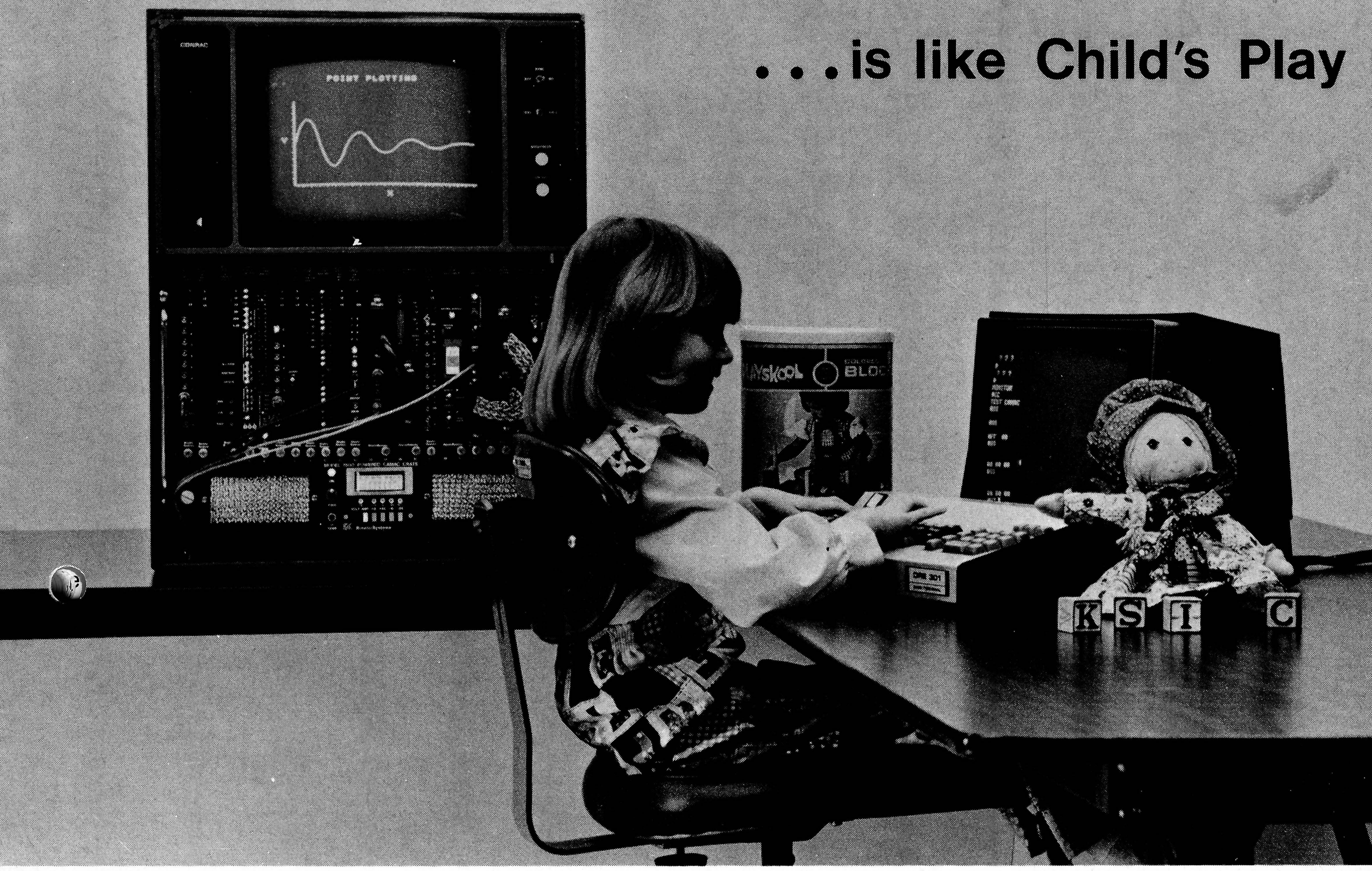

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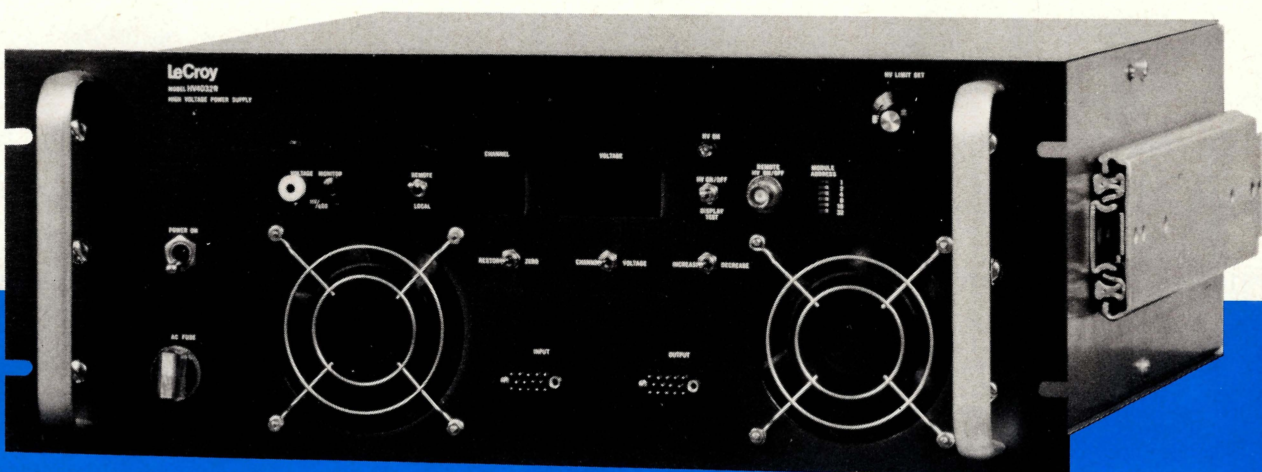

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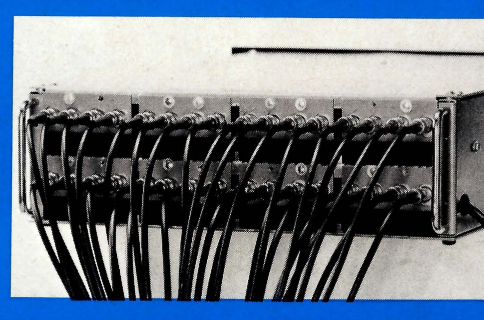

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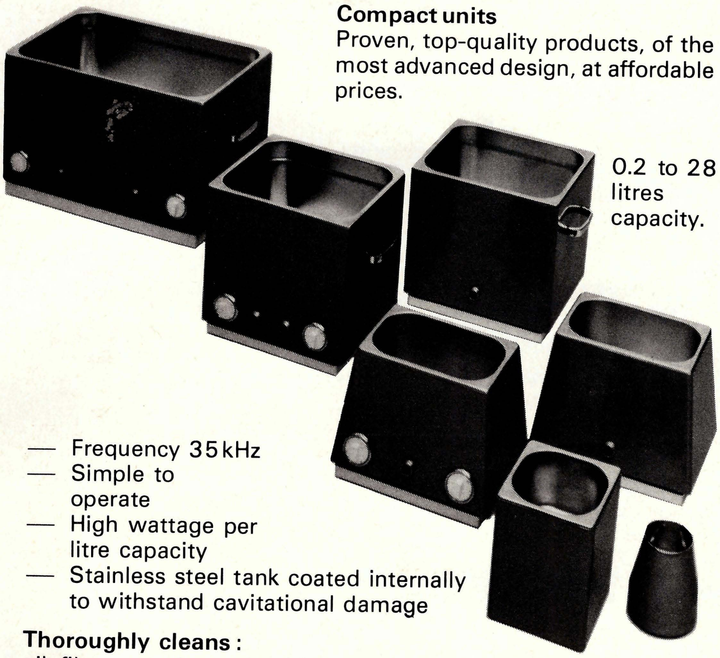

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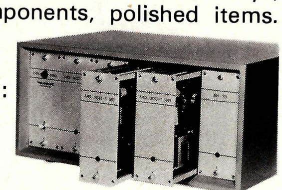

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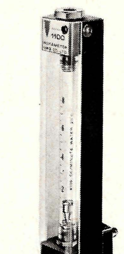

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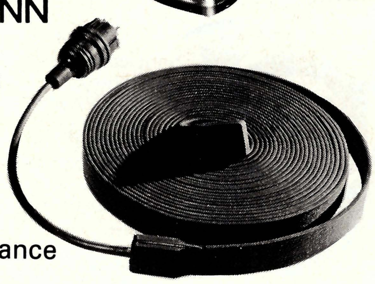

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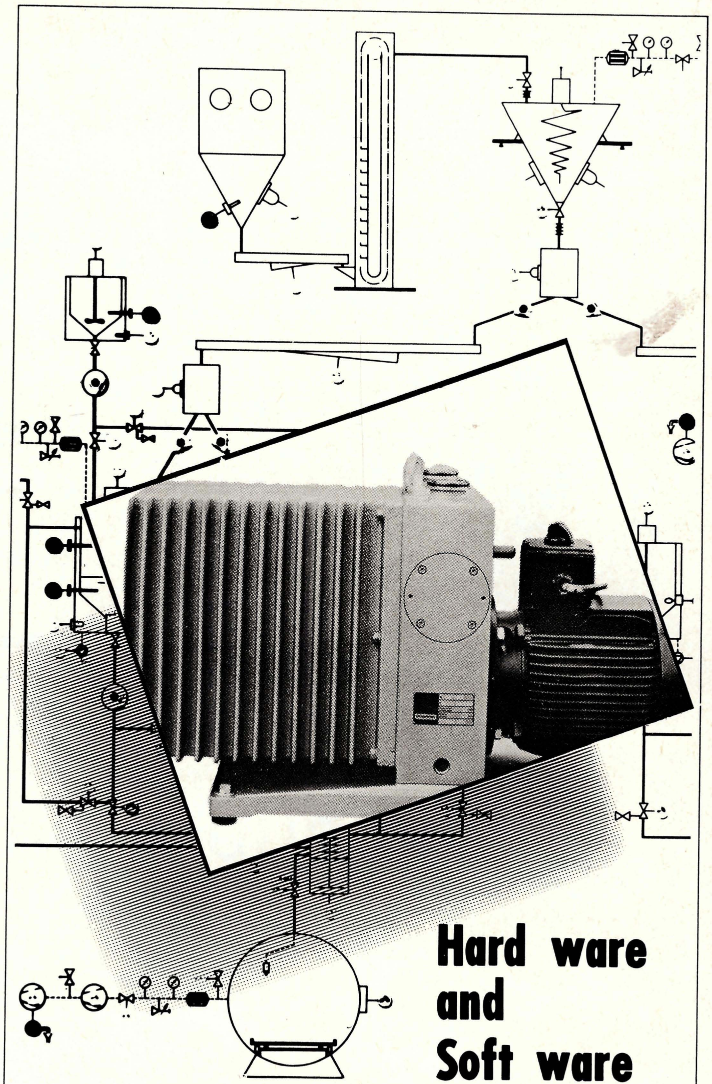

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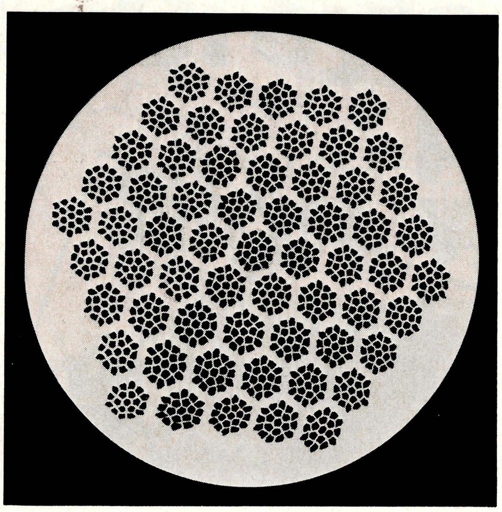

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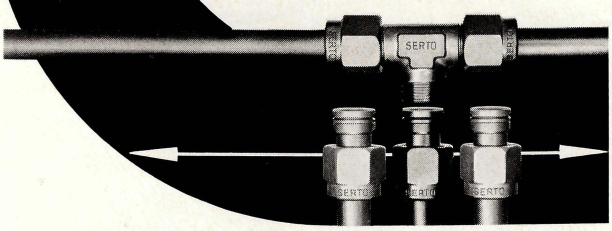

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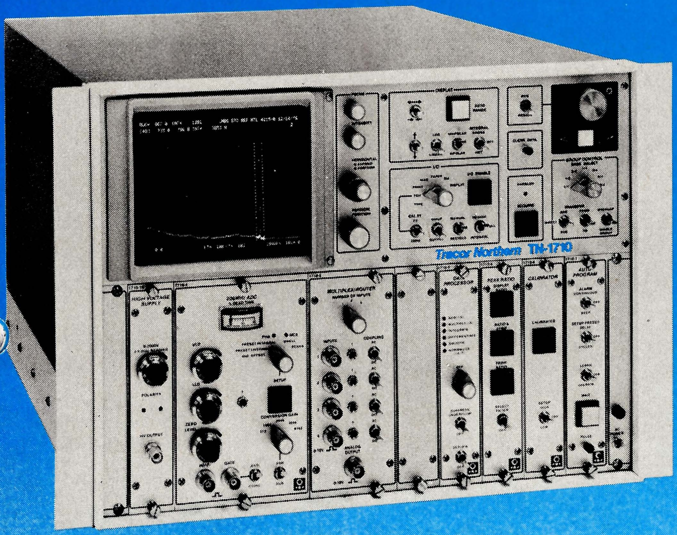

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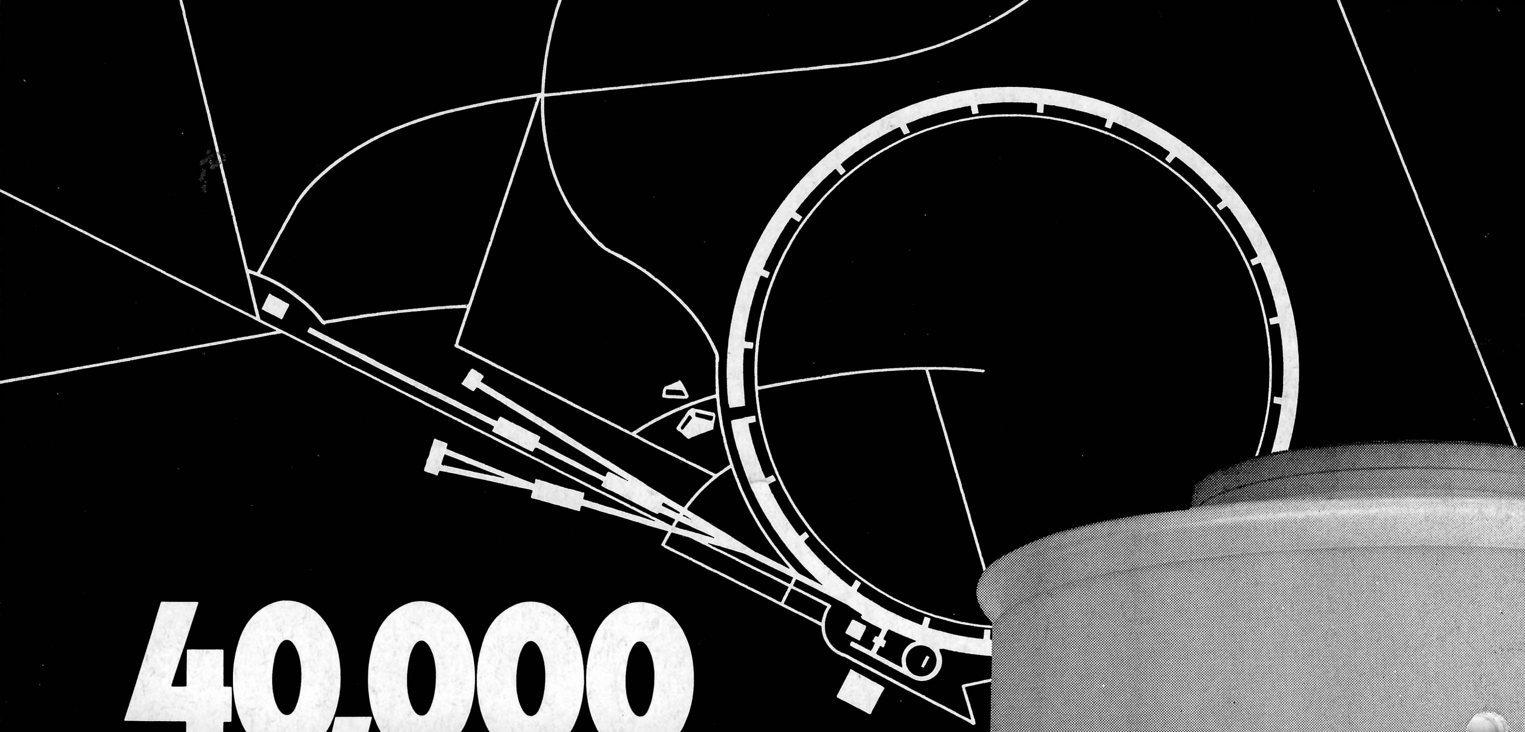

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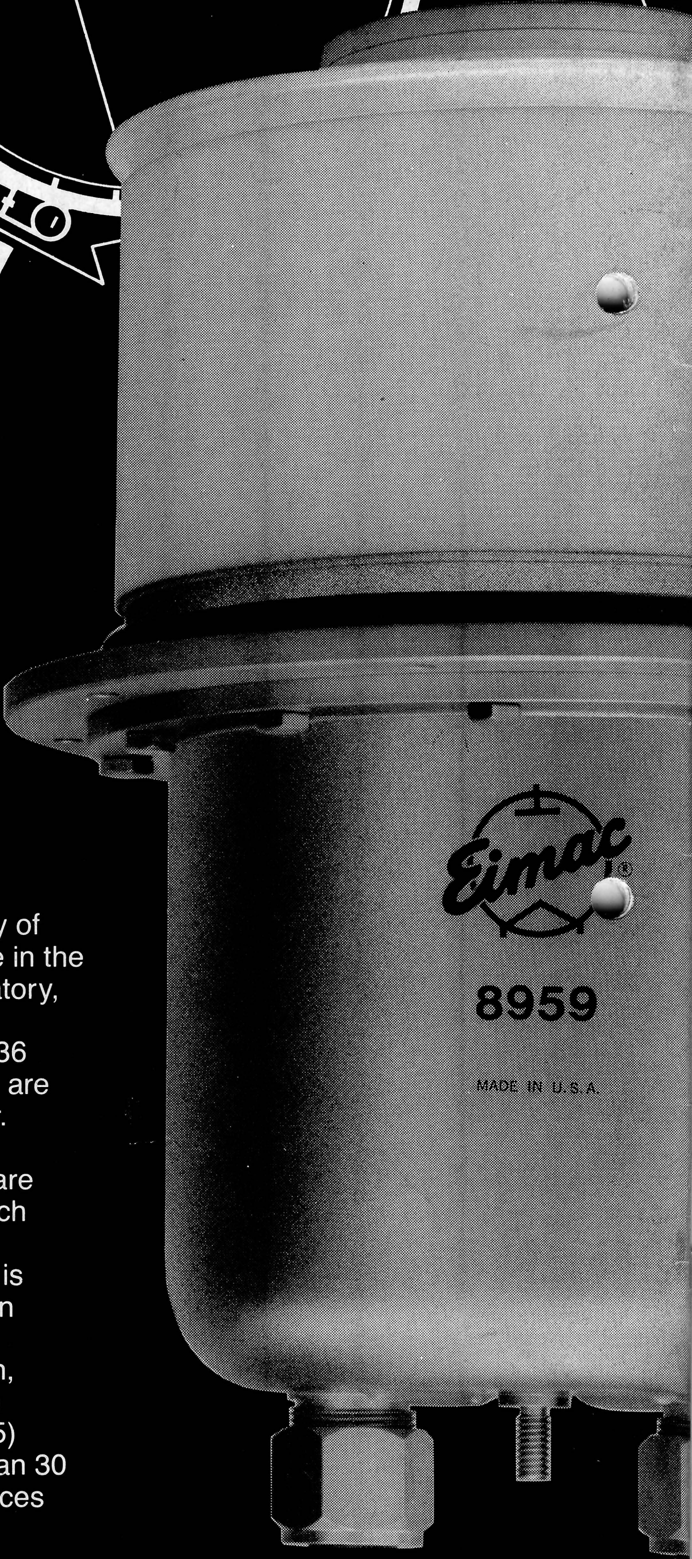

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