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Cover photograph: Not an excavation of early Egyptian pyramids, but work in progress for the new underground experimental hall in the North Area at CERN. The stepped pyramid-like excavations allow the construction of access shafts while protecting personnel working below against falls of stones, etc. (Photo CERN 158.7.78)

First beams at PETRA

Celebrations in full swing 15 minutes after the successful storing of an electron beam in PETRA. The champagne bottles on the control console are not part of the standard operator's equipment.

(Photo DESY)

It is not often that a new high energy physics machine is switched on, and even rarer for it to be completed a whole nine months ahead of the original construction schedule. Here Gus Voss of DESY describes some of the excitement, in front and behind the scenes, of the first particles in PETRA.

On Saturday 15 July at 22.30 the first stored beam was observed in PETRA, the new 19 GeV electron-positron storage ring at DESY, Hamburg. This was the climax of some hectic and almost chaotic weeks, during which the last vacuum chambers were mounted, shielding in experimental halls installed, power supplies connected, etc. On 14 July the 2.3 km tunnel was searched and closed and electron injection was started. A system of 32 scintillation screens and TV-monitors allowed the beam path to be followed on the first turn around the ring. With the help of these monitors and some steering coils a hotly debated question could be settled — the integral number of betatron oscillations was correct, the Q-value seemed to be off by about 0.4 only.

When the last screen was taken out and people braced themselves for the next turns, a water hose in the tunnel broke, emptying a few hundred litres of water into the tunnel, thereby turning off all magnets. However, this had happened before, and people knew how to deal with it.

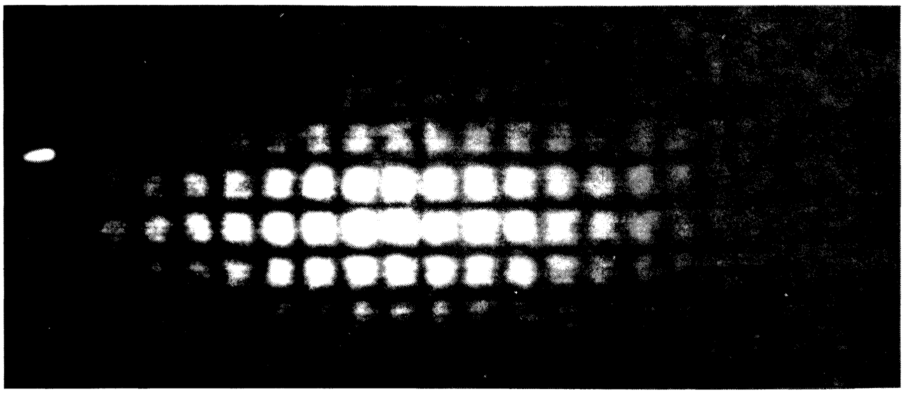
On 15 July injection was resumed and soon the second and third turns appeared. After the 20th turn was verified, the accelerating system was turned on. (Even at the low injection energy of 5 GeV from the DESY synchrotron during these trials, energy losses due to synchrotron radiation amount to 0.25 MeV / turn.)

After some expert knob twiddling, some few thousand turns could be seen and people faced the next question — are the beam oscillations damped or antidamped? In large electron storage rings damping depends critically on the beam position in the quadrupoles, and small variations in the accelerating frequency change the synchrotron radiation damping dramatically. In PETRA a relative frequency change of 6×10^{-6}, corresponding to an average change of beam position of 2 mm in the quadrupoles, would be sufficient to antidamp horizontal betatron oscillations.

Had the surveying group worked accurately enough? When no progress was made beyond the 1000th turn, the frequency knob was included in the 'tune-up', and indeed it helped. Just outside the expected stable frequency range, the beam suddenly stayed in the machine and could be seen over periods longer than a minute.

This was the moment for the champagne, cheers and smiles. Albert Hofmann from CERN and Helmut Wiedemann from the PEP group happened to be there and joined the crowd. When some enthusiasts, in-

The first synchrotron radiation seen from a 5 GeV electron beam stored in the PETRA electron-positron collider at DESY.



spired by the champagne, tried to accumulate current through repeated injection, their actions were no longer always coherent and logical and were unsuccessful. This confusion must have been contagious, because when the news was sent out, many of DESY's contacts abroad got the German version of the telegram, while all the German officials got the English version.

Several perplexing questions remained — why was the machine antidamped at the correct frequency and why was the adjustment of all optics parameters so critical ? On the first attempt sextupoles had not been used. Slowly it dawned on the experts that the chromatic corrections were more important than originally realized — changes of damping parameters due to orbit distortions are far more violent in machines without chromatic corrections.

This prompted the activation of the sextupole circuits, a very systematic first turn orbit correction using all 152 monitor stations, a first turn check on the chromaticity in both planes and many other things. Then on 18 July things seemed to be understood, after the electron beam was moved off the horizontal integral resonance of 25 (why does one always land on integral resonances ?) it stayed happily in PETRA with lifetimes of 2 hours.

Now suddenly everything behaved according to the book. Machine acceptances were good, beam cross-section was as anticipated and most important of all, the machine wanted to operate on the exact theoretical frequency, indicating that the length of the circumference was correct to within one millimetre.

On the next day, 20 July, injection was sufficiently understood to allow accumulation, and the one single bunch circulating in PETRA could be increased to average currents of 3 mA (1.2×10^{11} particles). This already compares favourably with the currents necessary for maximum luminosity at 5 GeV (between 1 and 5 mA, depending on the optics) and is 15 per cent of the maximum design current. One day later acceleration in PETRA up to 8 GeV without particle loss was accomplished, resonance plots were checked (no unpleasant surprises) and at the end of the first week PETRA looked like a good-natured electron-positron storage ring.

This was a great success for all the project groups working on PETRA. The optics group and the magnet people were happy that after all the confusion, Q-values were only off by 0.1. The surveying group was proud that in the first half of the ring the first turn stayed within 5 mm of the ideal orbit in both planes without any corrections and only in the more recently installed part of the machine were a few corrections necessary. The vacuum group was happy that nothing had been left in the chambers except a vacuum of 2×10^{-8} torr, which, even without bake-out and in-situ gas discharge cleaning, permitted lifetimes of two hours. The r.f. people were relieved that the first half of the transmitters and one quarter of the cavities could be installed just in time and worked as expected producing 24 MV (which should be good for energies close to 14 GeV). The control group got the highest praise for getting all the essential controls working although they were able to move into the control room only six weeks ago.

The management was happy that PETRA cost even less than the figure quoted in the 1974 proposal. All inflationary price increases could be taken care of within the original price tag, and the two years and nine months' period from authorization to first stored beam was nine months shorter than that mentioned in the 1974 proposal.

This of course is a challenge for the experimenters, who according to the original schedule were supposed to start experiments by summer 1979. But here too the timetable has been advanced. The first detectors could roll into their positions for data-taking at the beginning of October (1978 that is).

As everybody congratulates machine specialists on a job well done, physicists now wait for their first glimpse of new fields of physics. If new results at PETRA follow at the same rate as the construction schedule, then we shall all be in for an exciting time !

Weak interactions in harmony

New results from different areas of weak interactions suddenly seem to be pulling in the same direction.

STANFORD A remarkable experiment

As indicated briefly in the previous issue, an experiment at SLAC has succeeded in seeing parity violating effects in electron-nucleon scattering. These tiny asymmetries are the result of the delicate interference between weak and electromagnetic interactions and provide a deep insight into the underlying relationship between the weak and the electromagnetic forces.

The results agree with what has come to be known as the Weinberg-Salam model, a picture which unifies weak and electromagnetic interactions. This, together with a wealth of data from neutrino experiments, provides impressive evidence that the conventional description of Nature with four kinds of force (strong, electromagnetic, weak and gravitational), can be reduced to one with only three forces.

Led by Dick Taylor and with important contributions from Charles Prescott and Charles Sinclair, the experiment involved physicists from Yale, CERN, Aachen and Hamburg as well as SLAC. The results were announced at a formal SLAC seminar (and not at a press conference as indicated in the stop press announcement in the previous issue of the Courier).

In principle the experiment was simple. A beam of polarized electrons of energy between 16.2 and 22.2 GeV hit a liquid deuterium target, and the momenta of the inelastically-scattered electrons were analysed in a magnetic spectrometer. The aim was to look for a variation in the rate of detection of these electrons when the polarization of the incoming electron was reversed.

When viewed in a mirror, an electron spinning right-handedly in the direction of motion appears to spin left-handedly. If an experiment were to detect that different results were seen for right-handed and left-handed electrons, this would mean that a reaction and its 'mirror-image' behave differently.

Such violations of parity have long been known in charged current weak interactions where the participating particles permute their electric charges, but have only recently been sought in the neutral current interactions where the electric charge of the lepton remains the same. To reveal the underlying theory, it is essential to pin down the parity violating effect for the neutral current.

Previous experiments with muons and with electrons have searched for neutral current asymmetries, but have never reached the required level of sensitivity. Parity violation has been seen in some atomic physics experiments (see June issue, p. 200), but the results depend on complex atomic physics calculations. The results of the SLAC experiment are less open to question and give a cleaner indication of the subtle weak / electromagnetic effects with better statistical significance.

Perhaps the principal feature of the experiment was the intense beam of longitudinally polarized electrons. Average polarization at the target was 0.37, and the beam intensity varied between 1 and 4×10^{11} electrons per pulse, with 120 pulses per second. These polarized electrons were obtained by the interaction of laser light with specially-treated gallium arsenide, and accelerated to high energy in the two-mile linac.

Initial work at ETH Zurich, the Ecole Polytechnique, Paris, and the US National Bureau of Standards showed that after the semiconductor gallium arsenide is irradiated with circularly polarized laser light, the radiation given off when the excited electrons move back from the conduction band to the valence band tends to be circularly polarized. This shows that the conduction band electrons are themselves polarized.

By coating the semiconductor with caesium oxide, the polarized conduction electrons become easier to extract and can be used as input for an electron accelerator. In this way, SLAC was able to produce high currents by replacing the usual thermionic cathode of the electron gun by the irradiated gallium arsenide device.

To obtain the required statistical precision in a reasonable time, a flux of about a thousand inelastically-produced electrons per pulse was handled by integrating the outputs of the phototubes, instead of counting individual particles.

As small changes in the position, angle, intensity and energy of the electron beam could affect the results, a sophisticated beam monitoring system using microwave cavities was employed. This measured beam position to about 10 microns, energy to 0.01 per cent and angle to 0.3 microradians.

Varying the polarization state of the incident electron beam produced a definite asymmetry in the recorded electron level of about one part in ten thousand, with a greater yield coming from electrons with spin antiparallel to their direction of motion.

This result agrees with the standard Weinberg-Salam model using a value for the mixing angle parameter in agreement with most current neutrino experiments.

The different mix of quarks in protons and neutrons means that a different result is expected with a hydrogen target. A limited amount of data taken at 19.4 GeV using a hydrogen target also gives a result in agreement with the standard theory.

A new unity in physics

While the theory which lies behind the unification of weak and electromagnetic interactions is usually associated with the names of Steven Weinberg and Abdus Salam, it is worth remembering that this is in fact a saga which spans twenty years of modern theoretical physics.

In this time, a host of theoreticians have slowly pieced together the framework to handle the problem. This story has been told before (see September 1977 issue, p. 271). In addition to the tremendous effort which went into developing the required theoretical tools, injections of physical insight were made by Sheldon Glashow, who first applied ideas of spontaneous symmetry breaking, and by Glashow, J. Iliopoulos and L. Maiani, who extended the Weinberg-Salam model to include the weak and electromagnetic interactions of hadrons as well as leptons.

The picture we now have is of matter composed of pointlike particles — leptons and quarks. Both these kinds of particle have spin one-half, and so have two possible spin states, which we may call right- and left-handed (the neutrino appears to have no right-handed form).

The left-handed particles come in fours, each four being composed of a pair of quarks and a pair of leptons. The right-handed particles do not group in this way and remain as singlets. One set of four left-handed particles — the up and down quarks, the electron and its neutrino — would be sufficient to describe an everyday world. Additional left-handed quartets — for example the strange and charmed quarks together with the muon and its neutrino — are required to account for rarer happenings in high energy interactions.

With this neat unification scheme, one small problem remains — to find a name for it. In the same way as Maxwell's equations demonstrated the synthesis of electricity and magnetism into 'electromagnetism', the Weinberg-Salam model and associated ideas unite weak interactions and electromagnetism. As yet, nobody seems to have thought of a name for the new unity.

Steven Weinberg (left) and Abdus Salam. Two of a whole throng of theoreticians.

More data using hydrogen targets could be one of the next objectives for the beam. The investigation of electron-electron scattering, where the same behaviour need not necessarily be seen, is another possibility, although this would require an improved source of polarized electrons.

OXFORD
Well-behaved neutrinos

Most participants at the Neutrino Conference held at Oxford in July must have come away with the impression that for the moment, at least, their understanding of weak interactions in general and neutrinos in particular seems to be in good shape.

As always, there are some question marks, but the overall picture seemed much clearer than it was about a year ago. At that time there were difficulties in accounting for antineutrino results at higher energies, no parity violation at all had been seen for the neutral current outside the neutrino area and multimuon production was a bit of a mystery. Many different theoretical models were being put forward in the attempt to solve some or all of these difficulties.

The high energy antineutrino problem vanished last year in a flood of new data, and already this year new results have shown that parity looks to be violated in neutral current interactions outside the neutrino area in just the expected way. Multimuon results can now be accounted for by an unspectacular mechanism. At Oxford, the stage was already set for a well-behaved neutrino.

Inevitably there are puzzles. The excess of neutrino-electron scattering events seen in Gargamelle (see May issue, p. 151) is still there and taken on its own would point to some new physics. However at Oxford C. Baltay presented results from a Brookhaven/ Columbia experiment at Fermilab where neutrino-electron events are seen in the 15-foot bubble chamber.

Eleven such events are found in a sample of 106000 charged current interactions, a rate which agrees with the standard model and with other accumulated neutrino data. The Gargamelle experiment initially saw ten events in 25000 charged current interactions, where only a few would be expected on the basis of the standard model.

F. Romano from the Gargamelle collaboration pointed out at Oxford that a continuing search for neutrino-electron events does not seem to be coming up with events so quickly now, although the net result so far is still in excess of the standard model prediction.

Other bubble chamber experiments at BEBC at CERN and from Fermilab reported minimal numbers of anti-neutrino-electron events in their samples of charged current interaction photographs. For these samples, the standard model predicts just one or two events.

Despite having nothing directly to do with neutrinos, results from the SLAC experiment on polarized electron scattering and from the Novosibirsk atomic physics experiment (see June issue, p. 200) were described at the Conference. These displayed impressively the predictive power of the Weinberg-Salam model.

Atomic physics experiments at Oxford and Seattle Universities, together with the Gargamelle results, still do not tie in with the Weinberg-Salam predictions. However with at least some, if not all, data on the various aspects of weak interactions in accord with standard theory, theorists now seem reluctant to look outside the Weinberg-Salam picture.

Reports from the major CERN and Fermilab neutrino experiments indicated that observed violations of scaling behaviour now seem to be in broad agreement with each other and tie in with quantum chromodynamics calculations. So with SU(3) looking good for quark/parton dynamics and with SU(2) × U(1) agreeing with experiments on all aspects of weak interactions, Sheldon Glashow's summary at Oxford claimed that the symmetry secrets of Nature are within sight.

P. Bosetti presented evidence for an interesting bump between 1.8 and 1.9 GeV in the negative muon plus positive pion spectra seen coming from neutrino interactions in BEBC. After making kinematical selections, data samples using the wide band neutrino beam with a hydrogen target and the narrow band beam with a neon target both give the signal, which does not show up for antineutrinos. An invitation was issued to other neutrino groups to check out this bump, which occurs at a similar mass to the charged heavy lepton seen in experiments at electron-positron storage rings.

The overall picture from Oxford was a mass of results which agreed with current theory but only a few which didn't. On such a diet, it was easy to go away with the impression that neutrinos are well understood.

Projects galore at Brookhaven

The high energy physics / accelerator scene at the Brookhaven National Laboratory has come very much alive this year with the approval of two big new projects — the 400 GeV proton-proton storage rings, ISABELLE, and the facility for synchrotron radiation research, the National Synchrotron Light Source.

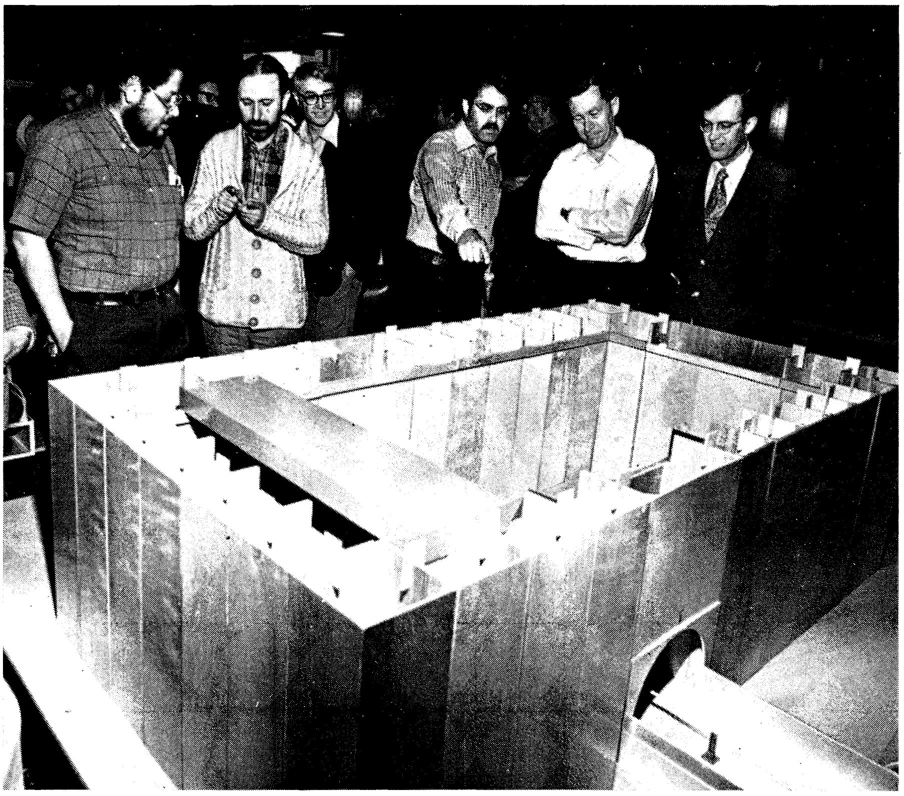
For a number of years in the 1960s, Brookhaven was the finest high energy physics Laboratory in the world. But the absence, for ten years, of further accelerator projects to improve the research facilities inevitably led to the Laboratory being overtaken by others and halted the recruitment of young new staff. However the initiation and construction of ISABELLE and the Light Source are already doing much to remedy this situation.

The ISABELLE project has been covered several times before in the COURIER, and a detailed description can be found in the report BNL 50718. The increase of the peak energy from the initial design figure of 200 GeV to 400 GeV implies collision energies equivalent to a fixed target machine of 340000 GeV! This will make whole new regions of uncharted physics accessible with high luminosity (10^{33} per cm^2 per s). Obvious topics for study are the variation of hadron total cross-sections with energy, hadron and lepton production at high transverse momentum, the search for intermediate vector bosons and for Higgs particles and continued investigation of the quark-gluon picture, with always, of course, the hope that unexpected new phenomena will be seen.

ISABELLE is specifically designed for the detailed study of these higher energy phenomena. Some signs of high energy behaviour will no doubt be seen in other systems such as the proton-antiproton colliders at CERN and Fermilab, but here available luminosities, experimental conditions and competition with other machine

Physicists at the annual High Energy Discussion Group (HEDG) meeting at Brookhaven cluster around a model of the wide-angle hall planned for the ISABELLE 400 GeV storage rings.

(Photo Brookhaven)



applications could preclude detailed investigations.

ISABELLE has two interlaced rings of superconducting magnets side by side around a circumference of 3.8 km. This economy of space compared to the Fermilab and SPS 400 GeV machines results from the higher fields available with superconducting magnets. The magnet lattice has six-fold symmetry, giving six intersection regions for experiments. The superconducting magnets, almost 1100 of them, will provide a 5 T field using niobium-titanium wire and operating at a temperature of 3.8 K. The vacuum in the rings will be about 3×10^{-11} torr. Injection will be from the existing Alternating Gradient Synchrotron (AGS) at 30 GeV using a beam transfer line drawn from the existing line serving the 7 foot bubble chamber. Circulating beams of 8 A in both rings will be built up in about half an hour.

A recent change of the proposed injection system has led to the experimental regions being rotated clockwise around the ISABELLE circumference by 30° so that injection takes place either side of a single experimental region rather than into two separate experimental regions (see diagram). This involves bending the injected beams more severely, but this does not interfere with the experimental region and is more economical.

The major technological challenge of the project is the mass-production of superconducting magnets of storage ring quality. In recent months, model magnets have confirmed that the field quality attainable is better than is needed (a few parts in 10^5). Pulse to pulse stability is well mastered and the cryogenic systems look in good shape with losses in the magnets down to 4 W.

However there have been problems in pushing the peak field as high as the design level — the magnets have been training only to around 4 T. It looks as though some small modifications in the mechanical rigidity of the magnets have produced these limitations, and the structures are now being tightened up again. The first coils wound by commercial manufacturers look good. The aim is to have the coils produced industrially and then to assemble the magnets at Brookhaven. The layout of the magnet production shop is now organized and bids are out to industry for a first 'engineering prototype' cell.

It is expected that $23 million will be made available for ISABELLE construction in the fiscal year starting 1 October. Ground-breaking for the project is planned before the end of the year, and the first portion of tunnel to be built will be that nearest the AGS. One uncomfortable feature of the construction schedule is that the timescale has been extended from five to seven years to conform with budgets which maintain a constant expenditure on high energy physics in the face of big new projects.

Input from the high energy physics community for the design of experimental areas and detection systems has been organized through the Brookhaven High Energy Discussion Group and through regular meetings of people interested in storage ring experiments.

At the end of July, a workshop was organized to discuss detectors, data handling and experimental areas. Experimental halls are presently assigned with two major facilities, one for wide angle experiments and one for small angle experiments. Two halls have been left 'open' to adapt to developments in physics and detection techniques during the long construction schedule.

New light on old problems

Facilities in the USA for research using synchrotron radiation from electron rings received a considerable boost following the 1976 'Assessment of the National Need' carried out by a panel chaired by Robert Morse. Major extensions are being carried out at the existing research centres at Wisconsin and Stanford, while a completely new facility, the National Synchrotron Light Source, is being built at Brookhaven by a group of around 50 led by Arie van Steenbergen. It will provide high fluxes of radiation both in the vacuum ultraviolet (VUV) and X-ray wavelengths.

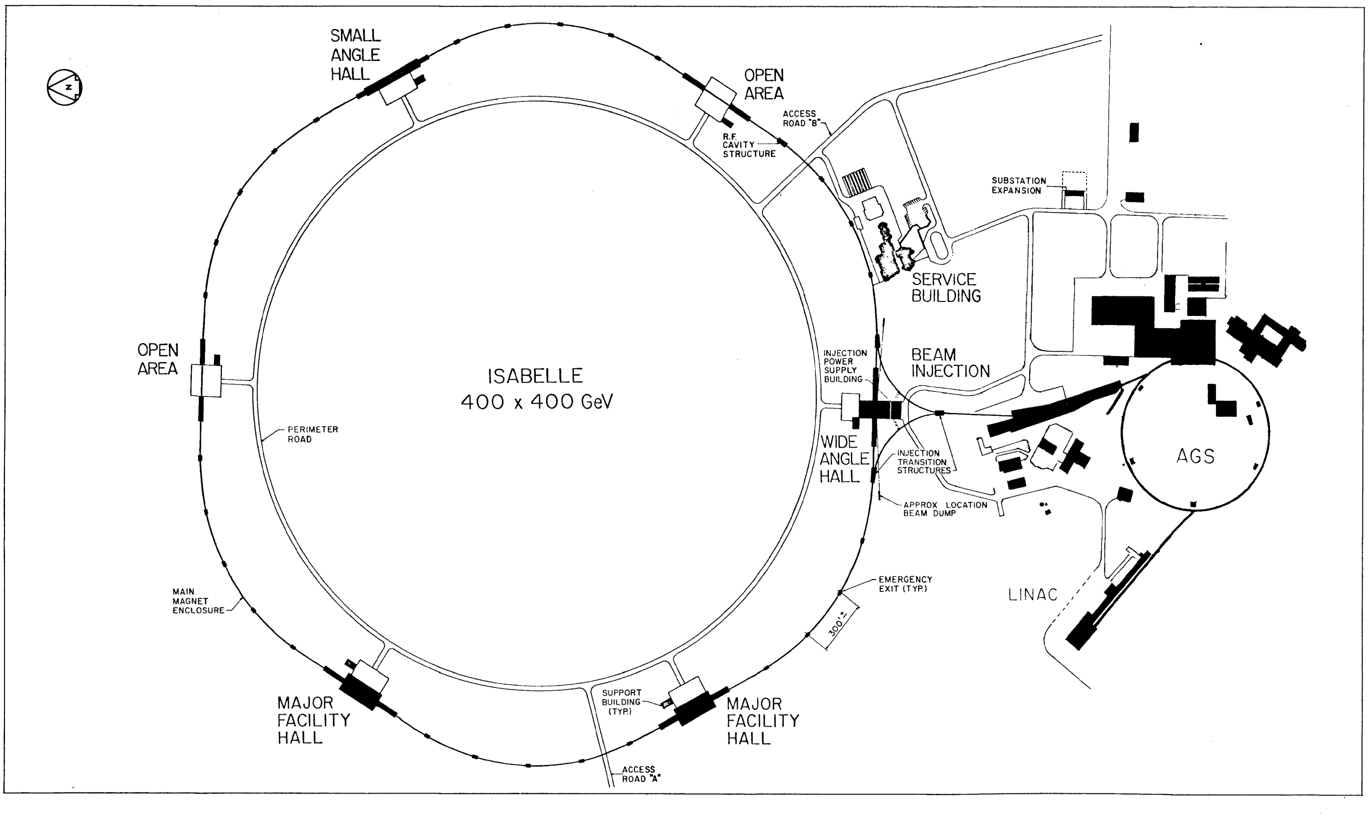
The source of the electrons is a 50 MeV linac followed by a 700 MeV booster synchrotron which feeds the VUV storage ring, operating at 700 MeV, and the X-ray storage ring, which further accelerates the electrons to 2.5 GeV. Separating the two rings allows VUV work to go on with a radiation spectrum peaked in that region and avoiding saturation of equipment by X-rays. The basic design of the system owes much to the work of the late Ken Green and Rena Chasman.

Architect / engineering work has been done. The X-ray ring design has changed from a sixfold to an eightfold structure and has been increased in size, allowing a wider spread of the emerging beam lines and more flexibility in the straight sections for the installation of 'wigglers' — portions of high magnetic field to bend the electrons more sharply and give shorter wavelength radiation. This increase in size led to an annular-shaped building. The world's most travelled linac, ex-Cambridge Electron Accelerator / Fermilab / Cornell, has arrived at Brookhaven for use in the light source and has been operated. It is now to be rebuilt.

The ground-breaking ceremony for the project is scheduled for October. It is hoped that the VUV section of the building will be completed rapidly so that construction of the smaller ring can start. The Light Source is due for completion by October 1981 at a total cost of $25 million, with funds from the Department of Energy Material Sciences Program.

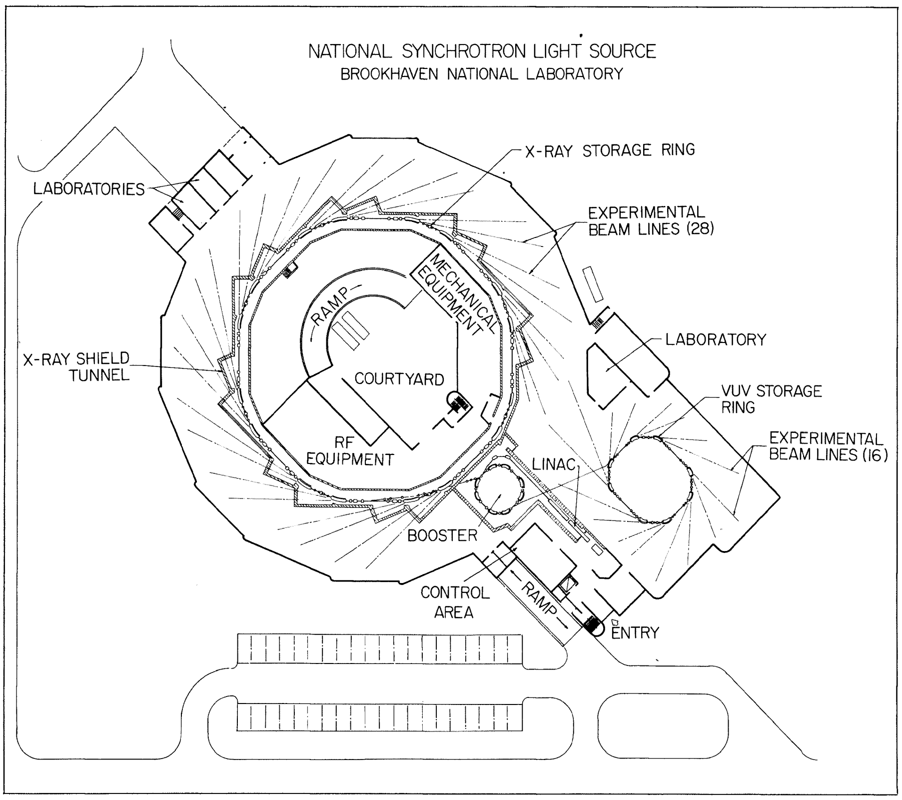
Initially, at least ten beam lines will be provided for experiments using the two rings and this number could swell to over 40 in later years. The user community is likely to be very large and varied, with as many as 500 scientists at the machine at any one time. The experiments are likely to exploit the continuous tunability of the intense radiation over a wide range of wavelengths.

In addition to the many pure research topics which can now be tackled more thoroughly than with conventional radiation sources (solid state crystallography, protein crystallography, EXAFS — the new absorption fine structure technique, diffraction studies, etc.), there are also practical applications which could prove very important, and industry is already showing an interest in the Light Source. In particular, the use of X-ray



New layout of the ISABELLE 400 GeV proton-proton storage rings at Brookhaven. Note the new configuration at the injection positions — now at a single intersection region where the hall for wide-angle measurements is to be located. Protons arrive at 30 GeV from the Alternating Gradient Synchrotron (AGS). Halls at three other intersection regions are already designated (two for major general-purpose facilities and one for small angle work) while the role of two others has yet to be decided.

New layout of the National Synchrotron Light Source to be built at Brookhaven. The building for the X-ray storage ring is now to be annular. The multitude of light channels which could eventually be drawn from the X-ray and the vacuum ultra-violet (VUV) rings are indicated.



lithography for integrated circuit manufacture looks promising, and the potential for studying catalysis has brought a lot of attention from the chemical and oil industries. The new project looks as though it will shed light on many problems in more ways than one.

From high energy to energy

People at Brookhaven have also been working on energy problems where the accelerator technology developed for the high energy physics programme could make a major contribution. The two ends of the nuclear power spectrum, fusion (using heavy ion beams to implode deuterium-tritium pellets) and fission (using intense proton beams to generate neutrons for reactor fuel breeding), have been studied.

A Heavy Ion Fusion (HIF) group under Al Maschke has been set up with a dozen people studying some of the problems which can be tackled in comparatively small experiments. They are building a small linac to check out a scheme for accelerating a high intensity ion beam through a cavity operating at 2 MHz. A 500 kV high voltage supply is expected soon, and two 4 MHz transmitter power supplies are already on site.

Several ideas to achieve economy and speed are being tried. One is a new column design without the conventional inset ion source or resistor chain. Another is the use of Gabor lenses (a solenoid surrounding a cylindrical electrode which sucks in electrons and provides focussing field gradients simultaneously in both dimensions). It is hoped to have the 2 MHz tank ready for operation within a year, and to follow it by a 4 MHz tank.

The aim of this work is to prove the 'front end' ideas of a heavy ion accelerator suitable for achieving pellet fusion. A conceptual design for such a system was recently presented by Maschke in report BNL 50817. It uses 50 mA sources of singly charged uranium ions (which looks feasible from isotope separator work) from 500 kV columns into a first bank of eight 2 MHz Wideroe-type linacs. Assuming 20 mA out of each linac, the current is taken as 160 mA stripping at 6 MeV with 50 per cent efficiency to produce doubly-charged uranium ions. The ions are fed through four linacs at 4 MHz and two at 8 MHz before the beams combine into a 48 MHz Alvarez-type linac. Final linac frequency of 192 MHz is reached at 480 MeV prior to ten turn injection into a 2 km-diameter 'multiplier' ring at an energy of 20 GeV.

The beam is then concentrated into a 200 m diameter ring, giving a total current amplification factor of a hundred, and transferred to one of eight accumulator rings. When all eight are filled, the beams are rapidly bunched beyond the space-charge limit and simultaneously fired at a pellet. The entire cycle takes about 7 ms and can be repeated fifteen times per second. The system could service a series of pellet reactor vessels in sequence.

A tentative cost estimate is $ 900 million for the accelerator and beam transport systems. The ultimate price of electricity generated by such a system will be far more sensitive to pellet costs than to fluctuations in the accelerator costs. Maschke maintains that, given the scale of energy problems now looming over the world, there is hardly any development cost which can be deemed too high.

Unfortunately these proposals are coming forward at a time when the US Department of Energy (DOE) is considering major budget cuts for its fusion programmes in fiscal years 1980 and 1981. The Head of Research, John Deutch, has been asked to look at reductions of the budgets for magnetic confinement systems from $ 325 million in fiscal year 1979 to $ 235 million in fiscal year 1981, together with comparable reductions in the budgets for inertial confinement systems, running at $ 126 million in fiscal year 1979.

Fission studies

The studies on the breeding of fuel for fission reactors at Brookhaven grew out of the work on an intense deuteron linac for producing 14 MeV neutrons to study the materials problems of fusion reactors. The concept of such a linac originated in Brookhaven, but the construction project has been assigned elsewhere.

The use of intense neutron fluxes for breeding fissionable materials such as uranium-233 or plutonium was a natural outcome of earlier neutron work. This application has been pursued by Pierre Grand of the Accelerator Department and by Jim Powell and Meyer Steinberg of the new Nuclear Energy Department, headed by Herb Kouts who has enthusiastically encouraged the work. A 'Conceptual Design and Economic Analysis of a Light Water Reactor Fuel Regenerator' (BNL 50838) has recently been edited by Grand and Kouts. This has emerged in the context of the DOE's Non-proliferation Alternative Systems Assessment Program (NASAP) which is a reaction to the worries about potential dangers in fast breeder reactors.

The accelerator under consideration is a 1.5 GeV proton linac with a beam of 0.3 A bombarding a lead-bismuth target to produce 10^{21} neutrons per second to irradiate a blanket of fertile material wrapped around the target. This material could be spent uranium from existing reactors or thorium to produce uranium-233 to burn in conventional nuclear reactors. The report points out that though the concept is still untried, it is based on existing technologies.

Fermilab looks to 1000 GeV

Installation of a superconducting Energy Doubler magnet threaded through the stands of the conventional magnets in the Main Ring at Fermilab. Some 20 of these dipoles are now in place and it is hoped to run protons through them before the end of August. A complete sector is scheduled to be in place by the end of the year.

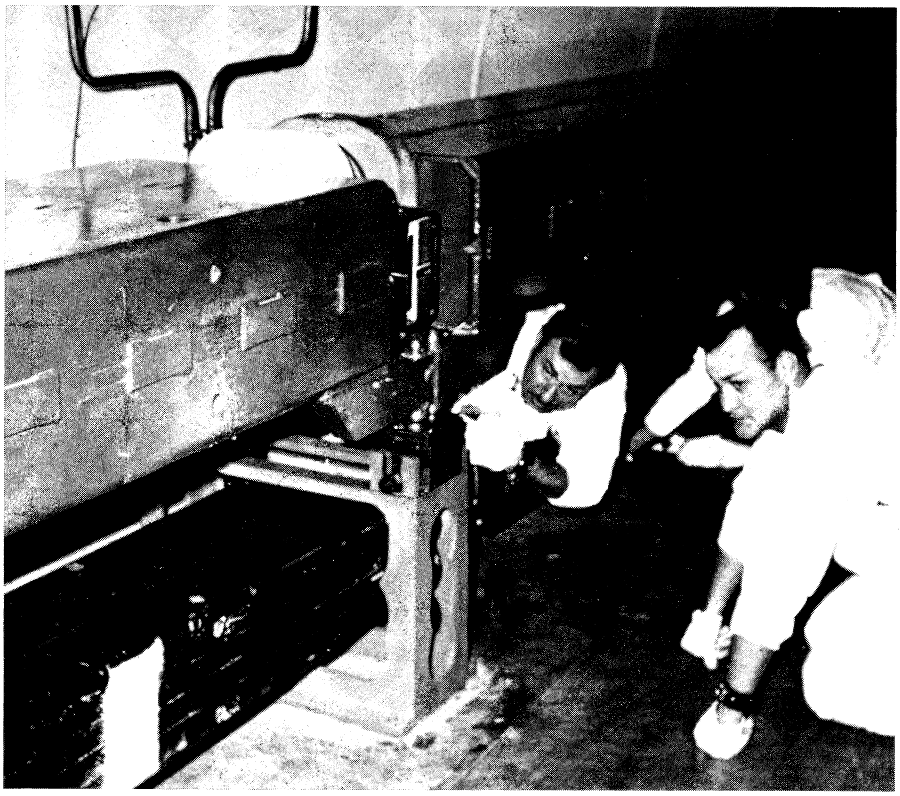
(Photo Fermilab)

The emphasis at the Fermi National Accelerator Laboratory is now very much on achieving a research programme with 1000 GeV beams in a few years' time. Work on the superconducting Energy Doubler is going ahead rapidly, limited essentially only by the rate of funding, and the upgrading of the experimental areas to take the higher energy particles is under way.

Performance of the existing machine has been poorer than anticipated this year — the main culprits being transformer failures during a bitter Winter and the disruptive effects of a series of 'fiscal shutdowns' which have prohibited long runs under steady operating conditions where the machine could settle down. 'Normal' beam intensity is around 2×10^{13} protons per pulse, but it is believed that 3×10^{13} is within reach given a settled period of machine development.

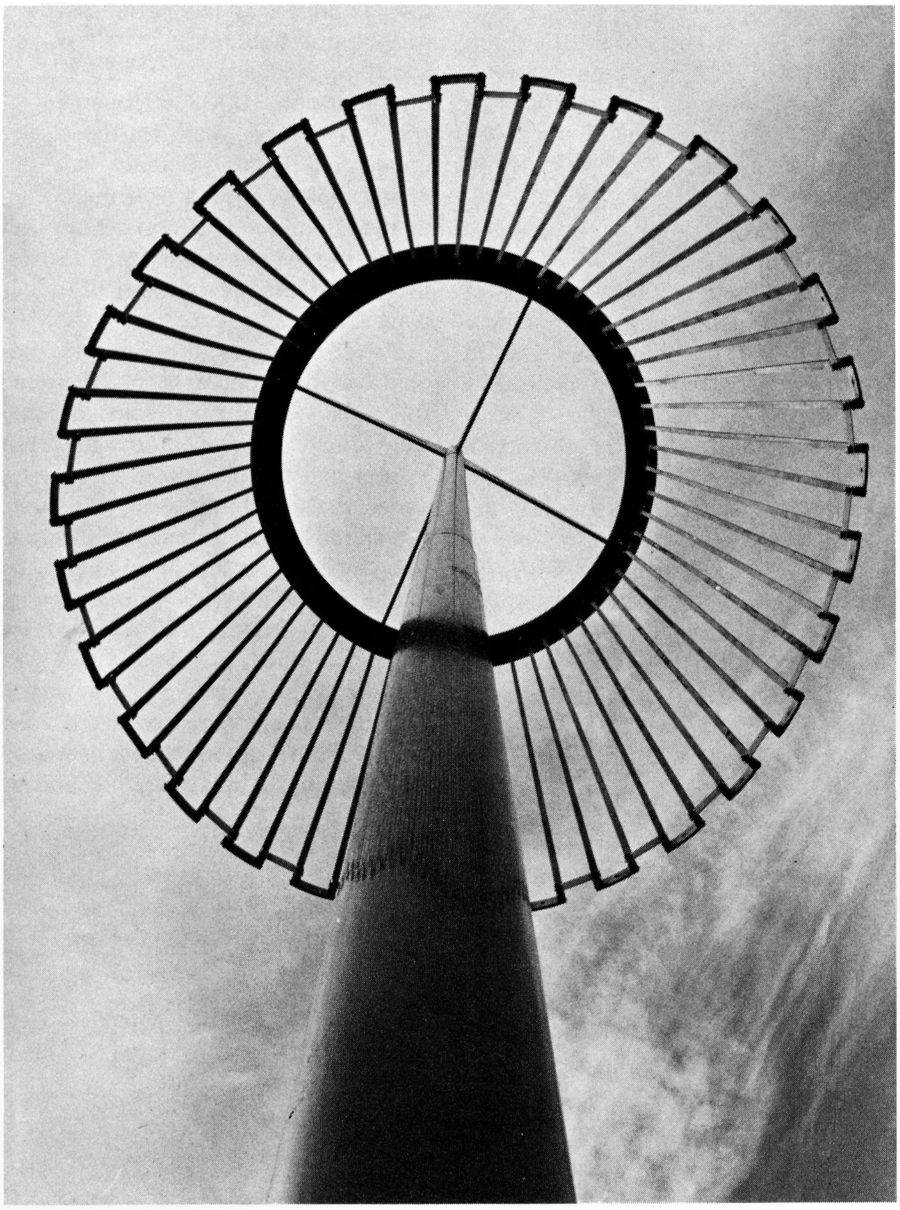
Operation with negative hydrogen ion injection is now standard and so reliable that conversion of the stand-by proton source to produce ions is being considered. The source could give 10^{14} to the Booster, but the maximum achieved so far is 3.45×10^{13}. The limitation in Booster acceptance seems to be the vertical aperture of a septum, which will be circumvented by introducing a 'dog leg'. This should allow over 4×10^{13} through the Booster, which, given the usual losses on transfer, etc., should yield over 3×10^{13} from the Main Ring.

The machine is operated normally at 400 GeV but it can now run reliably at 450 GeV. It is hoped to push this to 470-480 GeV during the Winter. Running at 500 GeV really strains the accelerator to its limits and is unlikely to become a reasonable proposition for regular operation in the near future. There is particular interest in using these highest possible energies for the neutrino experiments, where the competition from CERN has become too fierce at existing energies.



Functional structures have a habit of becoming elegant at Fermilab. This one is to dispel the heat generated in any quench of the superconducting Doubler magnets installed in the ring.

(Photo Fermilab)



In the coming months, most of the Fermilab experimental eggs are going into the neutrino basket, as the Meson Laboratory is to undergo a six-month 'Mesopause' while conversion work is begun in readiness for 1000 GeV. At the same time, beam will be split between up to three targets, and extensive construction work is under way in the Proton Laboratory.

A new neutrino detector with about 1200 tons of instrumented apparatus is coming into action for an experiment by a Caltech / Fermilab / Rochester / Rockefeller collaboration led by Barry Barish. It has a non-magnetic front section of 700 tons of 5 cm-thick steel plates interleaved with a hundred scintillation counters, each 3 m square, which collect light from the edges and can give positional information to a few centimetres through the attenuation of light in the scintillator. It is followed by about 500 tons of rather coarse-grained toroids.

Behind this detector is the 15-foot bubble chamber, now happily emerging from recent set-backs. The installation of plates to aid gamma detection was not successful because of unacceptable turbulence, and too low a helium level in the magnet cryostat caused the superconducting magnet to quench.

Both detectors hope for great new things from a refurbished dichromatic neutrino beam which is now comparable in intensity and momentum resolution to the excellent beam at CERN. The emphasis in the new beam has been on the reduction of the 'opposite sign' background (for example cutting down on the neutrinos in an antineutrino run) and on pushing the energy of the secondary particles higher than that achieved anywhere before. Initially it is operating with 300 GeV secondaries, and when the accelerator moves towards 500 GeV in the Winter, it is hoped that secondaries near 400 GeV can be produced.

Two novel detection systems in the Meson Laboratory hope to collect some data before the onset of the Mesopause. A Berkeley / Fermilab / Yale collaboration, led by Jack Sandweiss, has developed a high resolution high pressure streamer chamber to look for short-lived particles. The chamber is only a few centimetres in diameter and can measure tracks down to 10-20 μm. Using some special optics, this experiment could see charmed particles. A Fermilab / Minnesota / Rochester collaboration, led by Tom Ferbel, has brought into action the first liquid argon units to be operated at Fermilab.

The Mesopause will see the introduction of superconducting Energy Doubler magnets (the 'left bend' project) for use with higher energy beams, and a beam split so that two targets can receive protons simultaneously (rather than drawing all beams from a single target as at present). The M6 beam line will be upgraded to 400 GeV using superconducting magnets and should be fully operational in 1980. M1 is scheduled for upgrading to 1000 GeV in 1981 if the Doubler magnets are good enough to take beam over almost their full aperture.

In the Proton Laboratory, refurbishing of 'proton west' is well advanced and should be in use for experiments again in October. It has one superconducting Doubler magnet directing the beam onto the target. A Chicago / Princeton team will be looking at muon pairs and hoping to clarify their quark-antiquark composition. A Princeton team led by Val Fitch will be looking at D decays and searching for new CP violations. A Fermilab / Michigan / Athens team led by Brad Cox will be looking at muon pairs using an antiproton beam. 'Proton east' is the scene of construction work to install a multiparticle spectrometer in the photon beam. 'Proton centre' is scheduled for a hyperon beam.

The Tevatron, Doubler / Saver and Colliding Beams

The Tetravon project will double the peak energy of the accelerated proton beams at Fermilab from 500 GeV to 1 TeV. This will be done by installing a new ring of about a thousand superconducting magnets underneath the existing ring of conventional magnets.

As well as doubling the available energy, this superconducting ring will reduce considerably the energy required to power the magnets. It is estimated that one year of operations at 500 GeV, now costing about $ 15 million, could be carried out for $ 4.6 million.

The full Tevatron project requires the upgrading of the beam transfer systems and the experimental areas to take 1000 GeV protons. As there will be two rings close to each other, colliding beam experiments will be possible. Proton-antiproton, proton-proton and proton-electron schemes have been studied. The Tevatron project is estimated to cost $ 74 million of which the Energy Doubler itself is some $ 39 million.

The focus of the project is, of course, the production of the 22-foot long superconducting dipole magnets to produce fields of 4.5 T for 1 TeV beam (compared to the conventional magnets producing 2.25 T) and to give field quality good enough to accelerate and store proton beams.

Fermilab has approached this problem from virtually the opposite point of view to the ISABELLE project at Brookhaven both in terms of the magnet design (cold bore and warm iron) and the development technique. Magnets are produced according to a preliminary production design, and have been subsequently refined. This enables convincing statistics to be built up on the performance of many magnets so as to sort out the interrelated parameters affecting performance.

Well over a hundred magnets have been built, and are consistently taking currents over 19 per cent of the short sample value, achieving peak fields over 4.5 T with little training. There is no sign of 'amnesia' — once a magnet is trained to high field, it goes on to achieve high field on all subsequent pulses. Several troubles remain — the heat losses on pulsed operation are often higher than the design figure, quench protection could be further improved, and the field configuration may not yet be good enough for storage ring operation.

All these problems are being attacked. The latest series of magnets is being built with a variety of wire coatings and insulation to see if increased strand to strand resistance will reduce the a.c. losses. The 'helium inventory' is being reduced so as to cut down the amount of helium gas to dispose of in a quench, and the venting for the gas is being increased.

To help with field configuration, two changes have been made in the 'collar' which holds the 22-foot coils in place. Type IV horseshoe collars had interleaved gaps along the median plane which may have produced elliptical deformation of the coils when they were powered, and contributed to a quadrupole component in the field. In addition, fatigue tests had shown the possibility of failure after ten million cycles with this type of collar.

Type V collar has no gaps and should reduce these effects. Also the collars are now assembled from 1.5 mm-thick stampings which are stacked and welded. In the previous machined castings the necessary tolerances over the full magnet length could not be sustained. The stampings can be produced with a precision of 0.0125 mm which enables the collar to be assembled so as to limit coil movement to 0.75 mm.

The extent of the good field aperture which will be necessary for storage ring operation is debatable. However the Fermilab team believes that the magnets are good enough for acceleration to 1000 GeV and slow extraction at these energies. In the near future this will be tested directly by injecting protons from the Main Ring.

There are some 20 dipoles and five quadrupoles installed in the Main Ring tunnel and beam will be taken through these during August. Before the end of the year, a full sector (a sixth of the ring) of 129 dipoles and 32 quadrupoles will be in place. By running a different orbit, beam will be taken through the sector, bypassing that part of the Main Ring. If construction money continues to flow and the expected rhythm of magnet production is achieved, the Doubler is scheduled to be brought into operation in 1980-81.

The refrigeration system required to operate the first full sector is already in place. Work on the huge central helium liquefying plant (with a liquefying

Around the Laboratories

capacity twice that now available in the entire world) is well in advance of the rest of the project. The cold box and compressors are in place and the control system is being installed. Because it is so advanced, work has been largely halted so as to divert money and manpower elsewhere during the current fiscal year.

On the colliding beam front, most emphasis is on the proton-antiproton scheme. The small electron cooling ring was scheduled for completion on 7 August and electron cooling tests should start in October. A collaboration with Novosibirsk on electron cooling has started. Also it is hoped that a collaboration with accelerator specialists at Berkeley will begin work on stochastic cooling, since the addition of these techniques should increase significantly the available luminosity.

The cooling project is being mounted with great enthusiasm and the link with the Main Ring will soon be prepared. A colliding beam intersection region will be completed during the year to receive a solenoidal detector being developed by a collaboration led by Alvin Tollestrup.

CORNELL
CESR progress

Construction of the Cornell Electron Storage Ring, CESR, is going ahead rapidly so as to begin physics with colliding beams soon after the start-up of the PETRA storage ring at DESY. CESR aims to fill the energy gap between the existing SPEAR (SLAC) and DORIS (DESY) rings, which are below 5 GeV per beam, and the imminent PETRA and PEP (Berkeley / SLAC) rings, which will have their peak luminosities around 15 GeV per beam.

CESR will have its highest luminosity (10^{32} per cm^2 per s) at 8 GeV per beam, but to begin physics quickly, it will come on next year at 5 GeV. Of obvious interest is the centre-of-mass energy region around 10 GeV, where colliding electron-positron beams are likely to yield much more detailed information about the new upsilon states than is possible with fixed target machines. CESR was authorized for construction at a total cost of $20 million during fiscal years 1978-80 (October 1977 to September 1980). It is being built in the tunnel of the 12 GeV Cornell electron synchrotron which is to be used as injector. This keeps down both cost and construction time.

The project required an upgrading of the linac to provide sufficient positron beam intensity. This has been done by adding a piece of the former Cambridge Electron Accelerator linac on the front end, and this is now installed and working. Two more cooling towers are being provided to take the heat load of the additional magnets and r.f. cavities and, of course, a complete new ring for beam storage is being built.

The ring has 156 dipoles, 98 quadrupoles, 74 sextupoles and some special magnets spread around the 770 m circumference. Most of them are already installed, though not all yet

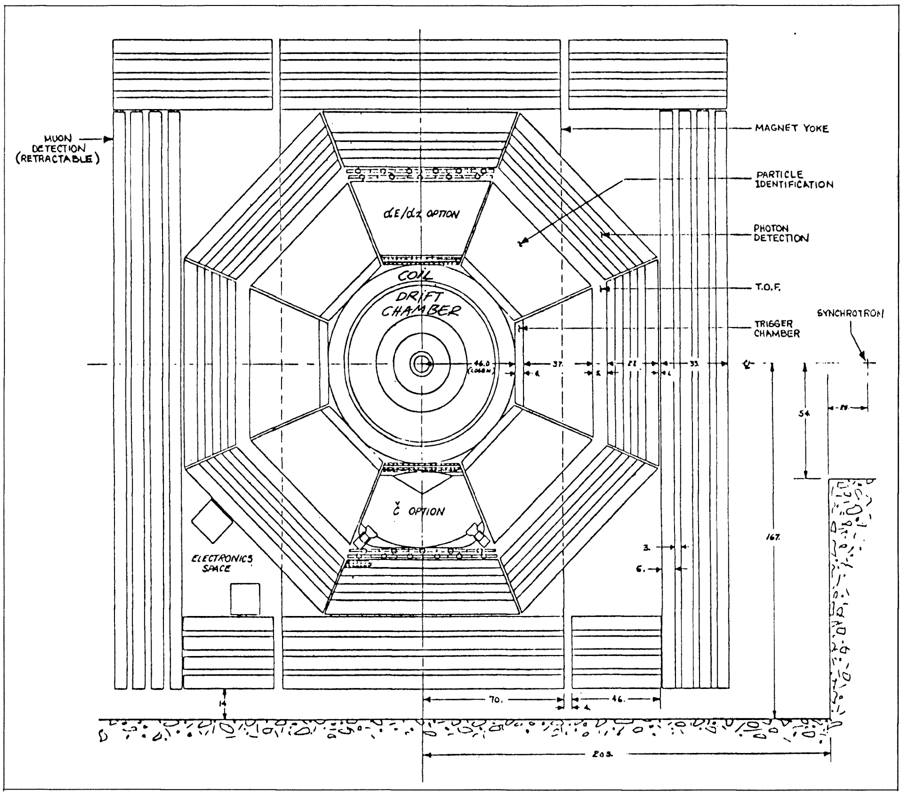


Diagram of the large magnetic detector, about 3 m long, being built for the Cornell electron-positron storage ring CESR by a Cornell / Harvard / Rochester / Rutgers / Syracuse / Vanderbilt collaboration.

with their coils in place. The dipoles provide a 3 T field for 8 GeV beams, except for a few magnets which handle abrupt bends. Vacuum chambers, with a cross-section like the PETRA and PEP types, are now available in quantity. To ensure a beam lifetime of some ten hours, a vacuum of 10^{-8} torr is required. A prototype r.f. cavity has been built and operated, and the two final versions are under construction. These are the 14 cell cavities operating at 500 MHz to provide 2 MW peak power to compensate for the losses at 8 GeV.

Work on superconducting r.f. cavities has not stopped at Cornell, despite the pressures of CESR construction. A different cavity structure is being tried to circumvent the multipactoring (breakdown) problems encountered with the 'muffin-tin' structure from which good results were obtained several years ago. The new structure, called the 'easitron', has protruding parallel bars rather than the orthogonal bars of the 'Jungle Jim' structure used in the conventional synchrotron cavities. The hope is that the electrons will find the electric field configuration so complicated that they will never work out how to multipactor ! Peter Kneisel from Karlsruhe, is joining the Cornell effort for a year.

To achieve the design luminosity, it is necessary to have a circulating bunch containing 1.5×10^{12} particles in each beam. The difficulty is, of course, to attain the positron intensity, and an injection scheme, known as 'vernier phase space compression' has been invented by Maury Tigner. Positrons produced in the linac are injected into the synchrotron at 200 MeV, accelerated to storage ring energy in 60 bunches and transferred to CESR. This is repeated at 60 Hz until the required circulating intensity is reached.

Bunch number one is then deviated back through the synchrotron and is advanced in phase before rejoining CESR, due to the different path length it follows relative to the storage ring. Bunch two follows the same route, going an additional circuit around the synchrotron so that it joins bunch one on reinjection into CESR. Bunch three goes round three times, and so on, until all 60 bunches are brought together into a single bunch. The total injection process for positrons takes about two seconds.

An alternative accumulation technique has been worked on by R. Talman, using longitudinal phase space stacking, and this could be used if the vernier method initially proves difficult to master. It takes about three times longer than the vernier technique. Tests on beam transfer between a protosector of CESR and the synchrotron were successfully carried out at the end of last year.

The two circulating bunches obviously can collide in two locations around the ring. The main experimental region will be in the South Area, where there is 5.3 m of space between CESR and the synchrotron, by introducing a bulge in the storage ring orbit. An eight-metre square pit has been dug five metres below the beam height to accommodate a large general-purpose magnetic detector being built by a Cornell / Harvard / Rochester / Rutgers / Syracuse / Vanderbilt collaboration to look at, for example, electron-positron annihilation cross-sections and the leptonic decay of new particles. The detector will have good energy resolution for photons and good particle identification capabilities over a wide angular range.

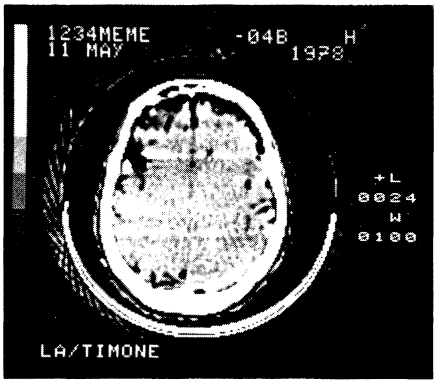
Initially, the detector will operate with an aluminium solenoidal coil 3 m long, now ready, but a thin superconducting coil may replace it later, providing a 1.5 T field inside the 1 m radius solenoid. Inside the coil and immediately around the beam pipe is a cylindrical proportional chamber (built by Syracuse) to give the interaction coordinate along the beam direction. Then there is a large 1 m radius cylindrical drift chamber (Cornell) with thousands of sense and field wires, like the SLAC Mark II detector, to provide positional accuracy down to 120 microns. This impressive unit is scheduled to be strung with wires at the end of September.

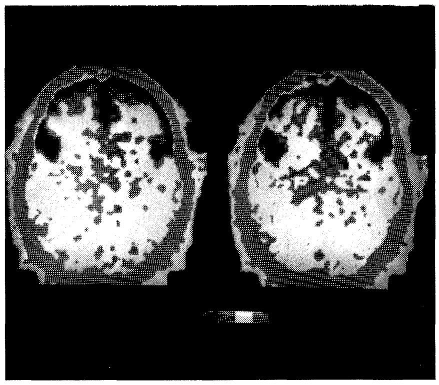
Outside the coil is another proportional chamber (Syracuse) followed by particle identification modules, 1 m deep, a time of flight unit (Harvard), gamma detectors, again 1 m deep (Rutgers) and an iron shield interlaced with drift chambers for muon detection. The detector outside the coil is in independently-removable octants. Initially two of these will have Cherenkov counters (Harvard) as the particle identifiers and six of them will have dE/dx detectors (Cornell / Vanderbilt) operating at five atmospheres pressure and with 120 sampling sections as the particle identifiers. An octant is scheduled to be assembled in the Autumn.

In the North Area the space available for installation of a detection system is not so great. It will be used by a Columbia group with a sodium iodide / lead glass system and no magnetic field, with the emphasis obviously on photon detection.

Some dismantling of the synchrotron was necessary for the installation work with the new storage ring. Reassembly will be complete by the end of October so that it can be operated again. A month later there will be tests of injection and ejection into and from the North section of CESR, which will be ready for beams. The complete ring will be ready to receive its first particles in the spring of next year. This is a remarkably fast construction schedule and a credit to the motivation and ability of the comparatively small group at Cornell led by Boyce McDaniel.

CERN
Nuclear radiography looks good





Comparison of radiographs of slices through a human head using X-ray tomography (left) and the new nuclear scattering radiography method (right). Although the nuclear method appears to show details not visible on the X-ray scan, their authenticity has still to be checked out. The X-ray scan, which can only deal with one slice at a time, requires a dose of 2 rad while the proton scan, which amasses data on the whole head, needs a dose of only 0.3 rad.

In an important spin-off development from high energy physics instrumentation techniques, results from a CERN / Saclay collaboration have clearly demonstrated the possible usefulness of Nuclear Scattering Radiography (NSR) for medical and biological work.

These results show that the detectors and instrumentation developed for NSR have now reached the stage where the potential advantages of NSR over conventional X-ray techniques for clinical examinations are within reach.

In principle NSR has the major advantage of being able to handle the examination of a three-dimensional object in a single irradiation. Conventional X-ray tomography supplies information on a two-dimensional slice, so that three-dimensional examinations can only be achieved by exposing successive slices.

However different types of radiation have different interactions and it was not clear, for a given acceptable dose, how the information obtained using the two methods could be compared. Recent experiments with human tissues now show that the potential advantages of NSR techniques are attainable.

The problem with NSR was that existing equipment could not record and handle data fast enough to achieve a realistic exposure time. However recent progress in instrumentation shows how to handle the flood of data during the short irradiation periods permitted in clinical work.

Instead of relying on absorption effects, as in X-ray work, Nuclear Scattering Radiography exploits the wide angle scattering of an incident proton beam with the nuclei of the target material.

Each scattered particle is picked up by multiwire proportional chambers surrounding the subject and its position measured. This enables the position of the collision with the target nucleus to be determined. By amassing sufficient data from these scattered particles, the nuclear density of the target is obtained, so revealing the inner structure of the target. With an on-line computer, the data from the same irradiation can be used to obtain different 'views' of the subject from different angles or at various depths.

Another advantage of the NSR method is its ability to distinguish between different types of nuclei. This is done by detecting subtle differences in scattering behaviour such as the variation between the true elastic scattering of protons on hydrogen and the quasi-elastic scattering of protons with nuclei, which is affected by the Fermi motion of the constituent nucleons. To enable the method to be used clinically, the detectors and instrumentation have to be able to handle the data on the scattered particles as quickly as possible. An optimum performance figure for realistic operation with a patient would be about 10^5-10^6 scattering events per second — much faster than anything possible using conventional laboratory equipment. The aim is to take data in just a few minutes and obtain a full analysis so that a diagnosis can be made within about five or ten minutes. This poses special problems for memory and for readout.

To achieve the required speeds, special purpose hardware is required to calculate the coordinates of each scattered particle in a fraction of a microsecond, and this information is stored in a buffer before being passed to a PDP-11 computer.

This important project is under way using a Saturne beam at Saclay following successful initial tests with human tissues at the CERN PS. Radiographs have been obtained of a succession of slices of a human head preserved in formalin, and compared to the same slices taken with an EMI X-ray scanner at Marseille.

The radiation dose in the proton radiography is only 0.3 rad against 2 rad for that of X-rays. The new instrumentation aims at handling data from the same dose of protons in a few minutes and then comparing the two methods in a series of clinical examinations using living patients.

The main drawback of the method is the restricted availability of proton beams. However NSR requires proton beams which are crude by high energy physics standards — only about 1 GeV in energy and with effectively no requirement for energy resolution. This contrasts with the need for highly monochromatic beams in proton absorption radiography — another candidate method for making clinical examinations.

Such a proton machine could be built relatively cheaply or made economically by converting an existing machine. It would enable a dozen or so patients to be examined simultaneously, and could provide a valuable additional facility for clinical diagnosis and research to complement the capabilities of X-ray tomography equipment. Before any large-scale NSR facilities can be built, the relative merits of NSR and X-ray methods have to be compared in detail. This is the objective of the next round of experiments.

Hyperon beams

One of the unique features of the experimental programme at the SPS 400 GeV proton synchrotron is the high energy hyperon beam used by a Bristol / Geneva / Heidelberg / Orsay / Rutherford / Strasbourg collaboration to study rare baryons such as the omega minus.

The discovery of the omega minus at Brookhaven in 1964 provided the missing link which finally established the SU(3) model as the definitive classification for hadrons. However up to this year, a total of only about 160 omegas had been seen anywhere. These scanty results gave conflicting measurements of the lifetime of the particle and very little information about decay modes.

Initial runs with the SPS in 1977 showed that a significant flux of omegas was being produced, and now the first results are available. With the SPS hyperon beam, some 1700 examples of omega decays have been seen, giving a tenfold increase in the available world statistics on this rare hadron.

This is incidentally the first time that omegas have been detected electronically, and the first time they have been seen in proton-proton collisions. Previous bubble chamber experiments used meson beams (usually kaons).

Hyperons are produced when a 210 GeV/c proton beam from the SPS strikes a primary target. Magnetic fields separate out the forward-produced hyperons in an eight per cent momentum bite centred around 98.5 GeV/c. For every 3×10^{10} protons received on target, about 4000 sigmas, 400 ksis and 0.1 omegas are produced, and a DISC counter selects out the different types of particle.

The omega decays weakly in a number of different ways, the most common of which (accounting for about two-thirds of the decays) produces lambda particles and negative kaons. The other main decay modes produce ksi particles and pions.

The lifetime of the omega has been determined using the predominant lambda / kaon decay mode, and a sample of 1400 events shows that the omega lives for 0.82×10^{-10}s.

No examples have been found of decay into a lambda and a pion, which would represent a jump in strangeness of two units, forbidden by conventional selection rules. A few candidate events have been found which might correspond to semileptonic decay producing a ksi, an electron and a neutrino. Provisional results indicate that these semileptonic processes represent about one per cent of the total decays.

The experiment makes complete measurements on all the particles produced through the lambda / kaon decay mode of the omega (the lambda subsequently decays into a proton and a pion). By using information from the lambda decays, physicists can determine the asymmetry of the decay of an omega about its spin polarization axis without having to worry directly about the polarization of the omega. This asymmetry parameter measures the level of parity violation in the decay.

Very little asymmetry is found, and the result agrees with theoretical predictions. Previous attempts to measure the angular distributions of this decay used only very small samples and had significant errors.

One of the next tasks for the experiment is to determine the spin of the omega. This is predicted by the SU(3) model to be 3/2, but has in fact never been accurately determined. If the 3/2 prediction is not confirmed, this will be a gigantic step backwards for the SU(3) model.

This experiment mirrors the fast rate of development in high energy physics. Just fourteen years ago, the omega minus was a curiosity, and it required a considerable experimental effort just to observe a single particle in a bubble chamber. Now these rare hyperons can be focussed into beams and monitored by electronics !

Antiprotonic hydrogen turns up

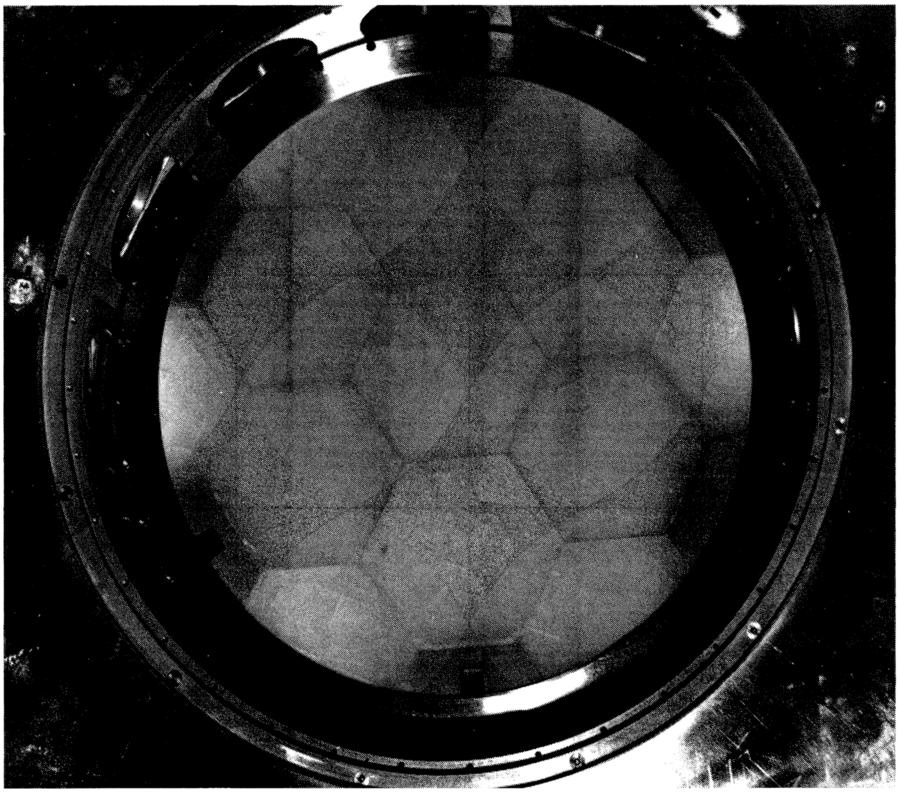
A Daresbury / Mainz / TRIUMF collaboration working at the 28 GeV CERN Proton Synchrotron has made the first observations of spectral lines from antiprotonic hydrogen — atoms in which a proton and an antiproton orbit round each other under the influence of the electromagnetic force.

The study of such exotic atoms in which the usual orbital electrons of everyday atoms are replaced by heavier negatively-charged particles, such as pions or kaons, has long been a speciality at CERN. These atoms are formed when beams of the negatively-charged particles are steadily attenuated in a target, and particles eventually move slowly enough to be captured by individual atoms.

Although these exotic atoms are governed by electromagnetic forces, if the heavy negative particle is a hadron there are additional effects due to strong interactions. These can become appreciable, especially for the inner

Cherenkov counter of diameter 60 cm, made up of a mosaic of silica aerogel blocks 5 cm thick, is seen here mounted during vibration tests designed to assess its suitability for use under space research conditions.

(Photo Saclay)



atomic orbits where the orbiting particle passes close to the nucleus. Comparison of the behaviour expected from electromagnetic effects alone with the observed details of the spectral lines therefore gives important information on the strong interactions.

Spectra from antiprotonic atoms were first observed at CERN back in 1970, and since then a range of different antiprotonic atoms has been studied. These experiments have concentrated on the use of solid and liquid targets to capture incoming antiprotons. For liquid hydrogen, the Stark effect due to the electric field of adjacent nuclei affects the exotic atomic energy levels, which frequently disappear through strong interaction annihilations. This makes difficulties for the observation of spectral lines from the simplest antiprotonic atom of all (sometimes called 'protonium').

The Daresbury / Mainz / TRIUMF collaboration used gaseous hydrogen to minimize Stark effects and used a special X-ray detector with large angular acceptance and low threshold. The observed spectral lines are in the X-ray region, with energies typically in the range 2 - 3 keV, and are due to transitions to the 2P level (one rung of the energy level ladder up from the 1S ground state). The observations show that this level decays by strong interaction annihilations at least 10 times more frequently than electromagnetic radiative decay to the 1S ground state.

There is much more work to be done to establish evidence of transitions to the 1S ground state and details of the spectra become clear enough for the effects of the strong interaction between single protons and antiprotons to be deduced, but the door is now open. The results would be of special interest for the investigation of quasi-nuclear proton-antiproton bound states, in which the two particles are stuck together by strong interactions into a 'baryonium' state (see July / August 1977 issue, p. 243).

The discovery of these spectral lines from antiprotonic hydrogen (together with the corresponding lines from antiprotonic deuterium) was one of the results announced at the European Symposium on proton-antiproton interactions held at Strasbourg in June. At this meeting, there was also much interest in the future possibilities using the intense antiproton sources now being planned at CERN and Fermilab (see April issue, p. 113).

As well as being used for feeding high energy proton-antiproton colliders, such sources could also provide a copious supply of low energy antiprotons for other types of experiment. Thus antiprotonic and other exotic atoms could become many orders of magnitude more plentiful and provide an important new source of information on the details of the strong interaction to supplement the data obtained from scattering experiments with hadrons.

SACLAY Manufacture of silica aerogel

Work on silica aerogel has been in progress at Saclay since 1972, and now has reached a stage where a semi-industrial manufacturing plant has been established producing appreciable quantities of the substance.

Silica aerogel is of particular use in the manufacture of Cherenkov detectors. Its refractive index can be controlled by the manufacturing process to be in the range 1.01 to 1.06. This makes it possible to build Cherenkov detectors using solid media instead of the traditional gases, avoiding problems of diffusion and particle absorption by the walls of the detector vessels.

The manufacturing process is particularly delicate and requires the use of high pressure techniques. Up till now only small production systems have been built, notably at Saclay, providing several litres of aerogel per week.

The manufacturing process has now been established at a semi-industrial level at the French Atomic Energy Authority's centre at Cadarache by adapting existing installations. The manufacturing process uses dangerous substances and large quantities of methanol under high pressures (210 atmospheres) and at a temperature of 300°, requiring considerable safety precautions.

Initial trials proved satisfactory, and a production level of some 50 litres per week has been attained — sufficient to supply the needs of outside users. Further details are available from J.J. Engelmann, Service d'électronique physique, Centre d'études nucléaires de Saclay, Gif-sur-Yvette, France.

Aerogel Cherenkov counters have been constructed at Saclay for an experiment by a Rome / Saclay / Vanderbilt collaboration now being prepared for the CERN 28 GeV proton synchrotron. This experiment will look at the reaction $K^-d \rightarrow K^+ +$ anything at 1.4 GeV/c for signs of dibaryon states carrying strangeness.

Each counter for this experiment consists of a light diffusing box 'seen' by two photomultipliers. They are effectively screened by two aluminized glass light guides located between the box and the photocathode. Two beam counters measuring 100 x 75 x 60 mm and a spectrometer counter measuring 300 x 150 x 140 mm have been manufactured, together with the required five litres of silica aerogel.

Each beam counter is 5 cm long, and uses 44 mm-diameter XP 2020 photomultipliers. The light guide of the third counter is 10 cm long and works with 110 mm-diameter XP 2041 photomultipliers. The indices of the aerogels are 1.05 and 1.07. The efficiency was measured above the Cherenkov threshold. With a gel of thickness 6 cm, 13 photons are collected in the beam counters and 8 in the large counter.

It has also been found that silica gels can replace water in Cherenkov counters. As they are immersed in methanol during manufacture, their index is very close to that of water (to within 1 %). The self-supporting structure of this 'alcoogel' which retains the methanol in the microcells by capillarity allows it to be held, unlike water, in a very thin-walled container. A glass prototype filled with 14 litres of alcoogel has been made. The detection area is 700 x 200 mm over a distance of 10 cm. The glass walls are 0.8 mm thick.

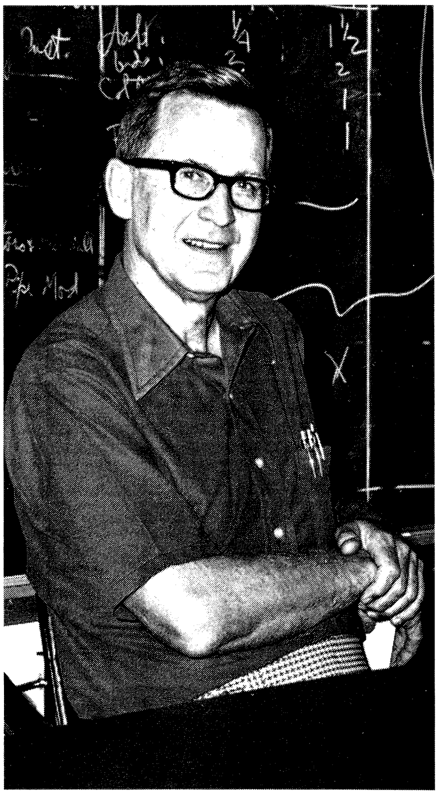
People and things

Bob Wilson steps down

On 17 July, Philip Livdahl became Acting Director of the Fermi National Accelerator Laboratory until a new Director is appointed to succeed Professor Robert R. Wilson.

As we reported in our March issue, Bob Wilson tendered his resignation on 9 February in protest at what he saw as inadequate funding of the present physics programme at the Laboratory and inadequate support for the construction programme of the superconducting 1000 GeV Energy Doubler. The Board of Trustees of the Universities Research Association, which operates Fermilab, accepted his resignation on 15 February.

Since then, representations in Washington have succeeded in introducing 'new' money, probably to the extent of around $10 million, into the likely Fermilab budget for fiscal year 1979 — an amount which



Phil Livdahl, new Acting Director at Fermilab.

Professor Wilson sees as meeting the minimum requirement for the continued health of the Laboratory. The Board of Trustees at a meeting on 10 July decided to continue its search for a new Director. Bob Wilson is to move to the University of Chicago where he will take a Chair in the Humanities.

Norman Ramsey, Chairman of the URA, in a statement issued on 17 July, said 'Robert Wilson has created a great institution at Fermilab. His brilliant personal contributions to the accelerator, the research programme and the beauty of the structures can be found everywhere and will remain as monuments to his genius. The end of his period as Director is a cause of great sorrow for all of us'.

Phil Livdahl has been at Fermilab since 1967, having previously worked at Berkeley and Argonne. He held senior positions in the construction of the 200 MeV linac, as Head of the Accelerator Department, and more recently in the Energy Doubler programme. He is a person of great experience, maturity and personal charm and will surely carry the support of his colleagues in his difficult task.

New President of CERN Council

At the CERN Council meeting in June, Professor Jean Teillac of France was elected President of the CERN Council, filling the post left vacant after the death of President-elect Bernard Gregory, last December.

Jean Teillac, 58, is Professor at the Pierre et Marie Curie University of Paris, and since 1975 has been Haut Commissaire for atomic energy in France. He is also President of the Council of the Joint European Torus (JET) project.

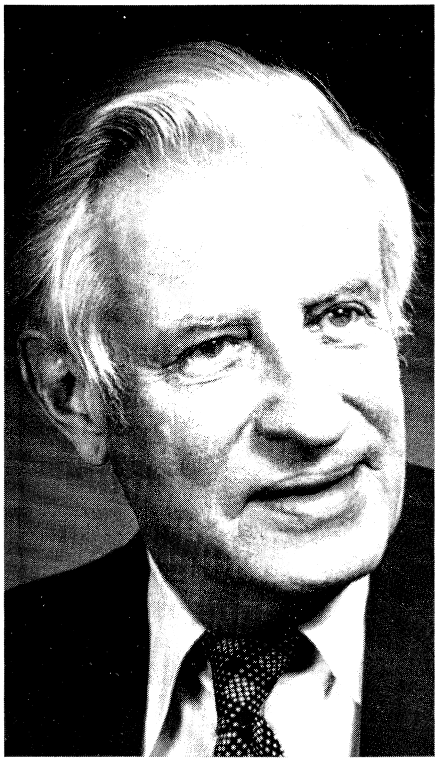
Prof. Teillac comes to CERN at an exciting time when the full potential of the SPS 400 GeV proton synchrotron is being realized. Also the recent success of beam cooling experiments at CERN has led quickly to the new proton-antiproton project in which the SPS will soon take on a new role as a colliding beam machine, accelerating beams of particles and antiparticles in opposite directions.

The aim is to bring the proton-antiproton collider into operation in 1981, so in the space of just a few years opening the door to a whole new realm of high energy physics without having to build any major new machines.

At the same time, Europe is eagerly looking to the future and formulating its accelerator plans for the end of the 20th century. The next few years could see these preliminary ideas crystallize into more definite plans. Prof. Teillac's period of office should certainly be an eventful one for CERN and Europe.

Jean Teillac, new President of CERN Council.

John Blewett.



On People

John Blewett formally retired from the Brookhaven National Laboratory on 30 June, though he will continue to act as consultant. John has had a very distinguished career in accelerator physics with major contributions to the design and construction of the world's first proton synchrotron (the 3 GeV Cosmotron), the CERN 28 GeV PS, the Brookhaven 33 GeV AGS and (with Fred Mills) initiating the 400 GeV ISABELLE proton-proton storage ring project. More recently he has led studies on energy programmes. It is fitting that this year he is working on Brookhaven's new project, the National Synchrotron Light Source, since his paper published in 1946 paved the way for the use of synchrotron radiation as a standard laboratory tool. He has a long list of publications to his name and was editor of the journal 'Particle Accelerators' from its inception.

John Blewett's expertise and thoughtful personality led to his being frequently consulted on national issues involving accelerator technology. He has been an important figure on the high energy physics scene for many years and it is good to know that he will still be active at Brookhaven.

Appointments at Fermilab: Linc Read, happily recovered from a serious car accident, is Head of a newly-formed Safety Section. Tom Kirk has been appointed Head of the Neutrino Department with Shigeki Mori as Associate Head. Ernie Malamud has been appointed Head of the Meson Department with John Elias as Associate Head. Paul Mantsch has been appointed Head of Research Services with Marvin Johnson as Associate Head.

Louis Rosen (below, right) receiving his bolo tie during a picnic on 10 June to celebrate his 60th birthday. With him in the picture is Darragh Nagle. Louis is an enthusiastic and highly able promoter of nuclear physics for whom many people have great affection. This regard was very evident at the picnic.

(Photo Los Alamos)

The top management of the ISABELLE project at Brookhaven, led by Jim Sanford, has been completed by the appointment of Parke Rohrer as Head of the Construction Division. Among many previous assignments, Parke was General Manager of DUSAF, the firm responsible for buildings and services at Fermilab. His deputy is Paul Mohn who has held important civil engineering positions at Brookhaven for many years. The Department of Energy has appointed V. Witherill as ISABELLE project manager.

Herman Winick and Mel Schwartz of Stanford have demonstrated their faith in the future of synchrotron radiation facilities in the most unmistakable way by participating in the setting up of the new Electron Storage Ring Corporation, to market storage rings for commercial applications.

Louis Rosen's friends and associates celebrated his 60th birthday in style with a picnic barbecue on the LAMPF grounds. This was an informal tribute to the man who has led LAMPF from its inception in 1962. The picnic was organized through the LAMPF Users' Group under John Allred, and Darragh Nagle acted as master of ceremonies. Louis was presented with a handsome bolo tie engraved with a Southwestern Indian motif, although a second look at the design shows it to be a Feynman diagram for pion-nucleus scattering. A more formal tribute is being arranged for the Users' Group Meeting during the week of 13 November, when a series of seminars with distinguished speakers will cover areas of research to which Louis Rosen has contributed.

First recipient of the Wolf Prize for Physics is Chieng Shiung Wu, the woman who first showed that parity is not conserved in beta decay. The prize, presented at a special ceremony at the Israeli Knesset, is in recognition of scientists who have made great contributions to humanity. Madame Wu was honoured for her work on the mechanism of beta decay in particular and on weak interactions in general. Her famous 1956 experiment showed that the direction of beta emission was strongly correlated with the spin of the decaying nucleus.

Saturne II switches on

On 27 July, particles were accelerated to 1 GeV in the substantially-rebuilt Saturne proton synchrotron at Saclay. Now called Saturne II, the machine appears to be performing well. In a future edition, we hope to include a full report of the start-up of operations with this revamped accelerator.

Synchrotron radiation meet

The Eleventh Annual Synchrotron Radiation Users' Group Meeting will take place at the University of Wisconsin on 23 and 24 October, just a few days before the Stanford Users' Meeting on 26 and 27 October. Further information on the Wisconsin meeting from Ednor M. Rowe at the Synchrotron Radiation Center, Madison, and on the Stanford meeting from Herman Winick at the Synchrotron Radiation Laboratory, Stanford.

Accelerator Physicist

The Stanford Synchrotron Radiation Laboratory (SSRL) expects to have an opening early in 1979 for an accelerator physicist to work primarily on the development of SPEAR as a synchrotron radiation source. The position also offers the opportunity for research with synchrotron radiation. SPEAR will be available for dedicated synchrotron radiation research operation for 50 % of its operations time starting approximately in early 1980. Development topics include wigglers, low emittance operation, high stored current, orbit control and steering of synchrotron radiation beams and working with experimenters to fully exploit SPEAR capabilities. The successful candidate will interact strongly with the SLAC storage ring group as well as the SSRL staff and users. Please send curriculum vitae and the names of three references to

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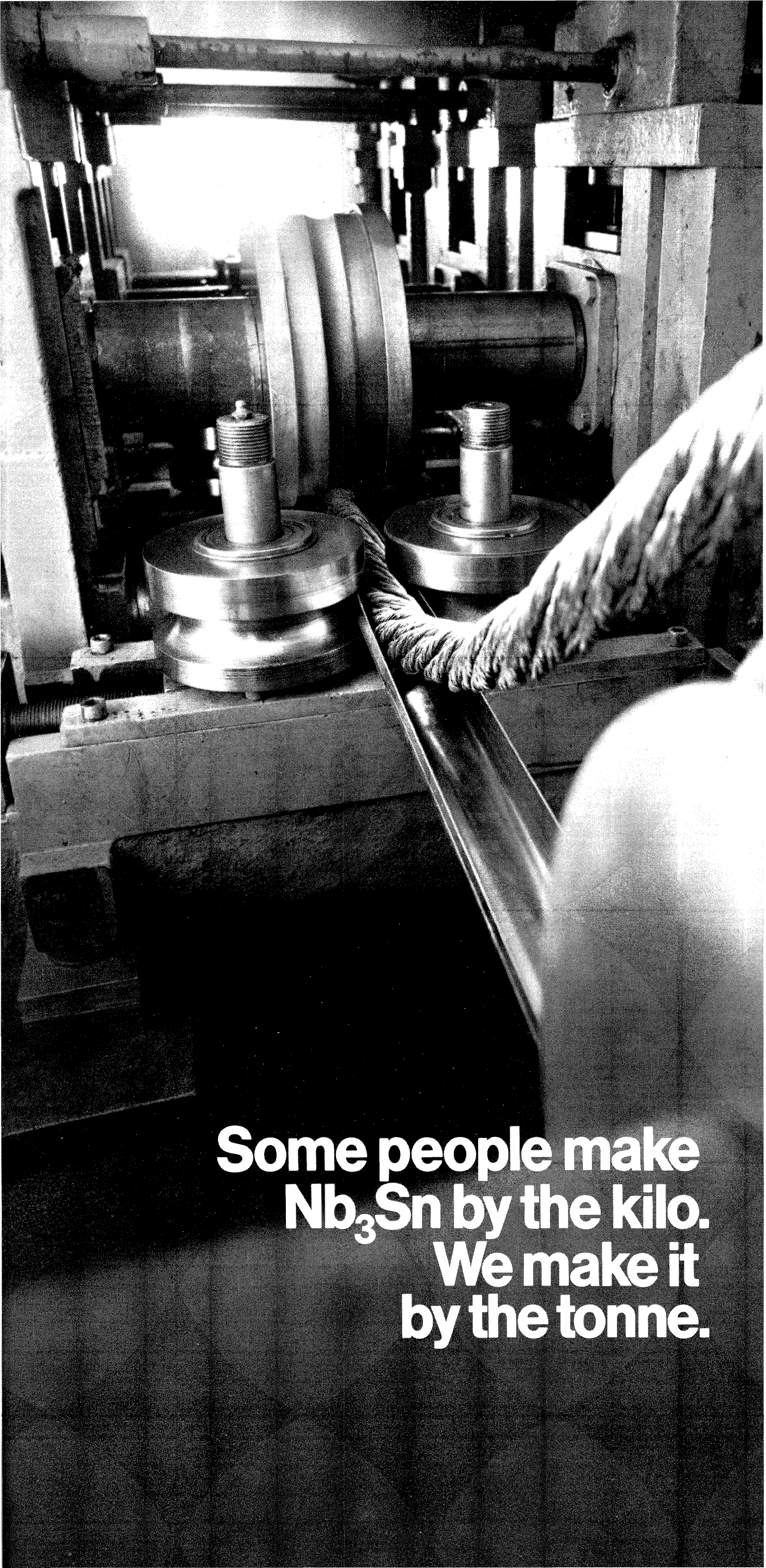

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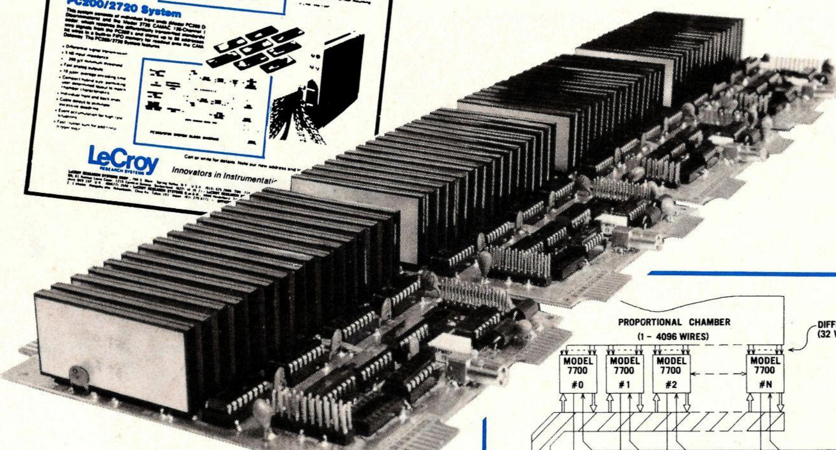

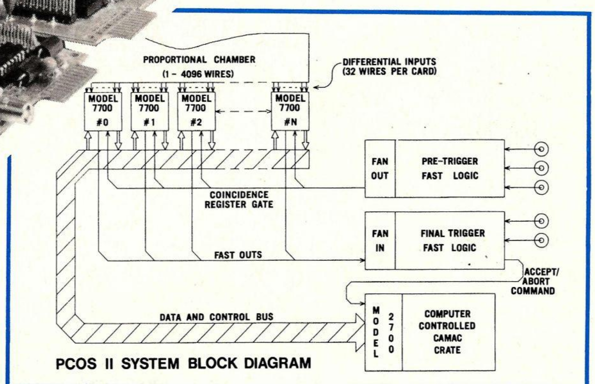

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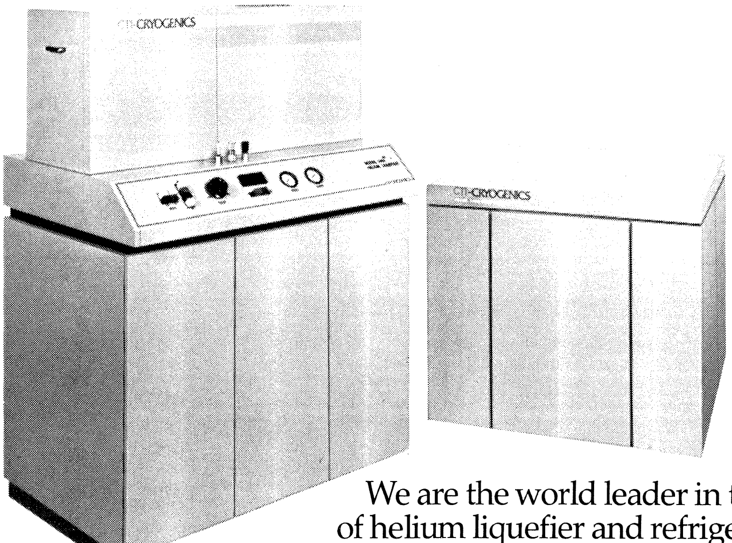

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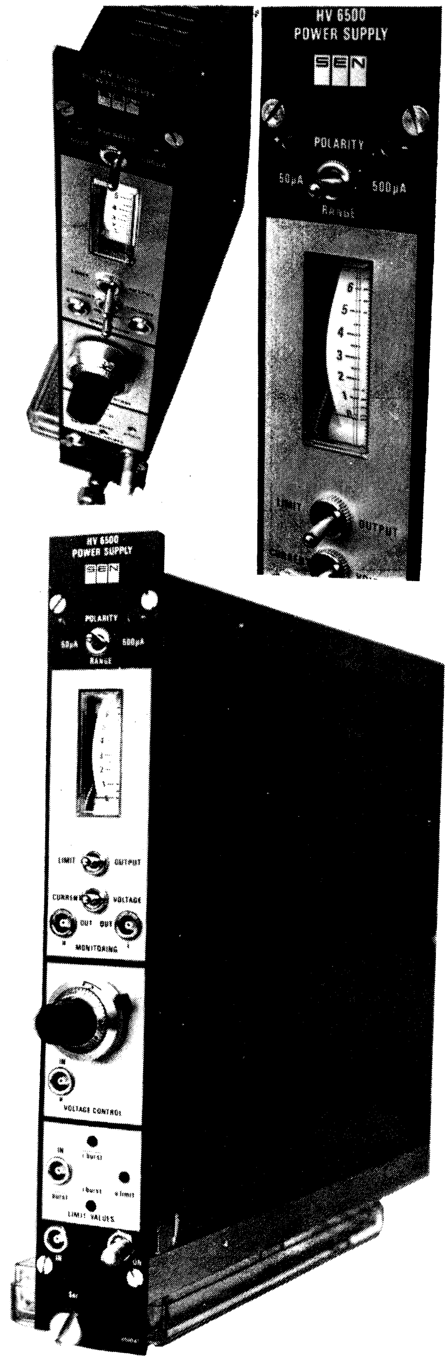

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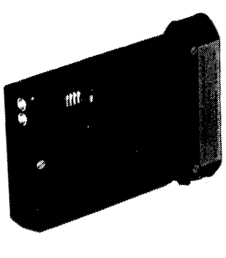

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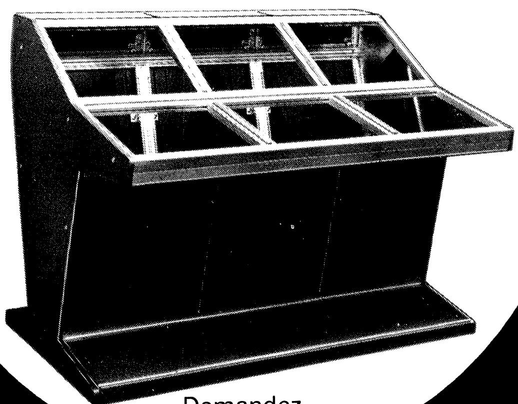

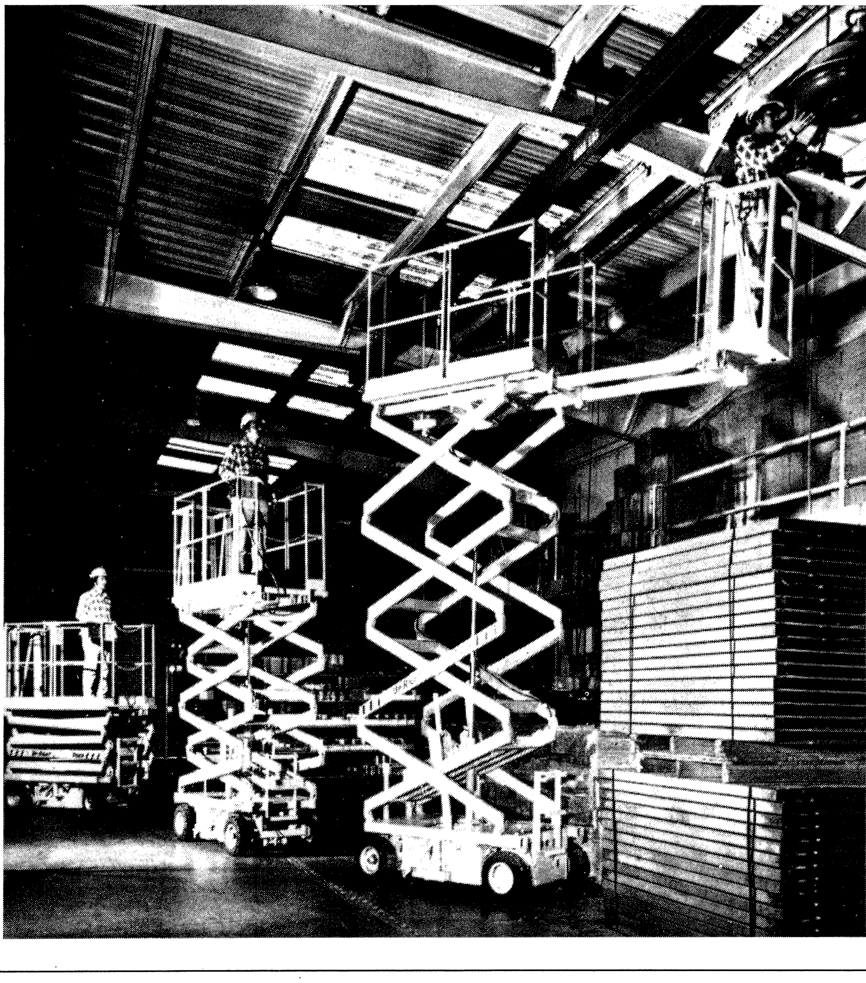

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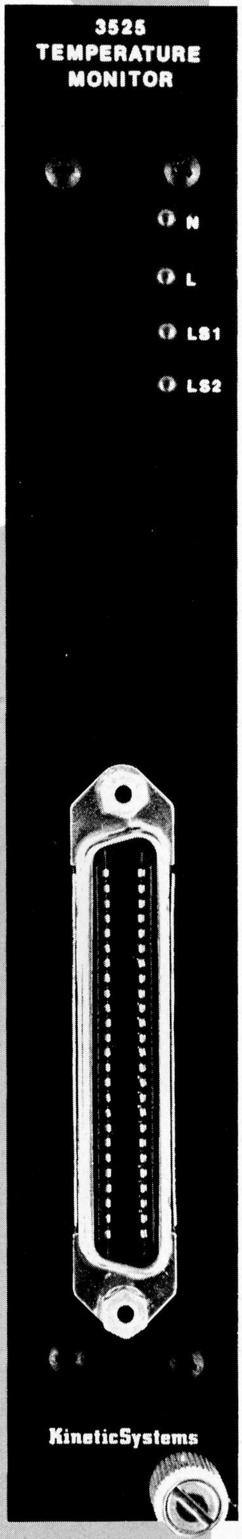

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