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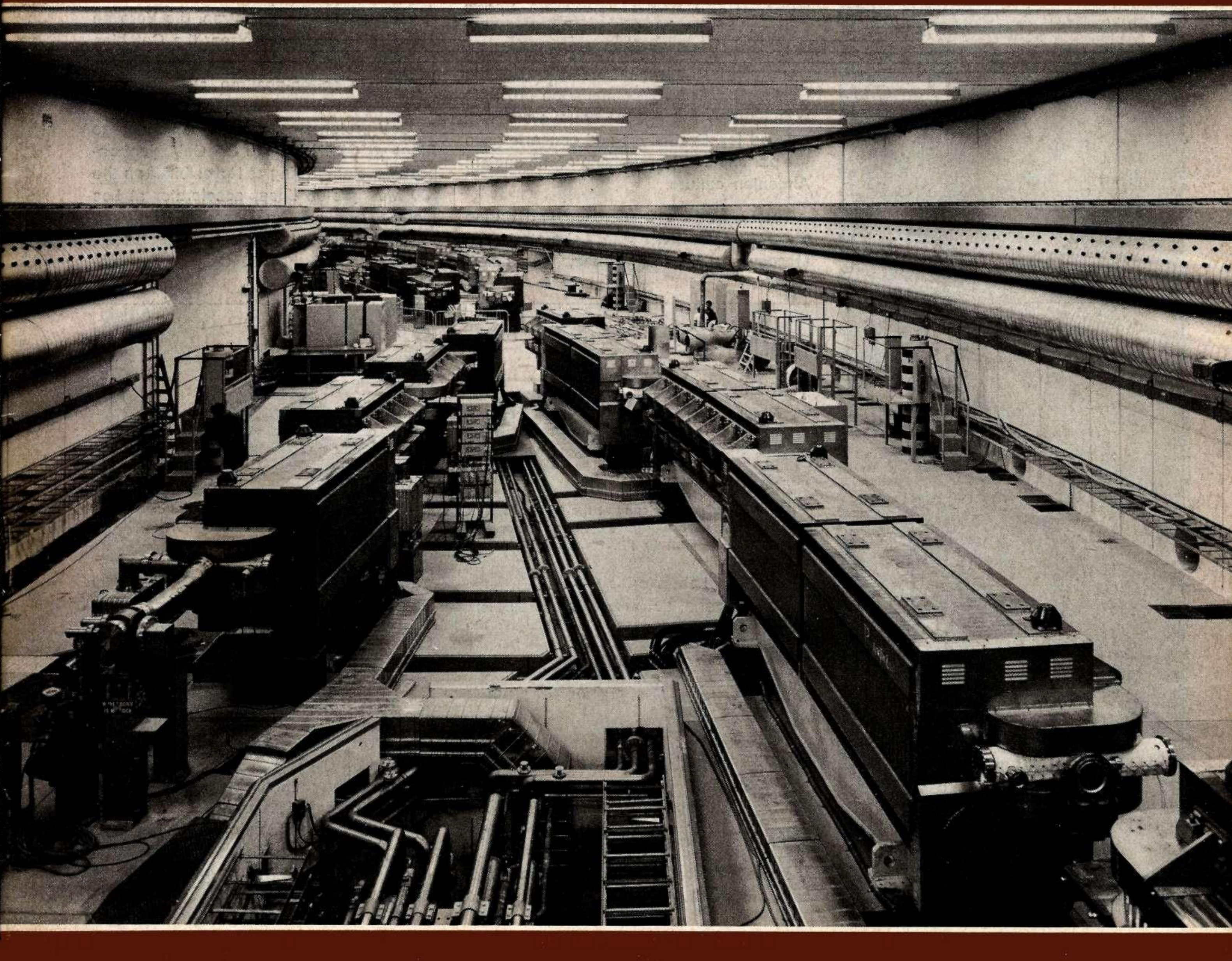

Yerevan Conference

The Seventh International Conference on High Energy Accelerators was held at Yerevan in Soviet Armenia from 27 August to 2 September. The article reviews some of the topics discussed at the Conference.

At the end of August some 180 accelerator specialists from Europe, North America and Japan struggled through Moscow to join 200 of their Soviet colleagues (representing altogether 85 research centres) at Yerevan for the Seventh International Conference on High Energy Accelerators sponsored by the International Union of Pure and Applied Physics (IUPAP), the USSR State Committee for the Use of Atomic Energy, and the USSR Academy of Sciences. The Conference was held in the mountain resort of Tsakhkadzor, at a height of 1500 m about 50 km from Yerevan city, where participants were able to enjoy the facilities of the State Sports Centre. This provided a lovely setting with richly wooded mountain slopes and with wonderful sunny weather every day of the Conference. The accommodation provided was spartan but leisure hours were well catered for. Excursions and concerts gave the participants a good taste of the ancient Armenian culture.

Throughout the Conference and during the subsequent visits to Laboratories in Moscow, Leningrad, Dubna, Serpukhov, Kharkov and Novosibirsk, the Soviet scientists displayed their usual very warm hospitality and socially the Conference was a great success.

Changes in two years

It is interesting to begin by comparing the situation in the accelerator world in September 1969 with that in September 1967 when the last Conference in this series was held at Cambridge, USA. Since Cambridge, several important machines have come into operation — the Serpukhov 76 GeV proton synchrotron, the Cornell 10 GeV electron synchrotron, the Yerevan 6 GeV electron synchrotron, the Gatchina 1 GeV synchro-cyclotron, the ADONE 1.5 GeV electron-positron storage rings. Construction work has advanced on the 28 GeV proton-proton Intersecting Storage Rings at CERN, on the 3.5 GeV electron-positron storage ring at Novosibirsk on the 800 MeV proton linear accelerator at Los Alamos and on the Canadian cyclotron TRIUMF. And, of particular importance, construction of the 200 GeV proton syn-

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Cover photograph : Inside the tunnel of the Intersecting Storage Rings showing how far construction has advanced. K. Johnsen reported at the Yerevan Conference on the excellent progress of the ISR project. The photograph shows a section of the tunnel where the magnets of both rings and some vacuum components are installed. Following the sweep of the two rings it is possible to identify (upper left of the photograph) a region where the beams will collide. (Photo CERN/PI 242.8.69)

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 1200 physicists draw their research material from CERN.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2800 people and, in addition, there are over 400 Fellows and Visiting Scientists.

Twelve European countries participate in the work of CERN, contributing to the cost of the basic programme, 235.2 million Swiss francs in 1969, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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Inside the ring tunnel of ARUS, the 6 GeV electron synchrotron at the Yerevan Physics Institute - the host Laboratory for the Conference. The injected beam comes in from the right on the photograph. In the ring itself can be seen one of the magnets in between two of the large r.f. cavities.

(Photo Yerevan)

chrotron at Batavia has started at a very fast rate.

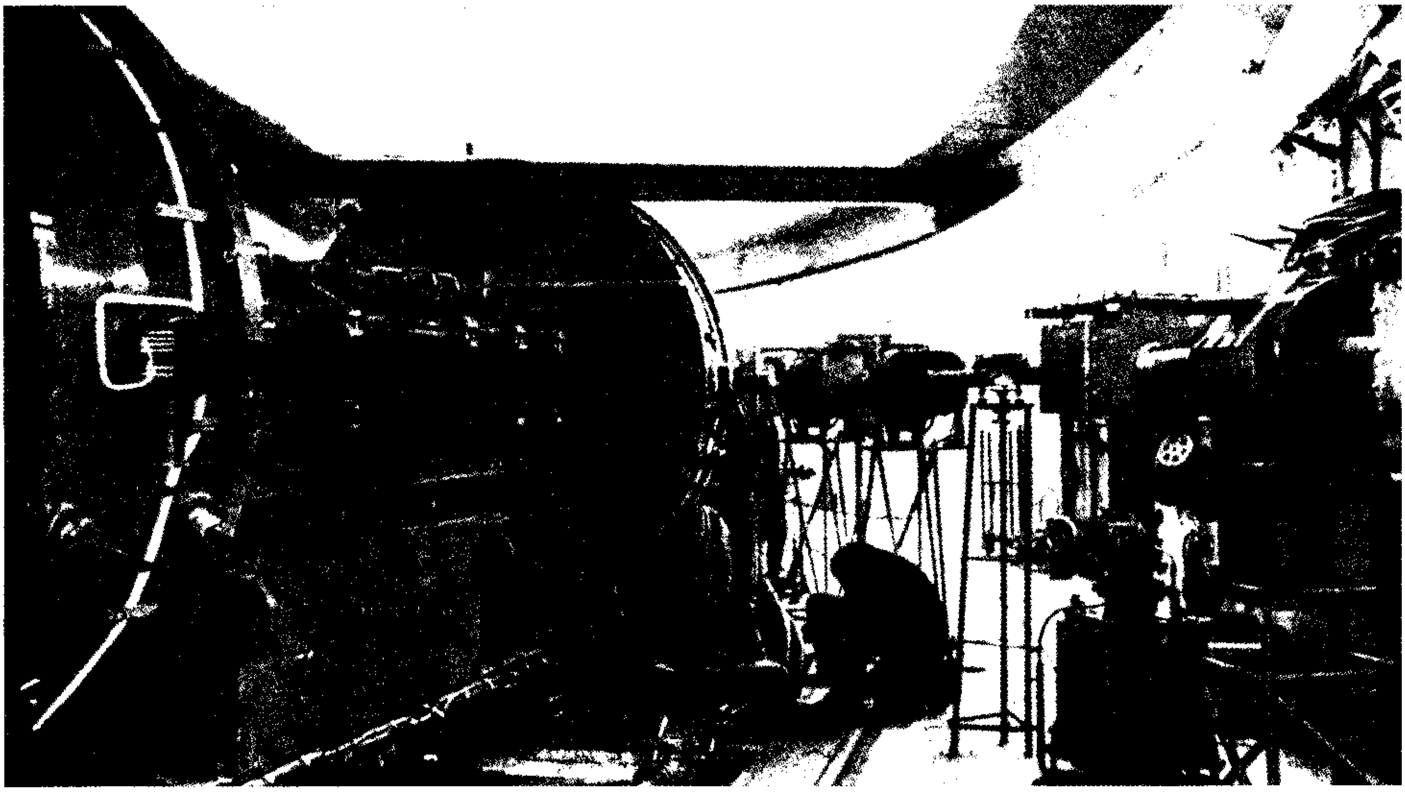
To put alongside these encouraging developments, we should mention the demise of some projects such as the 40 GeV proton synchrotron in Japan and the Intense Neutron Generator (ING) in Canada. (Incidentally, a decision from the Canadian government concerning participation in Batavia is believed to be imminent.) But some projects must always fall by the wayside and probably of more significance has been a general belt-tightening in the USA and in Europe which has restricted operation and development of existing machines. (There does not seem to be an equivalent squeeze in the Soviet Union at present and Laboratories such as Dubna, Novosibirsk and Serpukhov do not seem to be short of resources.)

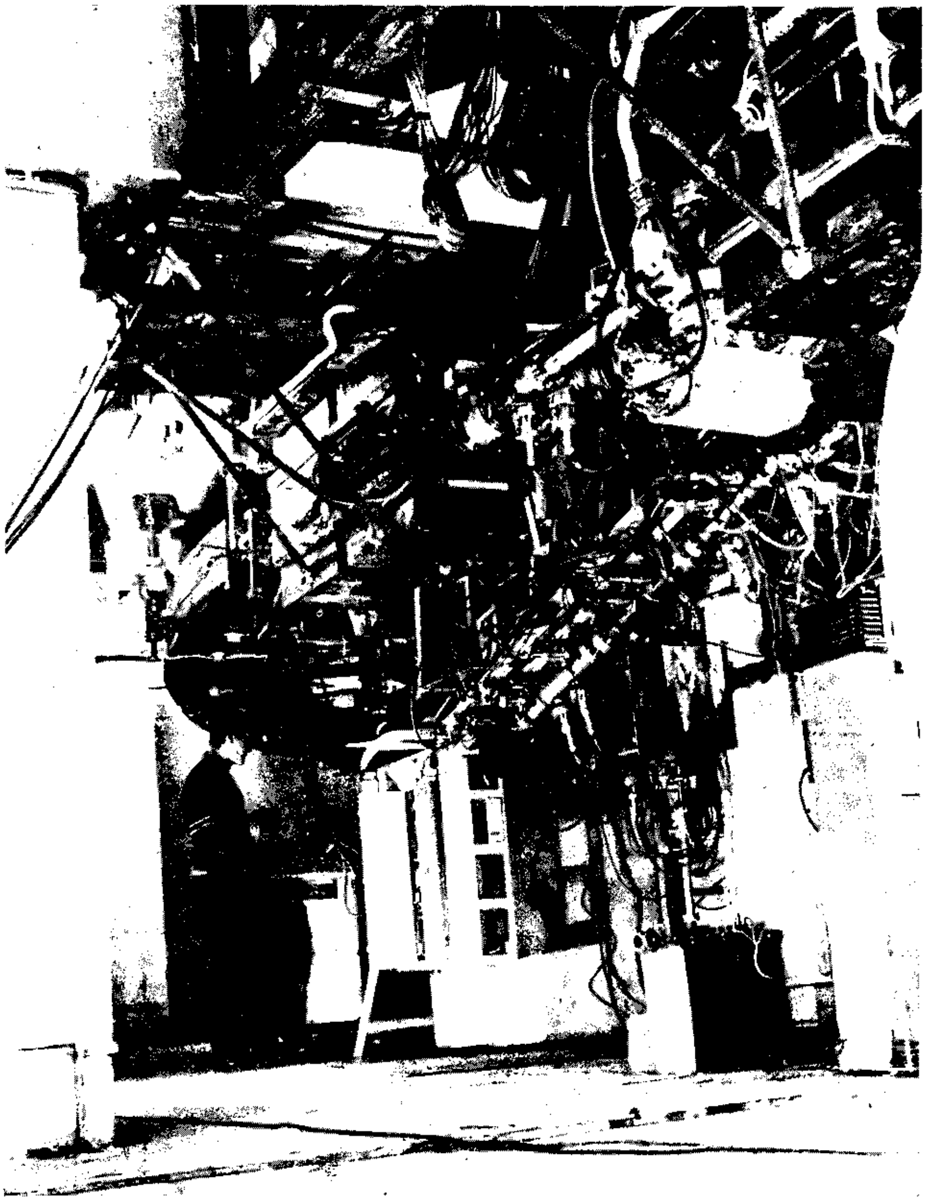
In the USA, Batavia has had its full construction budget of $ 240 million 'authorized'. These funds remain to be 'appropriated' and $ 96 million has been requested for fiscal year July 1969 to July 1970 — the decision is expected in November. But Batavia is receiving special treatment in an attempt to keep the construction programme on schedule so that the machine will be in operation at 200 GeV in 1972. Other Laboratories, in the context of an overall climate of restraint on pure science budgets in the USA, are, in general, being held dollar for dollar with their budgets of the previous fiscal year, which, in effect, means a reduction in money. Obviously, new projects, improvement programmes and developments in accelerator operation will find it very difficult to flourish in these circumstances.

If the situation continues, the bitter decision as to whether to close down some of the machines operating in the USA, such as the 3 GeV fast-cycling synchrotron at Princeton, so as to continue to develop the bigger centres, will have to be confronted. Another exception to the general picture of restraint is the Electron Ring Accelerator work at Berkeley (of which more later) which is being looked on with a very favourable eye.

In Europe, as CERN COURIER readers hardly need to be reminded, the 300 GeV project has continued to dominate the scene since the last Conference. In the wake of indecision on this huge project has come indecision in individual European countries as to the best course to follow in the coming years. Added to this, financial problems in several countries have come home particularly hard in budgets for pure science. The axe is swinging over the head of Nimrod, the 7 GeV proton synchrotron at Rutherford UK, and a severe cutback on science in France, following devaluation, will hit Saclay. (Saclay have just released the design study for their 23 to 45 GeV proton synchrotron proposal, but there is little point in describing it in the present situation.)

All this has obviously had an inhibiting effect on the European accelerator community and the contribution from Europe at the Yerevan Conference was probably weaker than ever before in a Conference in this series. Counting papers is not a reliable way of estimating contribution to a Conference but it is some measure of what has been said above to point out that less than 20 % of the papers given in the plenary sessions came from Europe. This





A section of the 3.5 GeV electron-positron storage ring, VEPP 3, at Novosibirsk. Note that the ring is suspended from the roof of the tunnel building. Construction of VEPP 3 is virtually complete and experiments are planned for the near future.

(Photo Novosibirsk)

is not because of a deterioration in the quality of European accelerator physics but because, for the past two years, it has been largely a question of 'stand and wait' to know in which direction effort can best be applied. The sad thing is that, when others are making progress, to stand still is to move backwards. When the hesitations introduced by the delay on the 300 GeV decision are removed, Europe should be in a better position to define its priorities.

Things of interest

Another revealing comparison with the situation in 1967 is to look at the topics which generated most interest then and now. At Cambridge the two key topics were :

1. Space charge effects
2. Boosters.

At Yerevan these were replaced by:

1. Electron ring accelerators
2. Superconductivity.

At the Cambridge Conference the start of improvement programmes to increase the intensity of existing accelerators and the start of new high intensity machines brought a lot of emphasis to space charge problems which become more severe as the beam intensity goes up. A lot of effort has gone into the understanding and solution of these problems over the past two years, and CERN, which has particular interest because of its PS improvement programme and the ISR, has been prominent in this work — as was recognized in a major review paper 'Some high current effects in accelerators' by E. Courant (Brookhaven).

At Cambridge, boosters (the intermediate accelerator between the linear accelerator and the main synchrotron ring, which 'boost' the injection energy into the main ring and thus make higher intensities possible) were a comparatively new phenomenon. At that time, it was very much a case of 'to each his booster'. A wide variety of solutions to the problem came from the various interested Laboratories and there was considerable controversy as to the best solution. In an excellent review paper, 'Features of boosters for super high energy proton synchrotrons' W. Hardt from CERN dotted the 'i's crossed the 't's and virtually put the full stop to the work of the past two years. It is now generally agreed that the fast-cycling synchrotron booster has emerged on top for very high energy machines over slow-cycling boosters, accumulator schemes and multiple booster ring schemes, in potential, in cost and in reduced complexity. All the major 'next generation' accelerator designs — the 200 GeV in the USA, the 300 GeV in Europe and the 1000 GeV from the Radio Technical Institute in the USSR — are in agreement, in broad outline, on booster design.

In the two Yerevan 'topics of interest', we should first balance our mention of the important work of CERN regarding space-charge and boosters by saying that here CERN is an interested bystander, with no contributed papers at all. There is, however, some work in Europe on these topics — Karlsruhe and Munich are beginning research programmes on electron ring accelerators, and Rutherford is particularly prominent in the research on the application of superconductivity to accelerators.

Electron ring accelerators

The first topic, electron ring accelerators or collective ion acceleration, has been covered in CERN COURIER in vol. 8, page 28 and vol. 9, page 40 and for an understanding of what follows we must, to save space, ask readers to refer back to these previous articles. It drew some twenty papers, which reveals what a Pandora's Box the single paper from Dubna, tucked at the back of a session in Cambridge, has opened.

The work at Dubna (reviewed by V.P. Sarantsev in a paper 'Accelerator with electron rings') where a large effort involving a hundred people is being mounted, continues to take first place. Their papers at the Yerevan Conference clearly revealed that, at least as far as the 'expansion acceleration' stage, electron ring accelerators work. In February and March of this year they formed electron rings, fed them with nitrogen for a length of time which produces triply ionized positive nitrogen ions sitting in the electron rings, extracted these electron rings holding the ions from the 'compressor' in which they are formed, and accelerated them by the expansion method in a decreasing magnetic field to give nitrogen ion energies of over 60 MeV.

The presence of the triply charged nitrogen ions in the rings and their energy was confirmed by having them hit a ring of cerium where the ions take part in a reaction at an energy just below 60 MeV producing radioactivity. They covered the bottom half of the cerium ring with a thin aluminium foil and detected no radioactivity from this bottom half.

Dubna also crossed an integer resonance (which can cause particle beams to 'blow up' and be lost) without losing the electron rings, though the ring minor diameter was increased by a factor of two or three.

This vital ability to confront resonances has also been confirmed at Berkeley in the very short time that they have had to play with 'Compressor III' (described by D. Keefe in a paper on 'ERA development at Berkeley'). They have built a pulsed coil so that the integer resonance could be crossed quickly if necessary, but it proved possible to approach it very slowly without losing the ring. This is an extremely encouraging indication of the ring stability.

Berkeley brought Compressor III into operation at the beginning of August. In two weeks of running time, the unstable performance of the Astron injector of electrons resulted in only a few hours of useful operation. These few hours served however to produce electron rings again, to compress them, to load them with hydrogen ions, and to power the coils producing the magnetic fields in the compressor in such a way that the rings could be moved about (over a few centimetres) along their axis. In the coming months the extraction of rings from the compressor and their expansion acceleration along a tapered solenoid field about 1 m long will be studied.

A high current electron source, capable of energies between 2 and 4 MeV and currents greater than 500 A, is being built to replace the Astron as the injector into the compressor. It will operate at 1 to 10 Hz with pulses 35 ns long and high stability. This injector will be ready for 15 March 1970. At the beginning of October, work will start on a tunnel to receive the injector and on a building for the compressor.

Superconductivity

We are still in the early days of demonstrating the use of superconductivity in the acceleration of particles but progress over the past two years has been very fast. This applies both to superconducting cavities for linear accelerators, and to superconducting pulsed magnets for synchrotron rings.

The most important work on superconducting cavities is being done at the High Energy Physics Laboratory, Stanford, and we will concentrate on their latest results while recording that there are also research programmes at Illinois, Karlsruhe, Dubna, Rutherford and Brookhaven. HEPL have a specific project well under way - to build a superconducting electron linear accelerator 150 m long for an energy of 2 GeV or above. (The project was described in CERN COURIER vol. 8, page 239).

E. Chambers began his status report by saying that all the major problems are now solved. The r.f. control problems associated with beam loading were accounted for earlier this year when a 1.5 MeV superconducting lead prototype operated successfully and continuously for a period of six weeks. It was only shut down after extensive measurements of the beam characteristics (average currents up to 140 μA were accelerated) showed that the design aims of a momentum resolution of about $\pm 10^{-4}$ at beam currents of 100 μA, could be met.

Excellent results continue to be obtained with niobium cavities reaching Qs of 10^{11} and field gradients of 27 MeV/m. (To achieve 2 GeV and c.w. operation of the accelerator under construction requires gradients of only about 13 MeV/m and Qs of 10^{10}.) The production of niobium cavities to the necessary standard appears to be completely solved by a special treatment involving cooking the niobium for many hours at 2 000 °C in a large furnace, allowing it to cool and etching off about 10 microns of surface material. This gives excellent surface characteristics without requiring niobium of extreme purity.

The tunnel for the accelerator has been built and a 'return loop' by means of which the beam can be sent through the accelerator again is contemplated. By mid-1970 it is hoped that the first section of the accelerator for an energy of about 30 MeV will be ready and that the whole accelerator will be completed by the end of 1971.

Turning to superconducting magnets for use in a synchrotron ring we will again concentrate on the work of one Laboratory, Rutherford (reported by J.D. Lawson), while recording that similar work is under way at other centres such as Brookhaven, Berkeley, and RTI.

The important contribution of Rutherford was brought out in the story on the Brookhaven Summer Study last year (CERN COURIER, vol. 8, page 186). They have attacked the problem of producing an intrinsically stable superconducting magnet which will have low a.c. losses (so that it can be used in the pulsed operation of a synchrotron) while remaining a financially attractive alternative to conventional magnets. Following theoretical studies, the approach has been to use very fine filaments of superconductor embedded in a normal metal and to twist the composite conductor. A three-part composite conductor has now been produced in experimental quantities to include also a high resistance metal. This conductor has fine filaments of niobium-titanium twisted to the required pitch, separated from the copper matrix by a resistive barrier. These manœuvres have been dictated by the basic theory of composites which is now quite well understood. The largest coils tested so far have contained 2 to 3 kgm of conductor (typically a 60 kG solenoid of 9 cm bore). Their performance has been in very good agreement with expectation reaching 'short sample' characteristics under a.c. conditions pulsing at a rate of up to once per two seconds.

Many questions remain to be answered. Nevertheless, it looks as if superconductivity will be the technique to take the synchrotron to its highest attainable energy, the higher fields giving a machine of tolerable radius. A good pilot experiment would be to replace an existing synchrotron magnet ring by a superconducting ring and a preliminary study of this possibility has been made for the 7 GeV Nimrod at Rutherford.

Accelerators

A large part of the Conference was, of course, given over to progress reports on the operation or the construction of the major accelerators and storage rings. We will record here some of the general information from these reports which has not been covered in CERN COURIER in recent months.

Serpukhov

Several papers described the performance, utilization and development of the 76 GeV proton synchrotron, the highest energy accelerator in the world, at the Institute of High Energy Physics, Serpukhov. The major review was by A.A. Naumov, 'Status report of the Serpukhov accelerator'.

Since it was commissioned in October 1967, the performance of the accelerator has been steadily improved. It has reached a peak intensity of 1.5×10^{12} protons per pulse and operates regularly at 1.2×10^{12}. The remarkable performance of the 100 MeV linear injector continues — without any of the clever coupling structures, which are being built into the new generation of linacs, it has produced a 15 μs pulse of 120 mA. It is usually operated at current levels of 50 to 60 mA for single turn injection. With the vacuum chamber dimensions in the main ring of 20 x 11.5 cm^2, it is probable that the accelerator intensity could be considerably increased using multi-turn injection though this has not been attempted yet. Something like 6×10^{12} should be quite feasible.

Two beam-lines for negatively charged particles are in operation (called channel 2 and channel 4) and a neutral particle beam-line. These can be operated simultaneously on a flat top of 1.5 ms. With an accelerated beam of 70 GeV, channel 2, (feeding three experiments) gives particles in the momentum range 40 to 60 GeV/c with 7×10^5 to 10^4 particles per pulse. Channel 4 (feeding five experiments) gives particles in the momentum range 25 to 40 GeV/c with 10^6 particles per pulse.

The ejection systems for the machine are now at an advanced stage of design with model magnets being built and tested. The slow ejection system will use the 9 2/3 resonance and have three septa of increasing thickness (beginning with one 0.5 mm thick). The ejection efficiency is designed to be over 90 %. The two fast ejection channels, one of which is being provided by CERN in the context of the CERN-Serpukhov collaboration, have been finalized and preparations are under way for the installation of the rather complex system of magnets. A prototype septum magnet has been made. One of the fast ejected beams will feed the hydrogen bubble chamber, Mirabelle, being constructed at Saclay for use at Serpukhov. The building to receive the chamber is almost complete.

Stanford (SLAC)

Progress on the 20 GeV electron linear accelerator at Stanford was reported by R.B. Neal. 79 % of all operating time now goes to particle physics. The electron beam can be accelerated to a peak energy of 21.5 GeV (it is intended to increase the power of the klystrons to take this to 25 GeV) and the average beam power is 500 kW; the equivalent figures for the positron beam are 13.5 GeV and 7 kW.

The phenomenon of beam break-up which initially limited the beam current to 15 to 18 mA has been overcome by optimizing the focusing and by de-tuning the mode which was causing the break-up. Currents of 65 mA can now be achieved, well above the initial goal of 50 mA, and it may be possible to push it as high as 80mA. Beam loading effects in the accelerator became troublesome as the intensity was increased but by timing the different sectors appropriately the fall off of accelerating field in one sector can be compensated by the rising field in its neighbour.

Any combination of electron and positron pulses can now be obtained — when positron pulses are required the electron beam is allowed to collide with a fixed wheel target to produce positrons for further acceleration; when electron pulses are required the beam is simply steered around this target.

Another new device is a beam chopper which can cut out a single bunch of particles from the beam. Since the bunches are spaced only 350 ps apart this ability to eliminate a bunch is useful for time-of-flight measurements.

Cornell

B.D. McDaniel reported on the operation of the 10 GeV electron synchrotron at Cornell University. This machine was built in 2 1/2 years at a cost of $ 12 million, beginning operation at 10 GeV in March 1968. In November 1967, the experimental programme began and by now involves 45 physicists with a laboratory operating staff of another 45 people. The beam intensity is about 3×10^{10} electrons per pulse at 60 Hz (2×10^{12} electrons per second).

No trouble has been experienced from the novel vacuum system — there is no vacuum enclosure within the poles of the magnet, the vacuum being sealed on the magnets themselves. There has, however, been trouble with multipactoring in the r.f. system and a new r.f. cavity is being installed to give some reserve and to make it possible to go to higher energy. The aim is to reach 15 GeV — this is well within the capability of the magnet ring which with its large radius of 100 m operates at only 3.3 kG for 10 GeV. An ejected beam for 2.5 GeV electrons is being prepared for operation by the end of this year.

Los Alamos

A paper on the 'Design and construction status of the Los Alamos Meson Physics Facility' was given by L. Rosen. The 800 MeV proton linear accelerator, LAMPF, was described in CERN COURIER vol. 8, page 132. It is designed for high proton beam intensity — an average current of 1 mA — and will also be capable of accelerating 100 μA of negative ions and 0.1 μA of polarized ions. Three Cockcroft-Walton high voltage sets are to be installed for the three types of operation.

Construction of the buildings is well advanced. The trench to take the accelerator, 850 m long, has been dug out and the beam channel completed. The injector building and the laboratory and office accommodation is nearing completion.

The first four tanks of the linear accelerator are to be of the Alvarez type but with post-coupled structure. (A slide of such a tank was shown at the Conference). The remaining tanks are to be of the waveguide type incorporating the new idea of a side-coupled structure. 30 % of the

An aerial view of the Serpukhov Laboratory which houses the highest energy accelerator in the world - a 76 GeV proton synchrotron. Part of the ring tunnel can be distinguished together with the huge experimental hall which spans a section of the accelerator.

(Photo APN)

radio-frequency power goes into the beam in this structure. The electron model where these ideas are being tested is working excellently.

Of the total cost of the project, $55 million, $33 million has been appropriated and about $27 million of this has been committed in contracts. So far the project is going to schedule aiming for completion in mid-1972 but LAMPF awaits with bated breath the announcement of the budget appropriations for the current fiscal year.

Batavia

The rapid progress in the construction of the 200 GeV proton synchrotron at Batavia has been underlined many times in CERN COURIER. When the construction time-scale of five years (the machine to be completed in mid-1972) was announced at the Cambridge Conference, it was generally regarded as very optimistic, to put it mildly. But the speed with which things have gone so far give no evidence that this date will not be met.

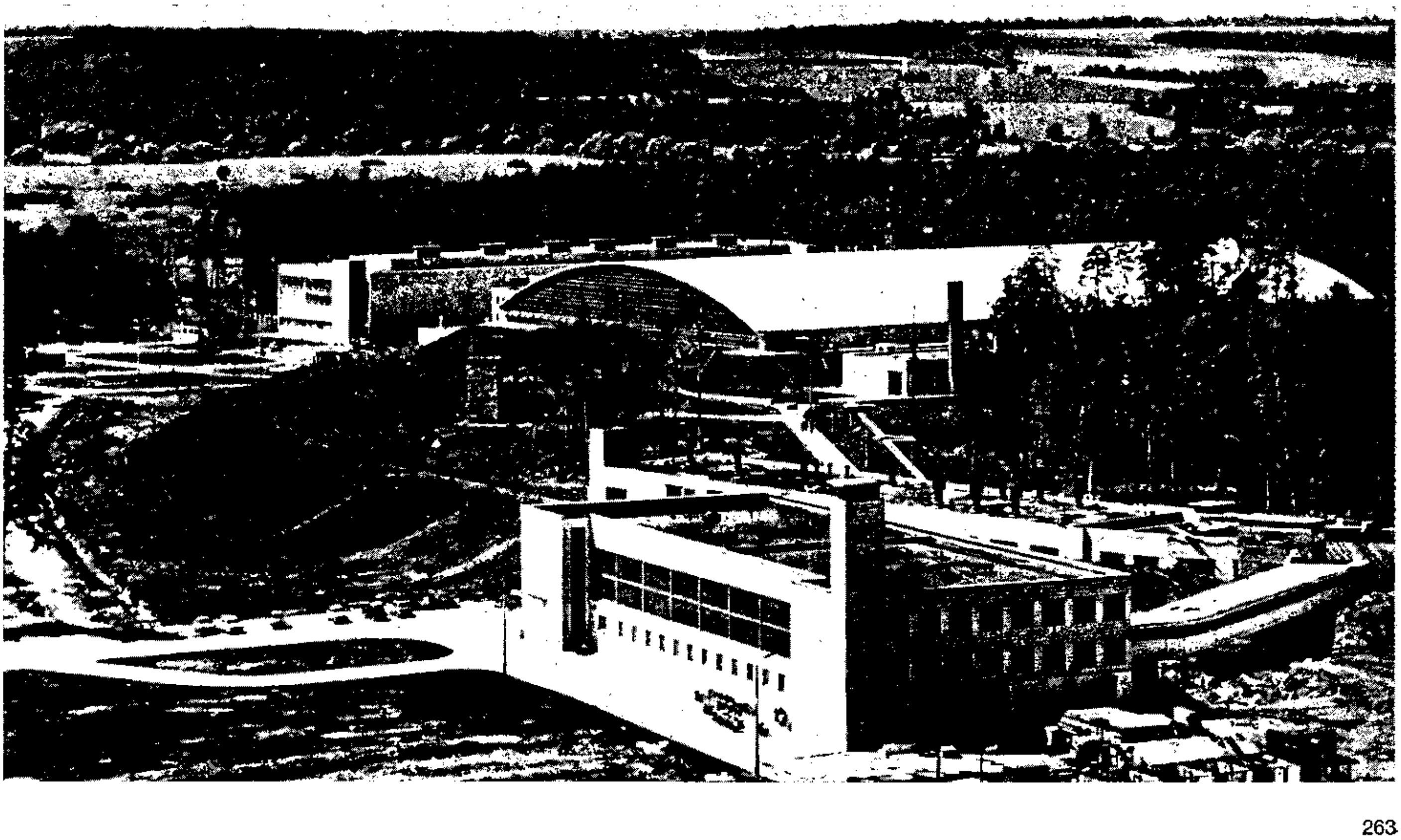
R. Wilson, Director of the Laboratory, gave an exotic paper at the Yerevan Conference called 'Future options at the National Accelerator Laboratory'. He listed several possibilities for future expansion. Two of them are firm intentions and should be mentioned here. After the accelerator has come into operation it is intended, as first priority, to double the facilities for the experimental utilization of the machine by duplicating the present provision of target areas, etc. (see CERN COURIER vol. 9, page 173), or by bringing out a second ejected proton beam. The second intention is to increase the maximum energy to 400 GeV one or two years after obtaining a 200 GeV beam. This is an important statement for it means that, if things continue to go well at Batavia, the USA will be at 400 GeV before Europe has its first 300 GeV beam.

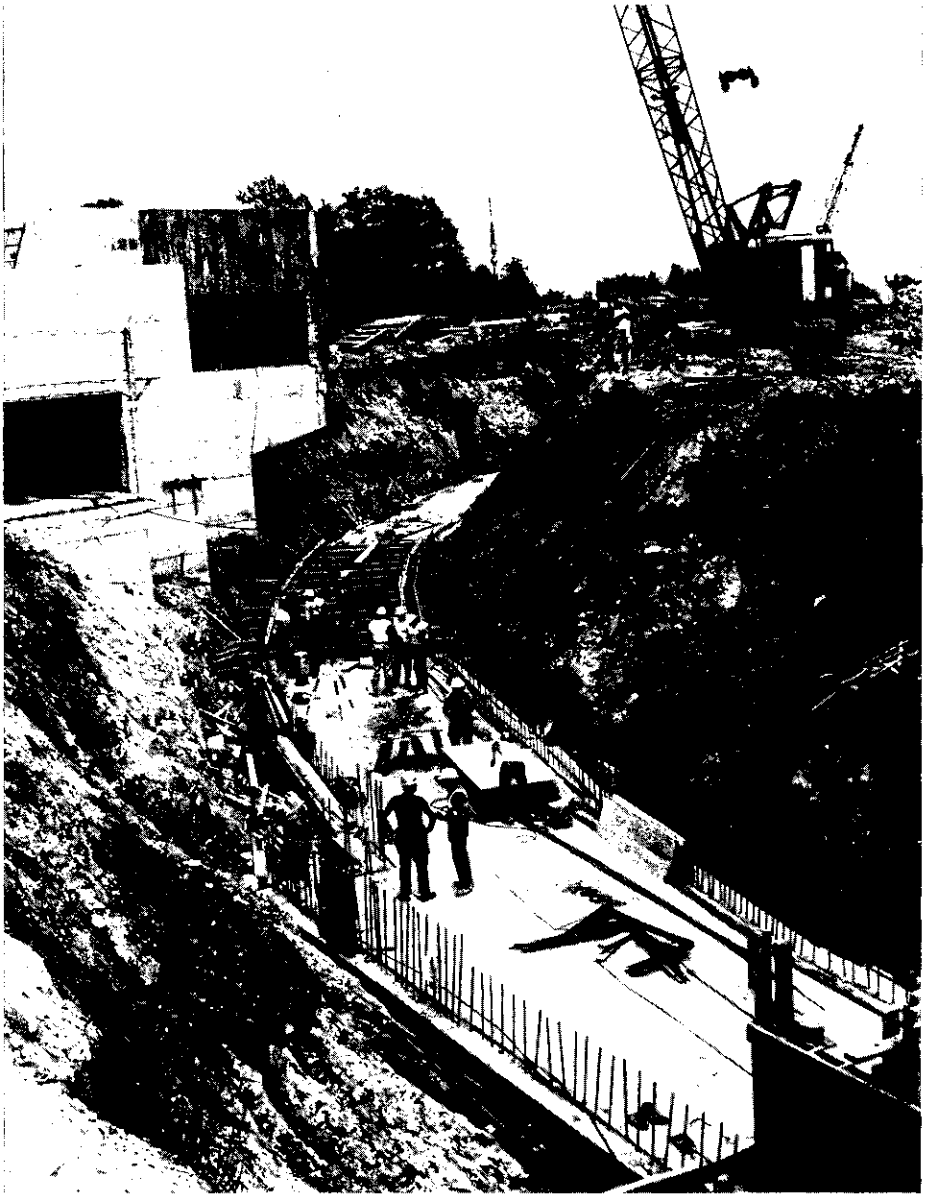
Further possibilities, which are much more remote, are to increase the intensity to 10^{14} protons per second (there would be capacity for this but at considerable expense); to add storage rings (see CERN COURIER vol. 8, page 313); to install a ring of superconducting magnets in the space available over the initial main ring; to build a three mile diameter superconducting ring (5000 GeV) just squeezed onto the Laboratory site. (One of the problems with Professor Wilson is that he is a rather difficult man to catch because he does not stand still for long enough).

Professor Wilson said however, that his personal hope was that the next leap in energy would involve a world-wide collaboration on an accelerator in the 1000's of GeV range. He here echoed the remarks of Academician A.L. Mints from the Radio Technical Institute, Moscow, who gave a long paper on the 'Design of a 1000 GeV proton synchrotron' (developing in several stages to 5000 GeV). These ideals have been in the air before without developing very far. Nevertheless, it is understood that both Soviet and American scientists are to make preliminary approaches to their governments on this topic.

Yerevan

During the Conference all the participants took the opportunity to visit the host Laboratory — the Institute of Physics at Yerevan (directed by A.I. Alikhanian who





Construction progress on the Booster for the 200 GeV accelerator at Batavia. The fast-cycling Booster is scheduled to produce 8 GeV beams by the middle of 1971. Its building will be completed by 2 April 1970.

was also Chairman of the Conference Organizing Committee). The Institute's 6 GeV electron synchrotron, ARUS, first reached its design energy on 25 October 1967. The beam current has now been improved to 12 mA and when a beam chopper is added in the linear injector it is expected to increase this to 20 mA — 10^{11} electrons per pulse at a repetition frequency of 47.5 Hz. These figures are comparable with the other major electron synchrotrons.

The accelerator has a radius of 35 m and the magnetic field rises from 66 G at injection to a peak of 8 kG at full energy. RF accelerating power, which has a maximum of 520 kW, is applied in 24 cavities distributed around the ring. The wavelength of the accelerating field is 2.25 m which was selected on the basis of the cost per unit of high frequency power. Although the power losses in the 2 m range are higher than, for example, in the 50 cm range, the total cost of power at Yerevan proved to be lower. The vacuum vessel is of corrogated stainless steel 2 mm thick with epoxy strips to prevent eddy currents. Its internal dimensions are 120 mm wide by 42 mm high. The operating pressure maintained by titanium and turbo-molecular high speed pumps is 10^{-6} torr. Electrons are fed to the ring from a 50 MeV linear injector (three tanks each six metres long) which provides a maximum current of 200 mA for single turn injection.

There are two stations where gamma beam channels emerge from internal targets into the South Experimental Hall which has an area of 1800 m^2 (a diamond crystal is now being installed to produce a polarized monoenergetic gamma beam). There are plans to install an ejected electron beam but this has not yet started.

The experimental programme has taken some time to get off the ground but several major experiments are now installed or are being installed. A heavy liquid bubble chamber with a volume of 300 litres, built at the Institute, has taken some pictures and is to be used in association with a 50 cm wide gap spark chamber to look at the photoproduction and decay of neutral kaons. A huge wide angle pair spectrometer is at an advanced stage of assembly and a large spark chamber array is planned for the observation of the decays of the vector mesons (rho, omega and phi) into lepton pairs (muons and electrons). This set up will also examine the properties of the pseudo-polar mesons (the neutral pion, eta and xi) and measure the lifetimes of the eta and xi using the Primakov effect.

Storage Rings

Here we concentrate on the information from Novosibirsk and CERN. A new storage ring proposal from Stanford (SLAC) is described on page 273 of this issue.

Novosibirsk

Several papers at the Conference came from the Institute of Nuclear Physics at Novosibirsk covering the performance of the 600 MeV electron-positron storage ring VEPP 2, the construction of the 3.5 GeV electron-positron storage ring VEPP 3 and the plans for the 25 GeV proton-antiproton storage ring VAPP 4 (see CERN COURIER vol. 7, page 88, and vol. 8, page 288.) There was also a general review paper by G.I. Budker, Director of the Institute, on 'Accelerators and Colliding Beams'.

Immediately after the Conference, many of the participants visited Novosibirsk and were able to amplify their information during thorough, open talks on all aspects of the Institute's work, and were able to see the very impressive machines. It is a measure of the high reputation of the Institute that the Novosibirsk tour was the most popular of those which were organized following the Conference.

Research at the Institute is concentrated on accelerator and storage ring techniques (absorbing about 50 % of the total effort), on plasma physics and on the production of accelerators in the few MeV range for use in industry. Storage ring work began in 1962 with the construction of VEPP I, an electron ring of 160 MeV which came into operation in 1965 and was used mainly for beam studies. This has been replaced by VEPP 2, a 700 MeV electron-positron ring coming into operation in 1966, which is again used for beam studies but also for particle physics. It contributed to the important measurements on vector mesons carried out in 1967 (see CERN COURIER vol. 8, page 245).

A major reconstruction of VEPP 2 to improve its capacity for particle physics experiments took place in 1968 and it came back into service in May of this year with modifications to the r.f. system (allowing for the use of the first and third harmonic to concentrate the particles into a shorter bunch) and an ion pump vacuum system which uses the magnetic field applied in the storage rings for the ion pumps. Electron and positron currents of upto 60 mA are stored during an injection time of about an hour and experiments are then possible for about four hours. The initial luminosity is 10^{32} cm $^{-2}$ h $^{-1}$.

Construction of VEPP 3, an electron-positron storage ring for 3.5 GeV began in 1967 and the ring itself is now complete. Just before the Conference, a proton beam was circulated in the ring for one turn.

VEPP 3 consists of two half-ring magnet sections of radius 8 m, each having eight magnet units joined by two 12 m straight sections. Each unit incorporates a bending, defocusing, bending and focusing length. These magnets are cut from solid (rather than being laminated) in the Institute's own workshop and are designed to operate with a maximum field of 16 kG. They are suspended from the ceiling of the tunnel in which they are installed, which is a rare sight in accelerator construction.

The vacuum chamber cross-section in 8 x 2.9 cm (varying a little around the ring) and is pumped by distributed ion pumps as in VEPP 2. The chamber is of stainless steel and can be baked out in situ by passing current through the walls (it is pre-baked before installation for 30 hours at 800° C). Pressures of 2 x 10^{-9} torr have been achieved and it is intended to reach 10^{-11} in the straight sections.

There are two r.f. cavities which will initially operate at an average power of 150 kW giving beams with a peak energy of 2 GeV. More power will be provided later to go to 3.5 GeV. The r.f. will operate on the first and the nineteenth harmonics (4.03 and 76.57 MHz). When positrons are injected (at an energy of 250 MeV), the r.f. will operate on the 19th harmonic so that particles will circulate in 19 bunches. When the 1st harmonic is switched on the particles will settle in one bunch and the 19th harmonic will then be brought back to concentrate the particles into one bunch with 18 r.f. 'buckets' empty. The energy of the positrons will be increased to 500 MeV before electrons are injected and then the two beams together will be taken into the GeV region.

The injector system is also unique. It begins with a transformer type, high voltage, high current accelerator as developed at the Institute for use in industry. This provides 3 MeV electron beams of 3 A which are fed into an ironless synchrotron of 1 m radius. The electrons are there accelerated betatron fashion to 10 MeV and then conventional r.f. accelerated to 500 MeV (the field rising to 17 kG) in 1 ms. Two channels will lead from this synchrotron to the storage ring — one takes the electron beam direct (inflecting through a pulsed magnetic field of 130 kG), the other has a converter to produce the positrons of 250 MeV energy which will then be inflected in the opposite direction. It is intended to store 100 to 150 mA in each beam with a luminosity of 5×10^{33} cm $^{-2}$ h $^{-1}$. The injector system, without the positron channel, is almost ready for operation.

VAPP 4, the very adventurous proton-anti-proton storage ring, is still in a state of flux concerning many features of its design (particularly the injector system and 'electron cooling' system). However, a model magnet for the ring has been built. From one block, poles are cut so that the magnetic fields are focusing, bending, defocusing and bending (separated function lattice) as in VEPP 3. It is intended to make the magnets in the Institute's workshop and to install the full magnet ring for VAPP 4 by February 1970. (The ring tunnel is ready to receive them.) First operation may be in 1971.

It is now no longer intended to use VEPP 3 as an element in the operation of VAPP 4. However, the first experiment using VEPP 3, to begin before the end of 1969, will be to carry out tests on the idea of 'electron cooling' (described in CERN COURIER vol. 6, page 219) which is a vital element of the VAPP 4 design. It involves running a specially prepared electron beam along a straight section in conjunction with a proton beam at the same velocity. Over many turns the electron beam steadily takes some of the 'heat' (the unwanted random motion) from the proton beam. For the experiment, a 200 MeV proton beam and a 100 keV electron beam will be used. VEPP 3 will be used for high energy physics in 1970.

The visitors to the Institute at Novosibirsk were very impressed by the ingenuity and the craftsmanship which is everywhere evident.

CERN

K. Johnsen gave a very neat report on the progress of the Intersecting Storage Rings project at CERN. The tunnel to house the storage rings is almost 'closed' (the walls and roof around the full 1 km circumference have been constructed) and about half the tunnel is ready to receive components. All the coils for the main magnets and more than three quarters of the magnet cores have arrived on site. About two thirds of the magnets are assembled and measured and many have been installed (around about one quarter of the tunnel in both rings).

All the major components of the r.f. system have been delivered and are being assembled. Seven of the high power units have been completed and their installation began in September. Virtually all parts of the low power system have been designed and built in prototype form and a substantial fraction built in final form.

About two-thirds of the vacuum pumps have arrived and have been tested. Some vacuum chambers with their pumping system are installed in the rings. Pressures a little below 10^{-8} torr are readily obtained without 'bake-out' and, after the first bake-out in situ a pressure of 2 x 10^{-10} was reached. In October, the first liquid nitrogen cooled titanium sublimation pumps will be moved into the ring for installation in an interaction region and it is hoped to pump down to 10^{-11} torr in November.

Among the many devices to observe the behaviour of the stored beam will be an unusual beam profile monitor. A ribbon jet (70 mm x 1 mm) of sodium vapour will be fired across the vacuum chamber condensing on the opposite wall. The circulating protons will release electrons from the sodium atoms and an electric field will bring these electrons to a fluorescent screen. The image of the cross-section of the proton beam can there be observed by a sensitive closed circuit TV system. The accuracy of the device is expected to be of the order of 1 mm.

Construction of the ISR is on schedule. The completion date remains as mid-1971.

Some news from other storage ring centres : At the Cambridge Electron Accelerator, USA, the bypass project (see CERN COURIER vol. 8, page 289) is almost ready to go. The last components of the bypass are being installed and the positron injector is undergoing acceptance tests. All the necessary techniques have been successfully tested and beams can be circulated through the bypass without loss. Electron currents of up to 30 mA intensity have been achieved so far at an energy of 3.5 GeV. It is hoped eventually to have 100 mA in each beam. Tests with both electrons and positrons circulating in the accelerator are scheduled to start at the end of this year.

After successful operation with colliding beams, reported in CERN COURIER vol. 9, page 171, the 1.5 GeV electron-positron storage ring Adone at the Frascati Laboratory has been hit by social unrest in Italy and particle physics experiments have not progressed.

The 550 MeV electron-positron storage ring ACO at the Orsay Laboratory in France, where some of the finest physics with storage rings to date has been carried out, has been undergoing some major changes since the beginning of this year to make operation for physics easier.

The Conference demonstrated how closely integrated are the particle physics Laboratories throughout the world. There was little 'new' at the Conference, which took something from the scientific interest but which reflects how good communications now are. It also reflects the fact that Conferences on accelerators have followed closely on one anothers heels over the past year (USSR Accelerator Conference in October 1968; USA Accelerator Conference in March 1969). It would help to even things out if the USA Conference (which has become very international) could alternate years with the International series.

There was friendly cooperation and openness in discussion from all participants to the Conference. The extent of collaboration between Laboratories is growing year by year — from necessity in many cases but with the willing involvement of the physicists — and the CERN-Serpukhov collaboration was prominent. If the trends in particle physics continue as they are now, this collaboration may prove useful, beyond its immediate purpose, as a pilot scheme for collaboration on a truly world-wide scale.

CERN News

Slow ejection efficiency

The efficiency of slow ejection systems has become increasingly important at CERN and at Brookhaven in the context of the improvement programmes to increase the accelerated beam intensities in the proton synchrotrons at both Laboratories. If high levels of efficiency are not achieved, the number of particles lost in the machines will seriously restrict the use of the slow ejection systems when the intensity of the accelerated proton beams is increased tenfold.

In 1968 CERN started detailed studies in this connection to discover why the theoretical efficiency (about 90 %) persistently eluded the PS, despite some important improvements made during 1967 which carried the efficiency to around 80 %.

The studies led to further improvements, which will be examined in more detail later, giving the excellent result reported at the end of this article. They also highlighted the problem of obtaining accurate measurements of the beam in a slow ejection system.

The need is to obtain a direct comparison between the number of protons ejected and the number of protons circulating in the machine prior to ejection. Three types of equipment can be used:

a) Beam current transformers (see CERN COURIER vol. 9, page 67). These devices measure the instantaneous intensity of the beam and can be installed to monitor either beam in the accelerator or an ejected beam. However they operate efficiently only at high beam intensities.

b) Induced activity detectors. These can take the form of thin metal sheets placed in the beam which are later removed and monitored for induced radioactivity. This measurement is related to the number of protons which have passed through the sheets. The method is only applicable to ejected beams.

c) Loss monitors — 100 air ionization chambers one on each PS magnet, an argon chamber carried by the manipulator, beam scanners in front of the ejection magnets.

To get at the slow ejection efficiency a round-about way is used involving all the above methods and measurements on the internal beam, the fast ejected beam and the slow ejected beam. There are no problems in determining the fast ejection efficiency. Beam current transformers are used (for the internal beam and the ejected beam).

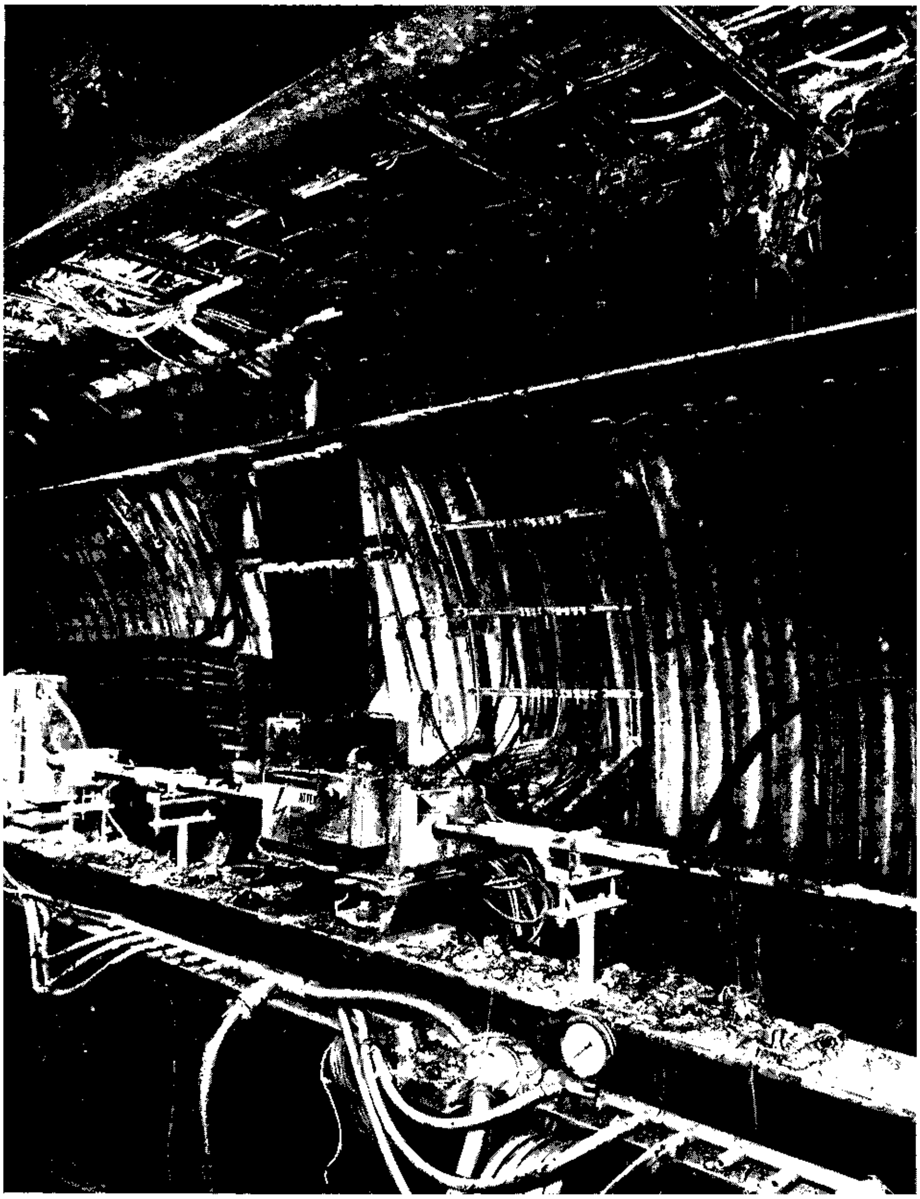
With slow ejection however, it is not possible to use a transformer on the ejected beam because, with the long spill time, the beam current is low. An induced activity detector must therefore be used. But determination of the number of protons by measuring the induced activity is not very accurate because of calibration errors and errors in the cross-section estimates. The result is accurate to within only ± 9% which is inadequate for thorough studies.

The present measurement method makes use of the fact that, whereas the absolute values of the number of protons, using induced activity detectors, are not precise, the relative values are accurate to within ± 1 %. This can then be used to compare the number of protons ejected in both fast and slow systems. The slow ejection efficiency then emerges as follows:

Over many cycles the ratio of the number of protons down the slow ejection channel compared with the number of protons down the fast ejection channel is found using induced activity detectors. Beam current transformers at the same time give the ratio of the number of accelerated protons when fast ejection is used compared to the number of accelerated protons when slow ejection is used. When the fast ejection efficiency is 100 %, these two ratios multiplied together give the slow ejection efficiency.

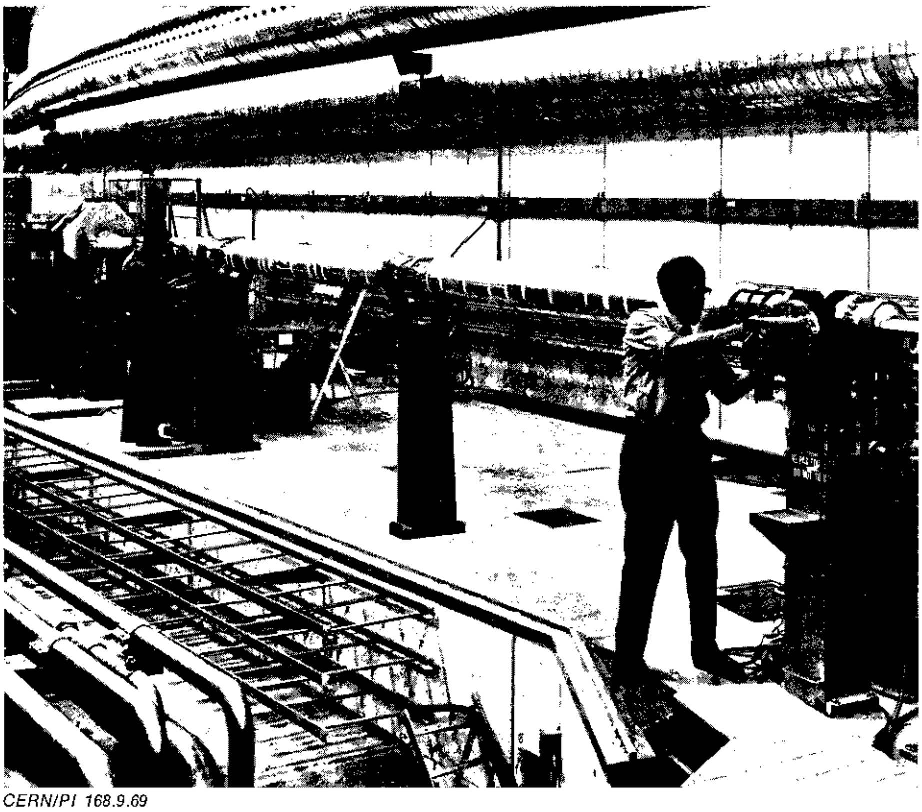
Using this method, the slow ejection efficiency has been measured as 90.7 ± 3.1 %. This figure has great significance. First of all it is a 'world record' for slow ejection systems — the result of many years of study and experiment which have steadily increased the understanding and control of these systems. Efficiencies had consistently, for reasons then unknown, been falling around 10 % short of what was expected, and slow ejection was becoming equated with things occult. Now the mystery has been dispelled and CERN can face their 10^{13} protons breathing easier. A paper by Y. Baconnier, O. Barbalat and D. Dekkers on the recent work at CERN was given at the Yerevan Conference.

On the morning of Sunday, 31 August, fire broke out in the middle of the outer tunnel in the south-east PS area, which houses the k 11 low-momentum separated pion beam and the neutrino beam which will feed the heavy-liquid bubble chamber Gargamelle. The neutrino beam was being tested.
It took the CERN firemen over two hours to put out the blaze, and the photograph gives some idea of the damage. Fortunately, no-one was injured. However, a whole series of cables were burned out and the pulsed magnets, the vacuum system and the beam control system were damaged by the intense heat and falling white-hot debris. Some of the synthetic mastic sealing of the building was destroyed.
Every effort is being made to have the k 11 beam operating again as soon as possible after the annual PS shutdown. With more than $1^1/_2$ million photographs already taken, the k 11 experiment was scheduled to run for a few weeks before the shutdown.
An investigation is under way to see how safety conditions can be improved before Gargamelle comes into operation. The accident should not affect the schedule for other experiments.



CERN/PI 1.9.69

Early in September, a pressure of 5×10^{-11} torr was achieved in a pilot section (16 m long) of the ISR vacuum system. This is the first section in the ISR tunnel which has been baked so far. Five 'bake-outs' at different temperatures and of different duration have been carried out (150 - 300 °C, 4 - 20 hours). The main purpose, apart from testing the bake-out equipment, was to find the best bake-out procedure. Before each new bake-out the chamber was exposed to atmosphere.
An average pressure of 10^{-9} torr has been specified for the ISR, but pressures of 10^{-10} torr or better could be achieved in uncomplicated sections like this pilot section. The average pressure in the completed rings will be determined by those sections where something goes wrong (such as poor pump performance, contamination or leaks).
Up to 17 September, out of a length of near 2000 m of vacuum system, 180 m were installed and 60 m are under vacuum. The installation is proceeding at a rate of about 40 m per week.



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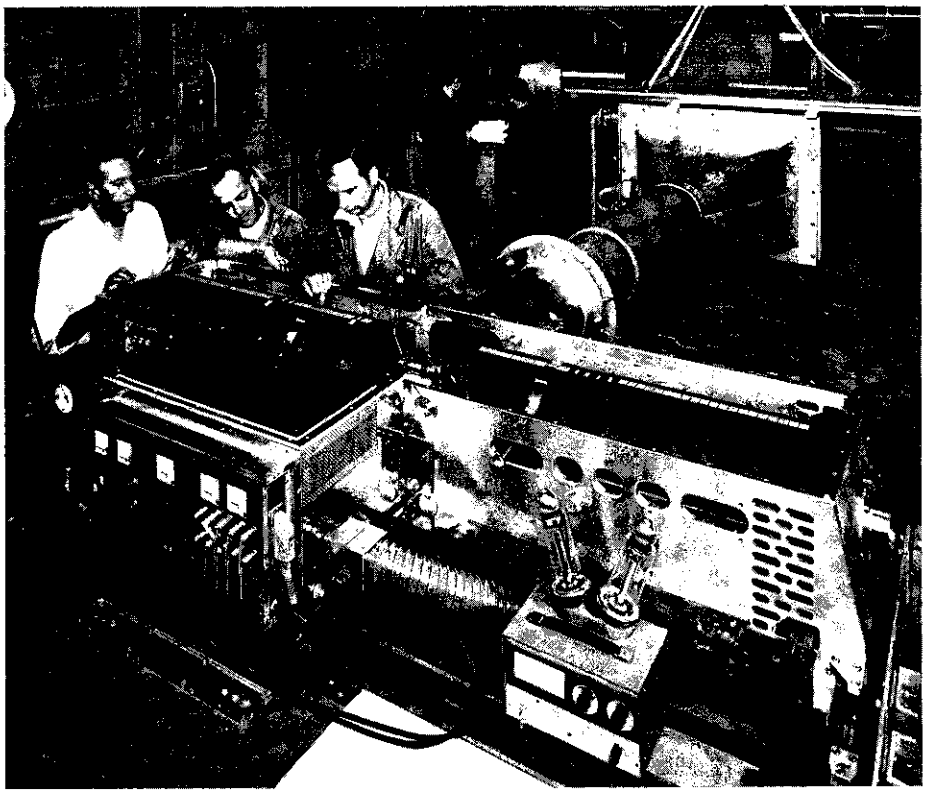
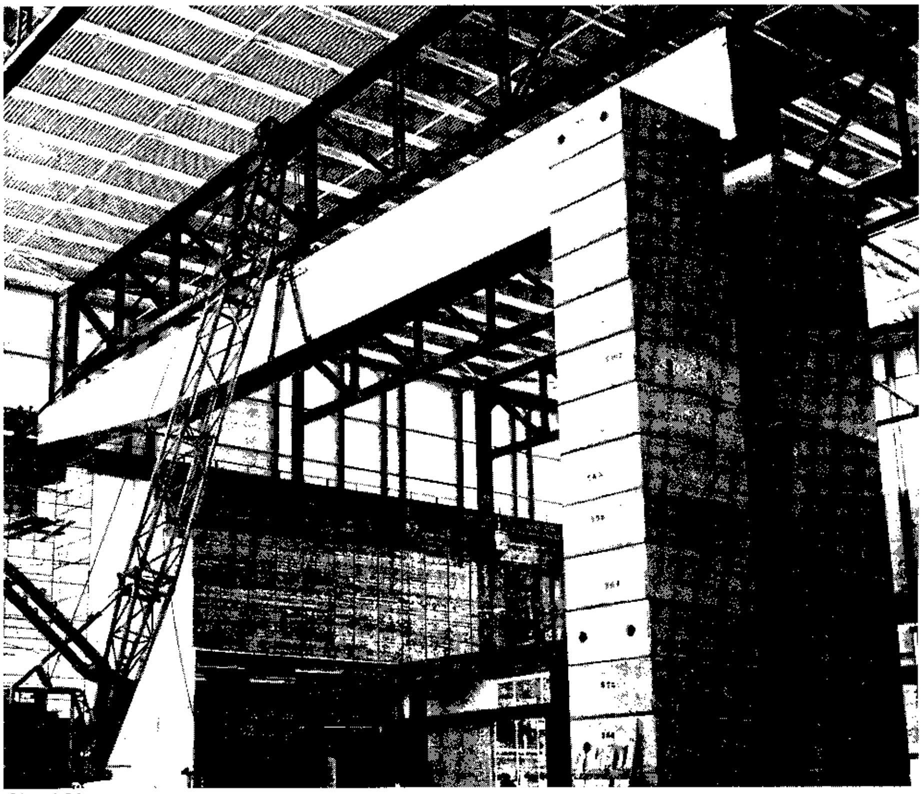


CERN/PI 98.7.69

A prototype r.f. cavity for the 800 MeV Booster; four cavities of this type will be installed (one in each of the four stacked rings). The cavities will operate over the frequency range 2.8 to 8.5 MHz with ferrite core tuning (a section of the cores is visible in the upper part of the cavity). Because of the space restrictions when the cavities are stacked one on top of another with only 36 cm between the mid-planes, the tuning is done by passing a current (up to about 700 A) through a spiral around the cores.
In the left foreground is the r.f. amplifier. The ferrite is kept at low temperature by an air conditioning system via the tube which can be seen perpendicular to the cavity. Tests are scheduled for completion at the end of 1969 and the final versions of the cavities should be ready for 1971.



CERN/PI 29.9.69

A photograph taken at the beginning of September during the installation of the crane-bridge in Experimental Hall I 1 of the Intersecting Storage Rings. This Hall covers one of the two interaction regions (from the eight where beam collisions can take place in the ISR) where extensive provision in terms of space for the installation of experimental equipment is being made from the start.
The crane-bridge, manufactured by Ceretti-Tanfani of Milan, will be the longest in use at CERN with the exception of that in the new West Experimental Hall (Hall E 1) described in CERN COURIER vol. 8, page 102. It will be capable of operation at continuously variable speed using d.c. current motors powered by a Ward-Leonard supply.
Its main characteristics are : total weight about 100 tons; maximum weight lifted : 40 tons; width : 47.6 m; maximum height of lift : 12.5 m; lifting speed : 6 m/min loaded; speed of bridge : up to 40 m/min.

Modifications to r.f. system

Among the major factors leading to the much improved performance of the slow ejection system at the proton synchrotron have been two modifications to the r.f. system. They have concerned techniques to remove the bunch structure from the accelerated beam. The first technique has involved the installation of remote control equipment which allows the amplitude of the accelerating voltage in the r.f. cavities to be modulated between 10 and 100 % of its peak value, and if necessary reduced to zero. The second technique concerns the tuning of individual cavities (or at present four groups of cavities) to different frequencies during the part of the cycle when the accelerating voltage on the cavities is equal to zero.

Acceleration in a synchrotron involves the formation of the orbiting proton beam into bunches (20 in the case of the CERN PS). For most uses of the accelerated beam (particularly for slow ejection) this bunch structure must be reduced as far as possible when the required energy has been reached. The structure is reduced by changing the stable phase associated with a change in the frequency of the voltage applied in the r.f. cavities.

This method has some drawbacks: since the full r.f. accelerating voltage is present on the cavities during the falling part of the frequency programme, resonances are excited causing an r.f. structure to appear in the proton beam. Also, during that part

1. *The top three graphs show accelerator operating conditions as they were until the end of 1968 : a) the magnetic field variation during the cycle, b) the fluctuation in the r.f. frequency (between 2.78 and 9.54 MHz) at constant amplitude, c) the stable phase variation. During the time between TA and BT2, the particles are subjected to the pre-transition phase, which has a debunching effect upon them. The bottom two graphs are recent modifications : d) the amplitude modulation incorporated at the beginning of 1969, e) the tuning of r.f. cavities to different frequencies incorporated in August.*

2. *Oscilloscope traces of the beam observed at the end of a cycle by a scintillator placed in an external beam. The top trace was taken prior to the improvements in August and still shows bunch structure in the beam. In the lower trace taken after the improvements, the bunch structure is no longer apparent.*

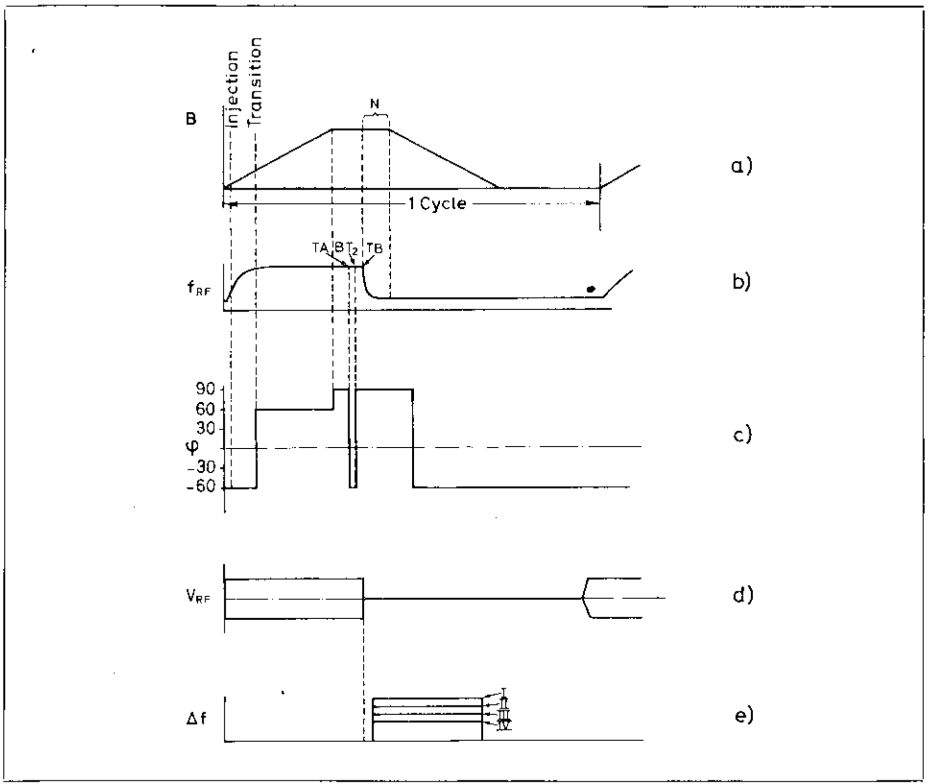
3. *Oscilloscope traces on the same scale (50 mV/division) of the proton beam observed by a wide band detection electrode in the magnet ring : a) the debunched beam with (b) and (c) from Figure 1 applicable, b) the beam after r.f. amplitude modulation is applied c) the beam after the cavity tuning has been set to different frequencies.*

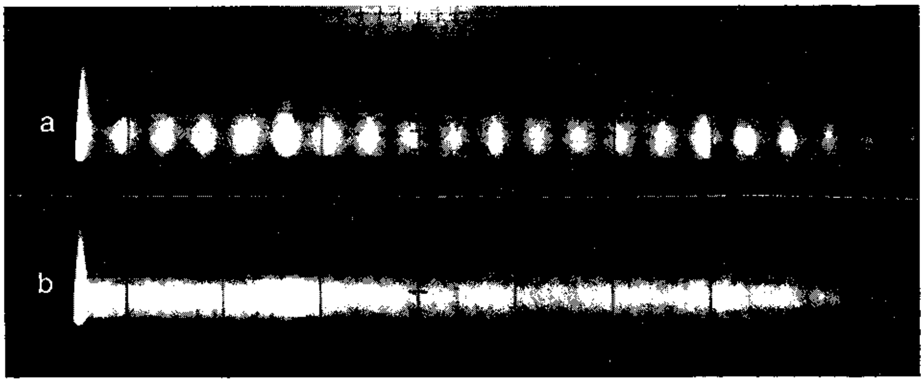
of the cycle when the protons pass through the fixed minimum frequency of 2.78 MHz, they tend to re-bunch at the sixth harmonic of the revolution frequency. Finally, the method does not reduce sufficiently the r.f. structure.

Since the beginning of 1969, it has been possible to use variations in the voltage applied to the r.f. cavities for debunching the beam. From the beginning of May, a method of operation has been introduced in which this voltage is reduced to zero and this has given a distinct improvement in the quality of the debunched beam.

However, the circulating beam as it passes through the cavities excites them at their resonant frequency (2.24 MHz). Since each cavity responds at this frequency, the beam-cavity interaction re-introduces structure in the beam (mainly at the fifth harmonic of the revolution frequency).

The ideal solution would be to short-circuit the fifteen accelerating gaps when the voltage on the cavities is reduced to zero. This method is being examined for the new accelerating system which is scheduled to be installed on the PS in 1972. In the meantime, a different method has been used for the existing system since the beginning of August. It consists of tuning the cavities differently when the voltage is reduced to zero. The fifteen r.f. cavities are divided into four groups which can be tuned separately to different frequencies in such a way that their effects become random. The result of these modifications can be seen on the photographs. The significant improvement in beam quality is such that they are already applied in normal machine operation while further tests are being carried out.





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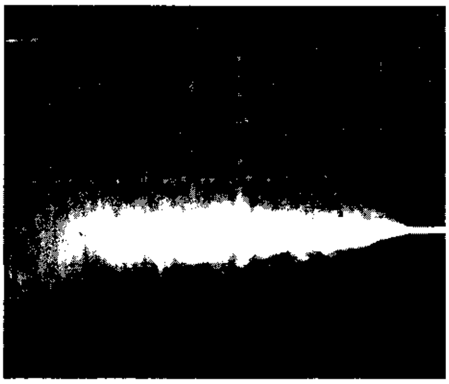
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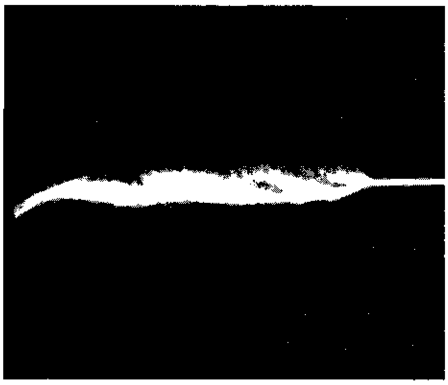
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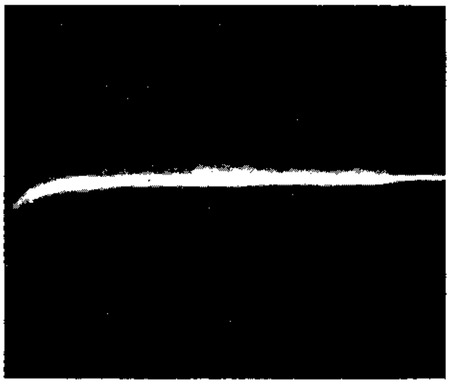
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Around the Laboratories

RUTHERFORD

Successful tests on target technique

The new bubble chamber target technique has been successfully applied in the 1.5 m hydrogen bubble chamber at the Rutherford Laboratory. The technique involves the installation of a hydrogen target within a larger chamber containing a hydrogen neon mixture. Such a system takes advantage of the merits of both the hydrogen and of the heavy liquid bubble chamber.

The Rutherford installation has a perspex 'bag' containing hydrogen running the length of the 1.5 m chamber whilst the main volume is filled with a hydrogen neon mixture.

The target bag has been developed and constructed in the Track Chambers Division at CERN on the basis of experience gained with similar devices for the DESY chamber and the CERN 1 m model.

The bag has plane walls parallel to the main chamber windows as can be seen in the photograph. It is constructed of perspex 2 mm thick and is 30 cm high by 4 cm deep. When the pressure system of the chamber is operated, the expansion is transmitted also to the hydrogen in the bag due to the movement of the perspex walls. Since the expansion needed is about 1 %, the movement of each wall needs to be only about 0.2 mm.

Thus the two liquids are simultaneously sensitive, i.e. charged particle tracks can be produced both inside and outside the bag. The bag is designed so that the optics are reasonably good.

The incoming beam is fired into the bag and particle interactions occur on free protons of the hydrogen (or also on neutrons if the bag is filled with deuterium). This preserves the advantages of a hydrogen chamber — simple production kinematics which can be used to identify the event and give the momenta and angles of missing neutrals or reduce the errors on these quantities if the neutrals convert to charged particles and are thus observed. Secondary particles pass into the hydrogen neon mixture, the perspex wall having no effect on them, and the advantage of the heavy liquid bubble chamber then comes into play — the mixture has a shorter 'radiation length' than pure hydrogen (particles travel shorter distances before converting to other particles which is often necessary for their complete identification). With this short radiation length the efficiency for converting gamma rays arising from neutral pions or neutral sigma particles produced in the initial interaction is similar to that of a heavy liquid chamber. It is also easier to identify electrons because of their characteristic tracks as they rapidly loose energy. (It is worth remarking that such a system will be of great advantage in the new generation of large chambers where, at high energies, efficient detection of gammas will be essential.)

The first test run has shown that the Rutherford system, by far the biggest of its type yet to be assembled, works well and will be an excellent instrument for physics.

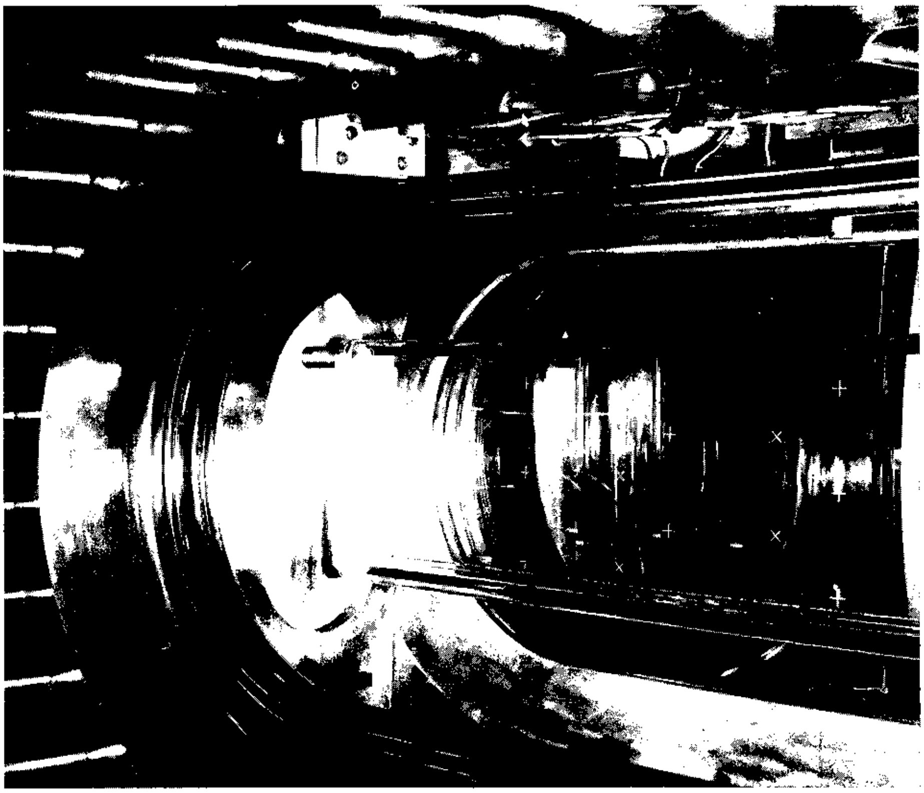
The run used a 50 molar per cent neon concentration in the mixture, which gives a radiation length of about 75 cm, and had good sensitivity conditions in both liquids. It is probable that higher neon concentrations could be used. (Previous tests at DESY have shown that, with deuterium in the target, a 93 molar per cent neon concentration can be used corresponding to a radiation length of about 30 cm.) There was some trouble with a perspex fixing pin and with ice forming on the perspex and spoiling the optics. These are the kinds of teething troubles to be expected and will be cleared.

The work has been a collaboration between Rutherford — C. Fischer, P. Williams and the bubble chamber operations group under M. Snowden — and CERN — H. Wenninger and H. Leutz (the proposer of this new technique .... see CERN COURIER vol. 7 page 112) and F. Schmeissner.

Two experiments are preparing to use the system. One is a study of the beta decay of the lambda which will take advantage of the hydrogen neon mixture's efficiency in detecting electrons. A Rutherford, CERN, University College London group will use a 1035 MeV negative pion beam to produce polarized lambda particles through the reaction

$$\pi^- + p \rightarrow \Lambda^0 + K^0$$

The production kinematics will make possible a complete analysis of the subsequent decay of the lambda into proton, electron



1. A view inside the 1.5 m hydrogen bubble chamber at the Rutherford Laboratory showing the perspex bag, which contains the target hydrogen, installed. It runs the length of the chamber with plane walls parallel to the chamber windows.

2. A photograph taken during the first test runs. The hydrogen and the hydrogen neon mixture outside the perspex bag are simultaneously sensitive and tracks appear in both liquids. There is negligible track distortion in going from inside to outside the target.

(Photos Rutherford)

and anti-neutrino, and a study of all the angular correlations involved.

The second experiment, proposed by an Oxford group, will use deuterium in the target bag and use the mixture to spot the two neutral pions from the reaction

$$\pi^+ d \rightarrow pp \, \pi^0 \, \pi^0$$

at a momentum of about 2.3 GeV/c. In this case it is only necessary to measure the angles of the gamma rays from the neutral pions as they convert to electron-positron pairs in the mixture. The detection efficiency for all four gammas is estimated to be around 20 %.

When the technical development period is over, it is intended to open the facility to European groups at large and perhaps all appropriate European experiments, which can benefit from the particular attributes of the system, will be carried out at Rutherford.

STANFORD (SLAC)

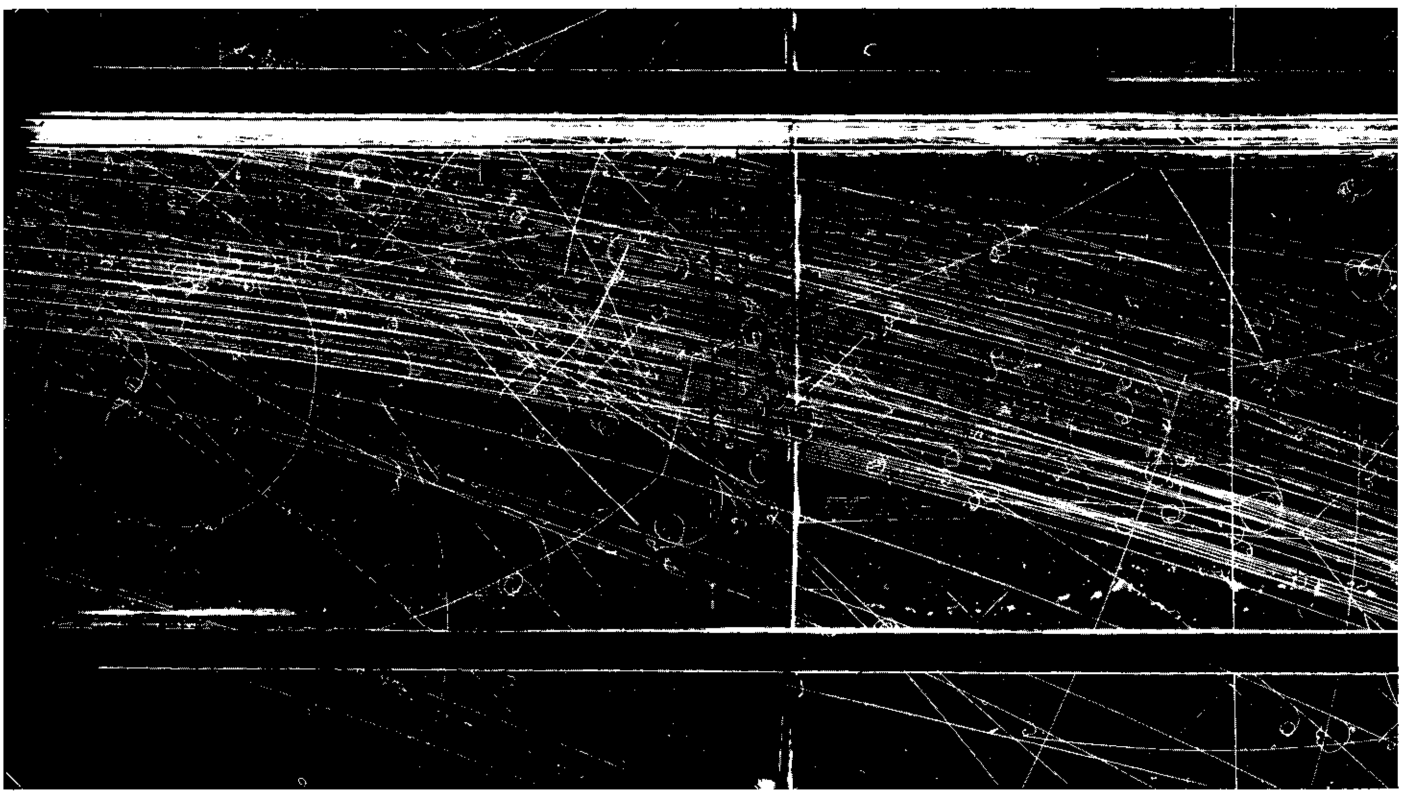
Storage ring re-think

Since 1966, the Stanford Linear Accelerator Laboratory have had a proposal for a 3 GeV electron-positron storage ring (see CERN COURIER vol. 8, page 288) on the table with no sign of any construction money. In view of the fact that DESY received authorization to build storage rings with very similar parameters, which would probably be in operation sooner, the SLAC team began a major re-think of their proposal in January of this year.

The aim has been to cut the cost severely by accepting lower performance figures for initial operation (with ability to climb higher later) while still retaining much of the physics potential. After surveying existing designs they have put forward a new proposal called SPEAR (Stanford Positron-Electron Asymmetric Rings). The name brings out a distinctive feature of the design — there are two asymmetric rings (each slightly pear-shaped) intersecting horizontally at an angle of 10.5° as shown in the diagram.

The decision to separate the two rings, as opposed to the initial single ring proposal, has followed the experience of storage rings such as ADONE where considerable difficulties were met in trying to cope with both beams at once in one ring. Separating the rings simplifies injection (no trouble from an intense stored beam affecting the other beam as it is injected) and the tuning of each beam (the beams can be monitored and controlled separately). At the same time, separating the rings did not push the cost up. The large horizontal crossing angle has some advantages. It does not require the complex quadrupole and septum arrangements of a vertical crossing design and is a benefit (giving a finite velocity to the centre of mass of the colliding beams) in some physics experiments.

Some main design parameters for Stage 1 are : Peak energy of each beam 2 GeV; intensity at peak energy 0.5 A; luminosity at peak energy 10^{32} cm^{-2} s^{-1}. At 2 GeV the machine will be above threshold for pair-production of all the long-lived mesons and baryons and of most of the meson and baryon resonances. If the physics proves interesting, a Stage II could be implemented taking the peak energy to 3 GeV with a beam intensity of 1 A per beam and a luminosity of 3 x 10^{32} cm^{-2} s^{-1}.



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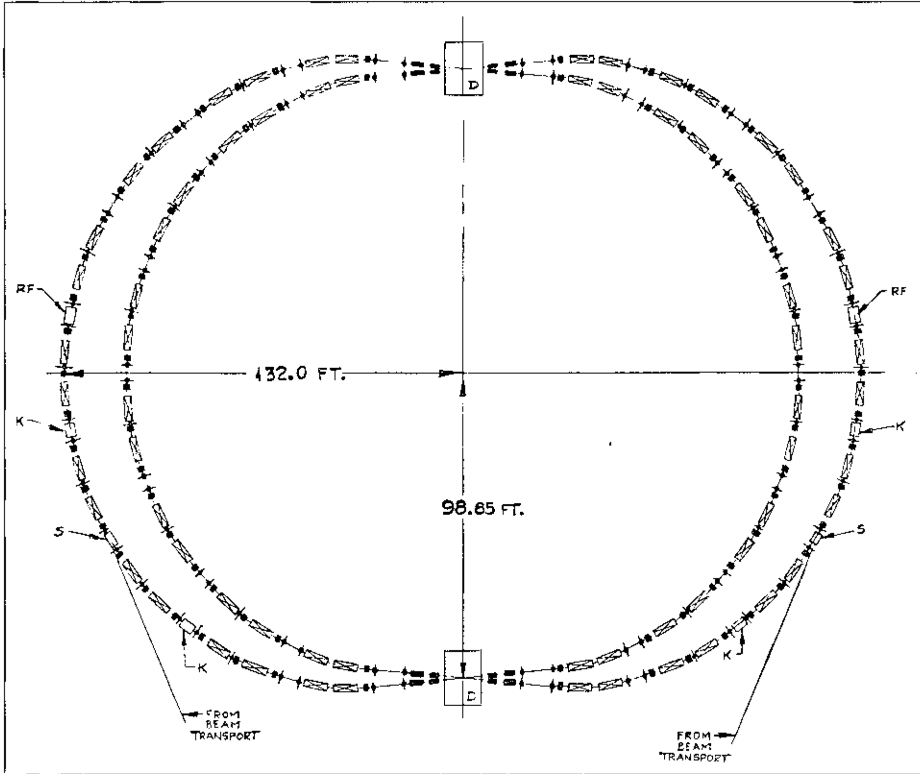


Layout of the two rings in SPEAR, the new electron-positron storage rings proposal at the Stanford Linear Accelerator Centre. The crossed rectangles represent bending magnets; the solid squares quadrupoles; RF the radio-frequency accelerating cavities; K kicker magnets; S septum magnets; D detectors; the solid circles vacuum pumps.

To save money in the construction of buildings, the storage rings will be positioned at the output end of the 20 GeV electron linac. The magnets are of conventional type and are designed to operate upto 3 GeV. One r.f. station per ring will initially supply 60 kW to combat energy loss due to synchrotron radiation. The vacuum chamber is of corrugated aluminium and will probably be pumped by ion pumps. Components will be pre-assembled in modules along a 30 ft girder before installation in the rings; alignment and connections of power etc. will be simple.

The Congressional Joint Committee on Atomic Energy and the Atomic Energy Commission have encouraged the Stanford team to carry out a research and development programme on the new storage rings design. The cost estimate for Stage 1 has come down to $ 9 million, less than half the cost of the initial proposal. It is hoped that construction money will be available from July 1970 so that the rings could be in operation at 2 GeV by mid-1972.

BERKELEY

HAPPE project

Plans are complete for the first flight of a new small superconducting magnet gondola (SSCM). The project has emerged from Alvarez's High-Altitude Particle Physics Experiments (HAPPE) group at the Space Sciences Laboratory and the Lawrence Radiation Laboratory of the University of California in Berkeley. The equipment, which is now in the final stages of construction and assembly, will be carried to about 120 000 ft by a 20 000 000 ft^3 helium-filled polyethylene balloon for the first series of experiments which will be a survey of the cosmic ray energy spectrum and composition in the region from 10 to 100 GeV per nucleon.

The heart of the gondola is the superconducting magnet, which is not really 'small', except in comparison to its big brother, the enormous 4 500 lb superconducting magnet, 1 m in diameter by 2 m long, that has also been completed by the group. The small magnet is expected not only to provide valuable physics in itself, but also to provide experience of the techniques required to fly the large magnet.

The SSCM gondola is essentially a cosmic ray spectrometer. Two optical spark chambers above the magnet determine the incident direction of a particle entering the telescope. The particle is then deflected in the magnetic field and its exit trajectory is determined by two lower optical spark chambers. The amount of bending in the magnetic field determines the rigidity (momentum/charge Z), and the Z^2 of the particle is determined by pulse-height measurements in cesium iodide scintillators.

First experiments with the SSCM gondola will concentrate on determining the energy spectrum of particles which have charge Z of 3 or above. High resolution measurements of the primary proton and helium spectra and a search for anti-helium will also be made.

The recent success of the rotating-neutron-star theory of pulsars, particularly as formulated by T. Gold of Cornell University, have greatly accentuated the need for accurate measurements of the various chemical constituents of high energy cosmic rays. Comparisons of the observed composition of neutron stars with that theoretically predicted could give important support to the speculation that pulsars are the major source of cosmic rays.

Observing particle interactions

The SSCM may be regarded as a beam survey using high-energy protons in the cosmic rays as incident beam particles for the study of interactions of high energy particles. Once the first flights have been successfully accomplished, the HAPPE group will be flying the large superconducting magnet with a hydrogen target in order to study proton-proton interactions between 100 and 1 000 GeV incident energy.

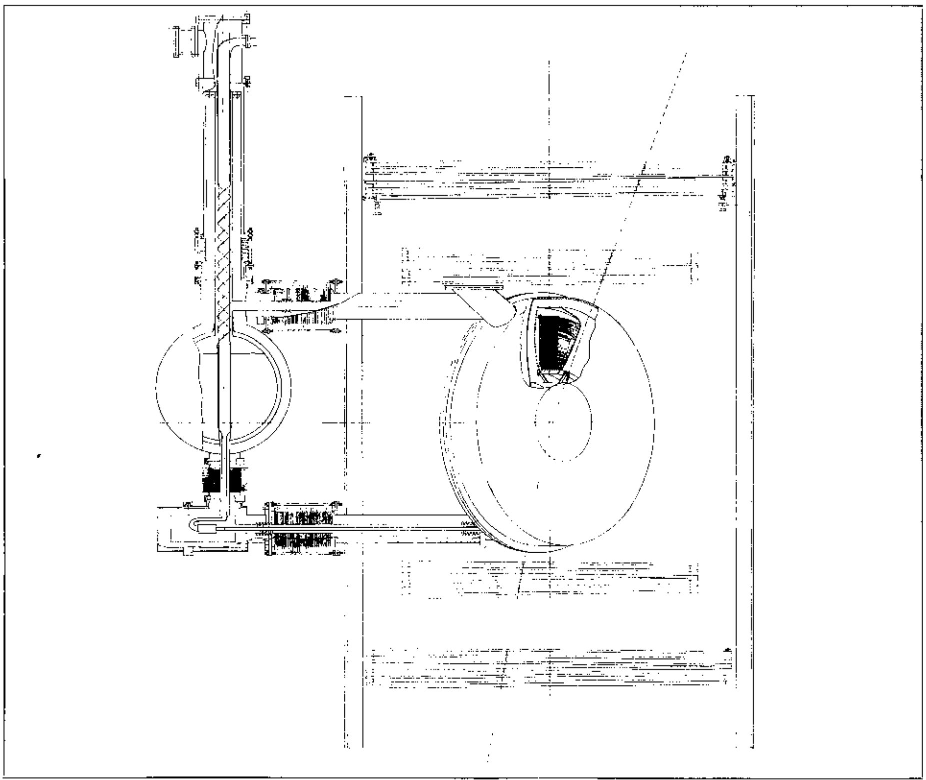
In order to measure these very high momentum particles in the magnetic field which can be produced, development is proceeding with tandem emulsion - spark chamber detector systems. Nuclear emulsions have a spatial resolution approximately 100 times better than the best optical spark chambers and when this is used in combination with a refined time resolution device like a spark chamber, the emulsion need be searched only in the small area of interest for a track of the proper angular inclination. This simplifies enormously the problem of scanning a meter-square emulsion for the relevant tracks. These techniques will make it possible to determine momenta in the region beyond 1 000 GeV.

Active development is also proceeding on a thin high-resolution liquid Geiger counter array with electronic read-out. This detector works on the principle that electron mobilities in liquid argon are sufficiently high for ionization electrons to follow a particle track, exactly as they do in a conventional spark chamber. Since the liquid densities are so much greater than gas, only a very thin layer of liquid is required; thus, the chamber is capable of high transverse resolution. It is hoped that such a chamber could operate with collector wire spacings in the region of 50 microns, yielding a moderately high-resolution detector with electronic read-out suitable for operation in magnet fields.

Spark chambers and charge determination system

A particle with incident rigidity of 100 GeV will be deflected only about 2.5 milliradians

A cross-section of the cosmic ray spectrometer (SSCM) which will take its first balloon flight in October. The superconducting magnet is indicated with its helium supply Dewar. Optical spark chambers positioned above and below the magnet will record the particle trajectory which will be bent in the magnetic field.



and to detect deflections of this order, a set of high-resolution optical spark chambers is used. For SSCM, spark chamber plates have been made by bonding aluminium foil to large thin sheets of Styrofoam. The plates are assembled between 1 cm thick optical glass windows, the assemblies forming modules of four gaps each. The incident trajectory is then determined by the sparks in two such modules - eight sparks give the particle direction. Similarly, the exit direction is determined by eight sparks. Spark averaging then determines the angular deflection to within about 2 mr.

In order to determine the momentum and not merely the rigidity, the particle charge must be measured. This can be done by measuring the light output from a scintillator, which is proportional to the square of the particle charge. Unfortunately, for high light levels (such as would be produced by particles with charge of 20 or above) conventional plastic scintillators saturate. CsI(Na) is a scintillator whose saturation properties are better than conventional plastic scintillator, and it is used in the spectrometer for this reason.

Development is in progress on a non-saturating Cherenkov counter. Light resulting from the Cherenkov effect ought to be free of the saturation effects exhibited by the scintillation process, remaining proportional to Z^2 even for very high Z, but there is difficulty with the extreme directional property of the Cherenkov light. To circumvent these directional effects the radiator is doped with a wave shifter, which should isotropize the light as well as reducing the frequency. Prototype detectors of this type are now being tested at the Bevatron in a joint effort with physicists from the Manned Spacecraft Center.

Five channels of 'down-link' telemetry information and 32 'up-link' commands are provided for data acquisition and gondola control. Thus the experimenter can examine the data during the flight and, if necessary, change the operating state of the cosmic ray telescope.

The superconducting magnets

The design of superconducting magnets for balloon or spacecraft use is radically different from the design of conventional superconducting magnets - very careful attention has to be paid to the 'weight budget'.

The small superconducting magnet is a single-coil design, wound with 13 000 turns of copper-stabilized niobium-titanium wire. The main parameters are :

Configuration : Single coil with access available to both faces for instrumentation.

Coil dimensions : 24 inch outside diameter by 12 inch inside diameter by 2.5 inch thick.

Maximum field in bore : 41 kG.

Current density : 2.4 x 10^4 A/cm^2.

Conductor : 0.73 mm Nb-Ti strand clad with 0.19 mm thick Cu; 210 lb.

Maximum current : 110 A.

Weight of coil and Dewar assembly : 350 lb.

The magnet has been tested to its flight current many times and has successfully sustained over fifteen intentional transitions from superconducting to normal conducting conditions without damage.

The large HAPPE magnet is a very different design, wound as two separate coils, each of a complex saddle shape; it gives a highly uniform transverse field and a very large acceptance bore. Its weight, however, requires that it be flown using Mylar balloons, which are considerably more expensive than polyethylene.

The main parameters are :

Configuration : Saddle-shaped split coils with 1 m diameter clear access.

Central field : 9.7 kG.

Conductor : 19 strand cable with three 0.51 mm diameter strands of Nb-Ti.

Current : 800 A.

Weight of coils and Dewar : 4 500 lb.

Flight operations

Under the present schedule the first flight series of the small superconducting magnet and gondola will start in October. On each flight the gondola will be launched from the High Altitude Particle Physics Experimental Faculty at Chico, California, and will ascend to an altitude of 120 000 feet, where about 4 g/cm^2 of residual atmosphere lies above the gondola. The prevailing winds at this altitude will drift the gondola slowly over the continental United States for a total flight duration of about 20 hours. During this time a telemetry receiving aircraft will track the balloon. Telemetry decoding equipment aboard the aircraft will provide a 'quick look' at the physics data and the equipment performance. At the conclusion of the flight the balloon will be vented down to approximately 40 000 feet and the gondola will be let down on parachutes when it is over a desirable recovery location.

The short exposure time available with balloon-borne instruments is a rather severe limitation, and as a result, considerable planning and design are being done by the group to include superconducting magnet cosmic-ray telescopes in future satellite programmes. The NASA Apollo Applications Program will be capable of carrying heavy payloads, with astronauts available for repair and servicing, and would provide a relatively frequent resupply schedule. Such a space-station facility would be able to conduct thorough experiments on proton interactions as well as observing the composition and energy spectrum of the incident flux of cosmic rays.

Professor Bogolyubov, who celebrated his sixtieth birthday in August, out walking with his grandson.

(Photo Yu. Tumanov)

Professor Bogolyubov 60th birthday

The distinguished Soviet theoretical physicist Nicolaj Nicolaevich Bogolyubov celebrated his sixtieth birthday on 21 August. For the past forty six years (his first work was at the age of 14 !), he has devoted himself to research, developing new trends in theoretical physics and founding a large school for mathematicians and physicists.

Bogolyubov was born in 1909 in Nizhnij-Novgorod (now Gorkij). In 1923, he joined a seminar under N.M. Krylov and by 1924 had written his first scientific paper. A year later, he started his post-graduate course in the Department of Mathematical Physics of the Ukrainian Academy of Science. In 1928, he submitted his thesis and became a scientific member of the Ukrainian Academy. In 1930, the Presidium of the USSR Academy of Science conferred on him the degree of Doctor of Mathematics.

In later years, Bogolyubov was involved not only in scientific research, which he continued without interruption, but also with the organization of science and with teaching. He held the posts of Head of the Department of Mathematical Physics at Kiev State University (1936-1950), Professor at Moscow State University (1943-1950), Dean of the Mechanical Mathematics Faculty at Kiev University (1946-1949). Starting in 1949, he directed the Department of Theoretical Physics at the Mathematical Institute of the USSR Academy of Science; he then (1953) directed the Department of Theoretical Physics at the University of Moscow, and was Director of the Institute of Theoretical Physics (from 1967).

In 1939, Bogolyubov was elected corresponding Member of the Ukrainian Academy of Science, becoming an 'Effective Member' in 1948. In 1947, he was elected Corresponding Member of the USSR Academy of Science, and became a Full Member in 1953. In 1956, he was appointed Director of the Laboratory of Theoretical Physics at the Joint Institute for Nuclear Research, Dubna, and was appointed Director of Dubna in 1964.

Bogolyubov's scientific work has covered a great number of problems in theoretical physics. He is one of the founders (with N.M. Krylov, in 1932) of the theory of non-linear oscillations. The methods he devised have had a decisive influence on the subsequent development of the statistical theory of irreversible processes.

To solve problems concerning the statistical mechanics of classical systems, Bogolyubov proposed methods using distribution functions and generating functions. A distribution function system was used for the analysis of non-equilibrium processes and led him to a general method for the construction of kinetic equations for interacting particle systems on the basis of the general premises of statistical mechanics. The solution of kinetic equations was based on a generalization of his asymptotic methods of non-linear mechanics.

This method proved most effective in the solution of problems in ferromagnetism. He studied the problem of the degeneration of non-ideal gases and showed that a weakly non-ideal Bose gas may exist in a degenerate state, in which case it will be superfluid, whereas an ideal gas does not possess this property. In this way, a theoretical model was evolved for the phenomenon of superfluidity. Bogolyubov brought out the decisive role of the interaction of correlated pairs of particles. He showed that the same type of excitation also occurred in superconductors, where a decisive part is played by the interaction of electrons with lattice oscillations. Overcoming considerable mathematical difficulties, Bogolyubov was able to construct a consistent microscopic theory of superfluidity and to show that superconductivity may be considered as superfluidity of the electron gas.

During the 1950's, Bogolyubov produced a series of papers dealing with quantum field theory, building a theory, not by means of the traditional Hamiltonian formalism, but on the basic of explicitly formulated basic physical requirements, the most important of which is the condition of causality. Bogolyubov's new formulation of quantum field theory is set out in the monograph 'Introduction to the theory of quantized fields'. A major landmark in the development of modern theory was Bogolyubov's work on dispersion relations, which are now widely used in particle physics.

The wide range of Bogolyubov's research, his profound ideas, and the powerful mathematical methods which he has developed, together with his exceptional ability as a teacher, have had a considerable influence on contemporary theoretical physicists. Pupils of Bogolyubov are carrying out research at scientific centres in many countries. He has been elected a Member of the Academy of Science of Bulgaria, the German Democratic Republic, Poland and the USA, and Doctor of Science 'Honoris Causa' at a number of Universities.

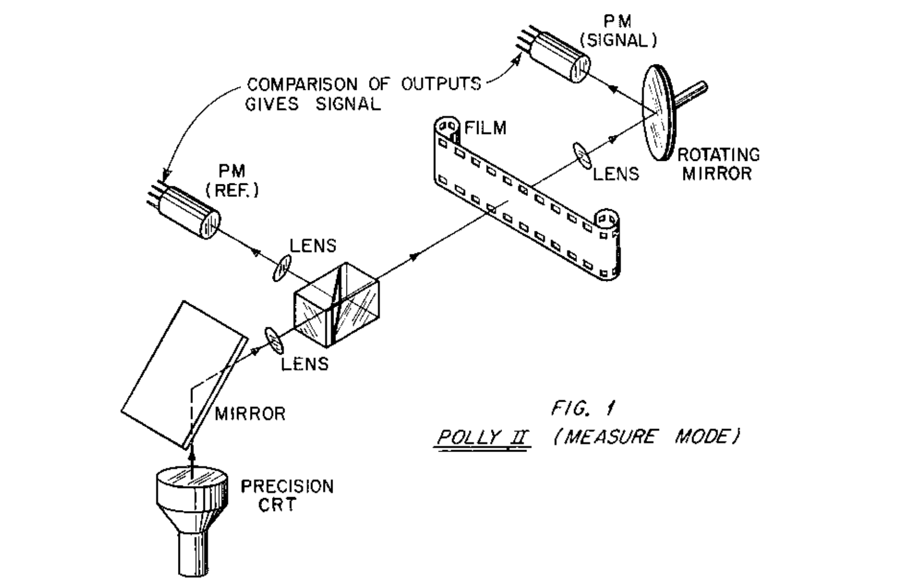


FIG. 1
POLLY II (MEASURE MODE)

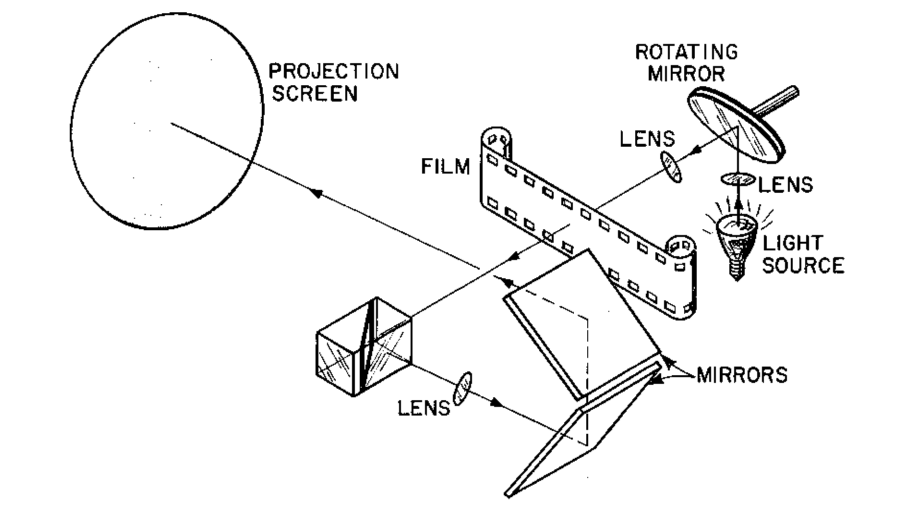


FIG. 2
POLLY II (DISPLAY MODE)

Diagrams of the optical paths in POLLY, the automatic system for measuring bubble chamber film at Argonne. Figure 1 shows the optical path when the system is used in the measuring mode. Figure 2 shows how, by a series of shutters and a rotating mirror, the film under examination is observed on a screen by the operator.

The photograph is of the actual hardware of POLLY with the lid off.

(Photo Argonne)

ARGONNE

POLLY puts its mettle on

The automatic bubble chamber film processing system developed at Argonne, known as POLLY, is now in full flight in its production version.

Early in 1966, the Argonne bubble chamber experts began to study the problem of automatic film measurement and, after looking at developments elsewhere, decided to produce their own system. They benefited from the experience of other systems, such as PEPR and the Spiral Reader at Berkeley and the HPD at CERN, and decided to concentrate on a highly 'interactive' system — one which would allow extensive, efficient communication between the computer which controlled the system and the operator.

Almost all of the automatic measuring systems now in use involve a major effort in scanning and pre-digitizing of the film to tell the system where to look. POLLY, however, can deal with film directly from the bubble chamber, without prescanning, at the rate of about 100 events an hour, with the help of an operator 'on-line'. The digitized output from the machine is fed directly into the geometrical reconstruction program in the computer with no intermediate filtering. (It also deals with pre-scanned film).

POLLY is a CRT flying spot digitizer which has extensive facilities to enable the operator to see what is happening and to help with the scanning and measuring process whenever this is necessary. The machine is on-line to an SDS Sigma 7 computer which does the filtering, track following, and event recognition and which also controls the display to the operator and the interaction facilities. The operator has two screens to observe — one giving him a direct optical display of the film which is being measured and the other giving him a computer-driven display. He communicates with the computer by means of a track ball, an orientation wheel and a series of buttons which enable him to feed in a decision in cases of doubt, to add or delete tracks and to give other information in exceptional cases.

The computer program is written so that

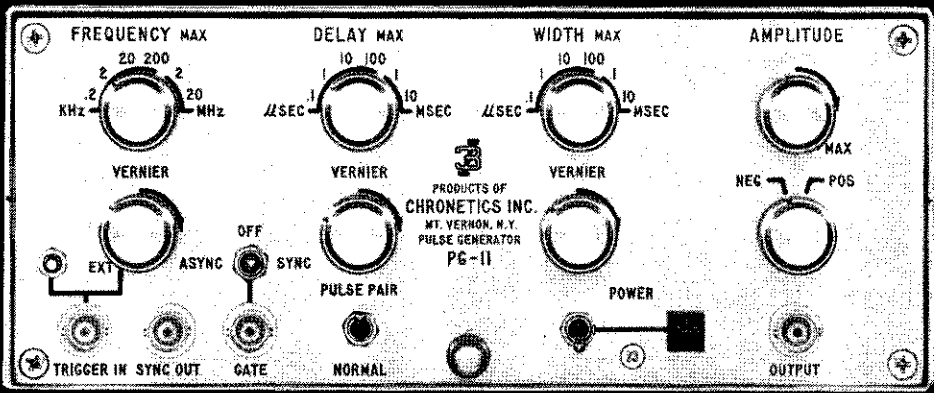
an event is normally scanned and measured automatically, while the operator is given the chance to approve the final measurement or to make corrections when the machine is in doubt. During the scanning procedure, particular care is taken to err on the side of asking the operator to intervene too often and thus to avoid missing valid events. Comparisons with 'hand scanned' film show that an event loss of about 5 % does occur. About half of this is due to the machine's inability to find beam tracks quite as well as the human eye and causes no physical bias. The accuracy of the measurement compares well with that of hand measuring machines.

Hardware for the prototype version, POLLY I, began to come together in 1966 and by March 1967 the machine was fed with film for the first time. A year later, POLLY I was in full-scale use and construction of, the production version, POLLY II, was already well advanced. Late in 1968, this became operational and POLLY I has retired.

POLLY II is now dealing with film from the Argonne 30 inch hydrogen bubble chamber in an experiment using antiprotons of momentum 2-3 GeV/c. It is being automatically scanned and measured for events giving 2, 4, 6, or 8 prongs (emerging charged particles). It is also being used with pre-scanned film where scan information is given to the machine on the topology and the location of the principal interaction vertex in one view. The events being measured are from an experiment involving negative kaons of momentum 5.5 GeV/c on deuterium. They have one or three prongs and a V-zero (two charged particles coming from a neutral particle) or a short spectator track may be present. Whereas the production vertex is handled automatically by POLLY on all measured views, the operator is required to indicate the V-zero vertex. These events are being processed at the rate of about 75 an hour, which is a typical speed for the more complex type of event.

During 1969, POLLY has measured over 100 000 events and about 65 000 of them have been using the system in the scan-and-measure mode. The program has been steadily improving in output during this time and recent measuring speeds of scan-and-measure have been about 8 800 events per week of 91 hours of operation.

A High-Performance, Compact Pulse Generator



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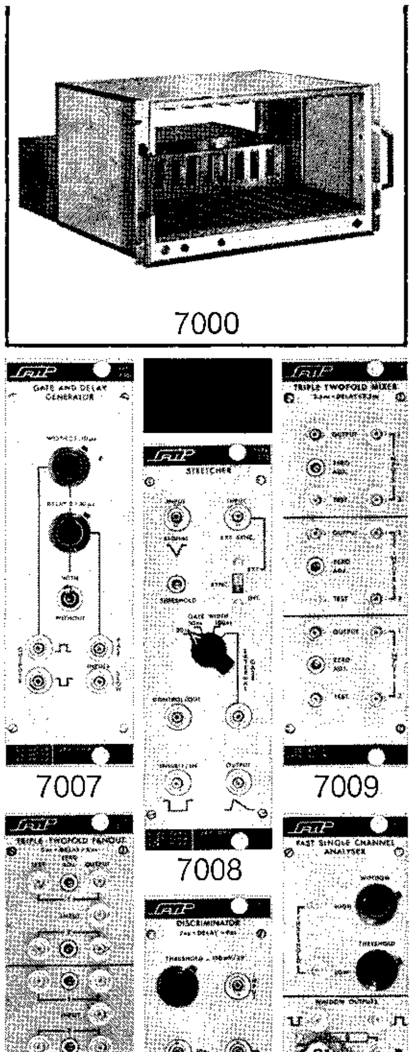

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7023 4-fold mixer
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Fast linear gate 7033

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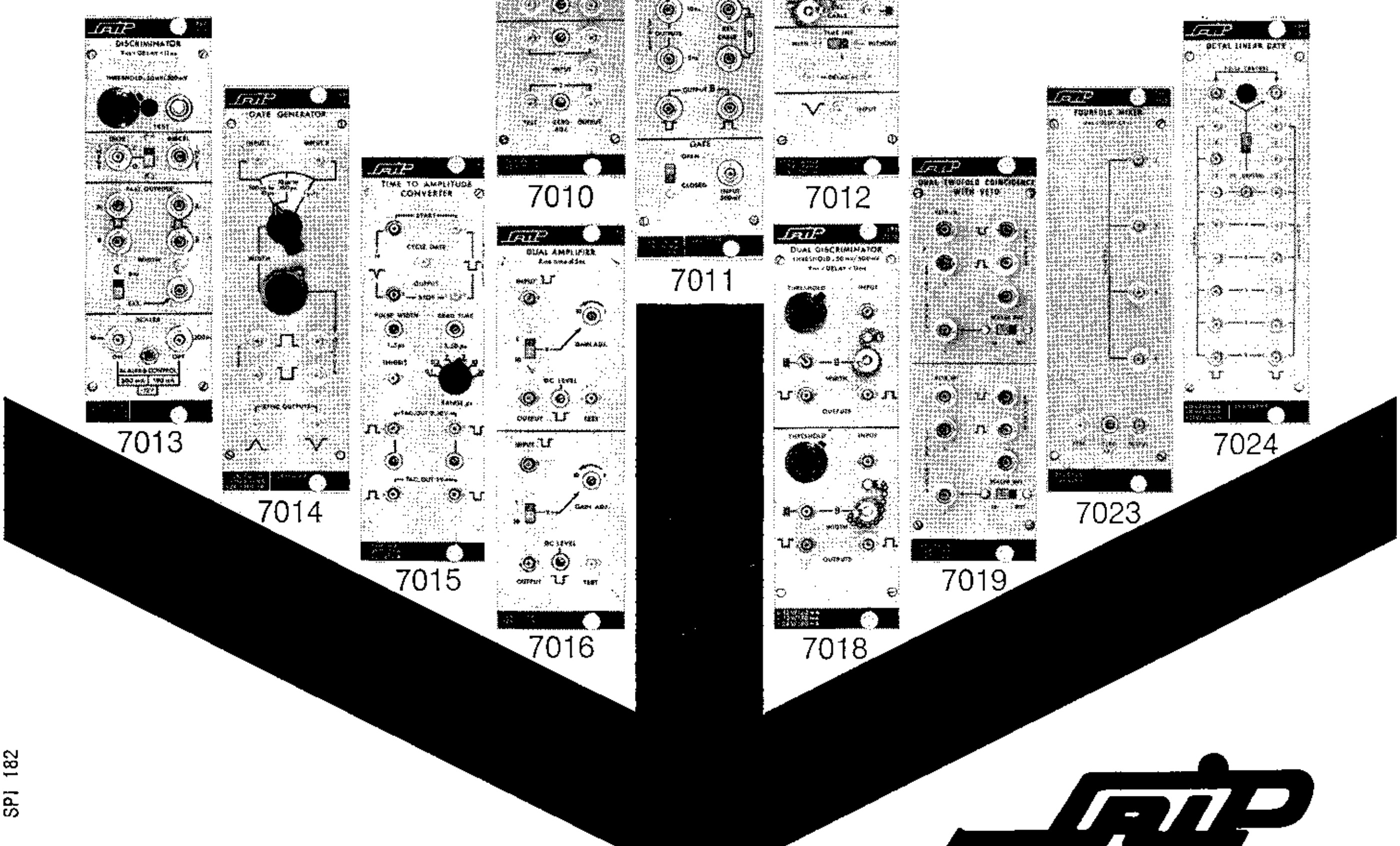

SPI 182

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(A JLI presentation)

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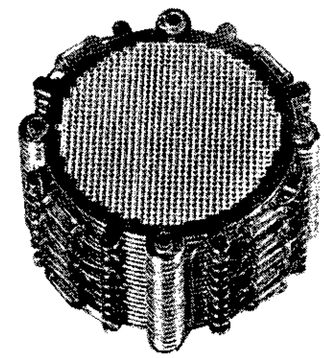

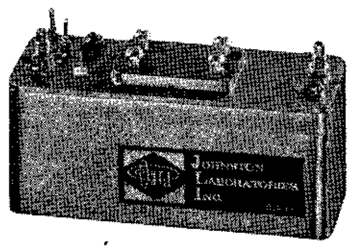

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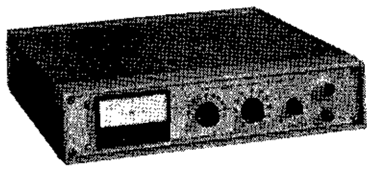

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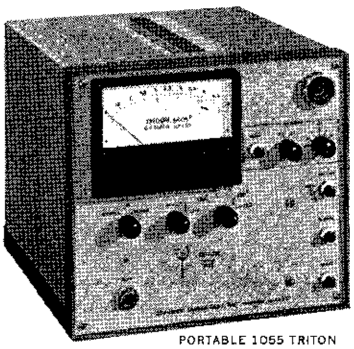
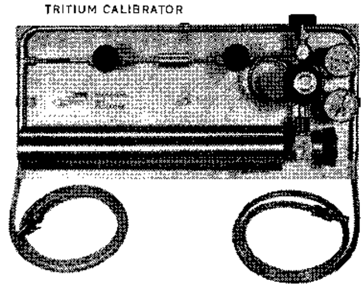


PORTABLE 1055 TRITON

TRITIUM CALIBRATOR



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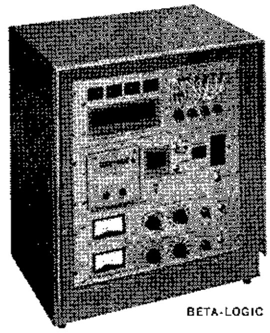

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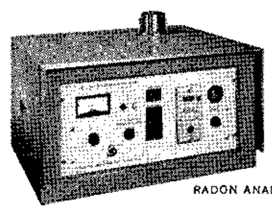

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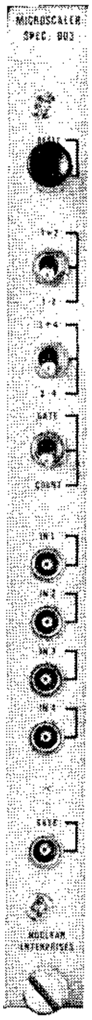

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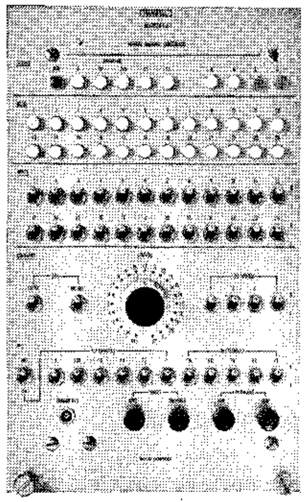

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7024 Manual Dataway Controller
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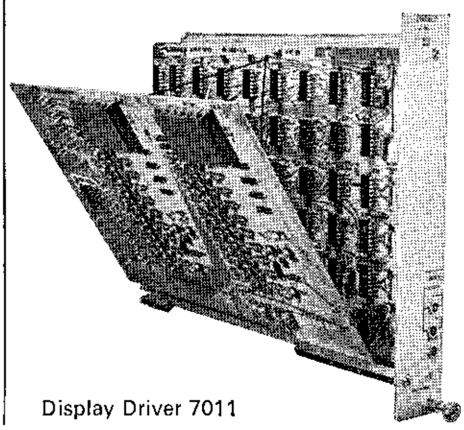

Display Driver 7011

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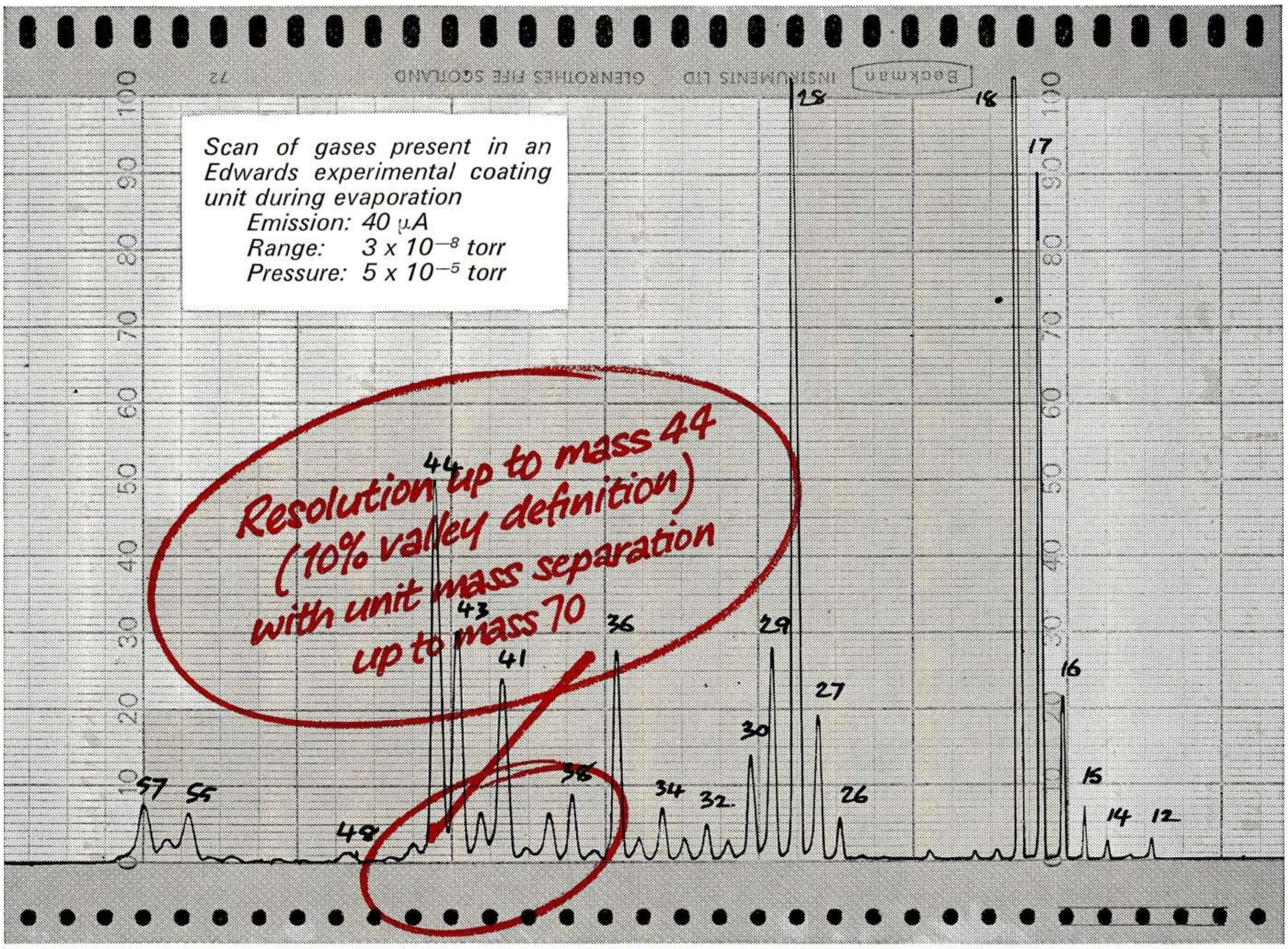

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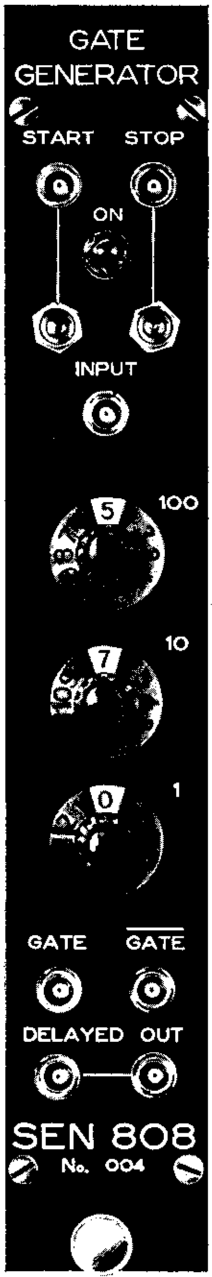
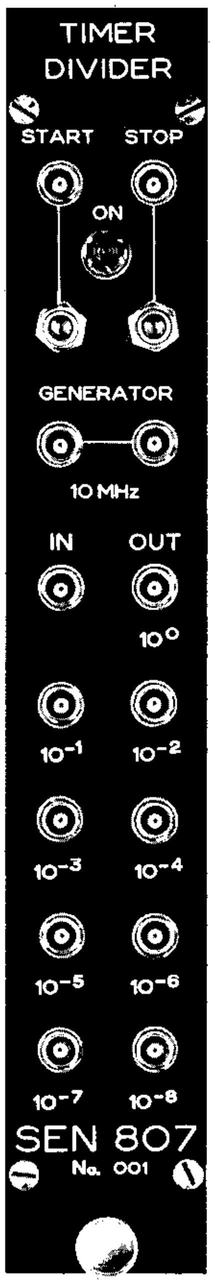
THE GENERAL PURPOSE GATE GENERATOR

The 808 GATE GENERATOR, together with its companion module, the 807 TIMER, solves all timing and sequencing problems encountered in Nuclear Physics.



The 808 GATE GENERATOR is a three decade preset counter driven by external pulses. Input is under control of a START-STOP flip-flop. It can be used for **preset time** operation if a constant rate pulse train is fed into its input or for **preset count** mode when event pulses are used.

For timing applications, the 807 TIMER-DIVIDER provides cristal controlled frequencies from 10 MHz down to 0,1 Hz. All frequencies are available simultaneously. The divider chain can be used for scaling down random pulses.



Timing and preset systems assembled from 807-808 modules offer:

- Large timing range: 0,1 us to 10.000 seconds.
- Digital accuracy on all ranges.
- Very convenient slaving of several GATE GENERATORS to produce elaborate timing sequences.
- Half-micro second recovery time on all ranges.
- Single width NIM-modules

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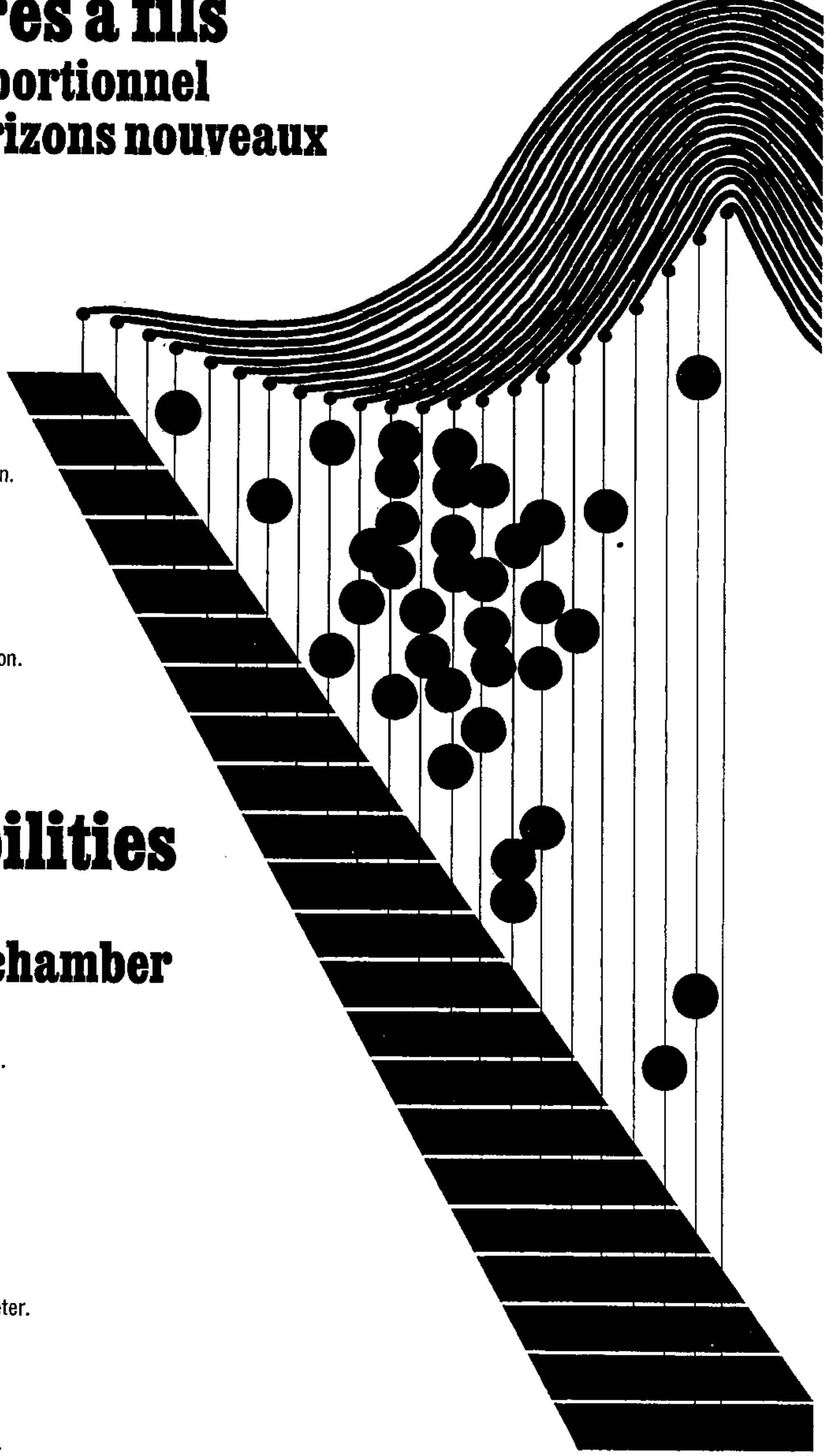
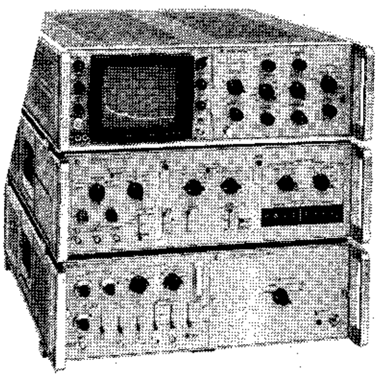


Expand your Universe of Nuclear Instrumentation with Hewlett-Packard

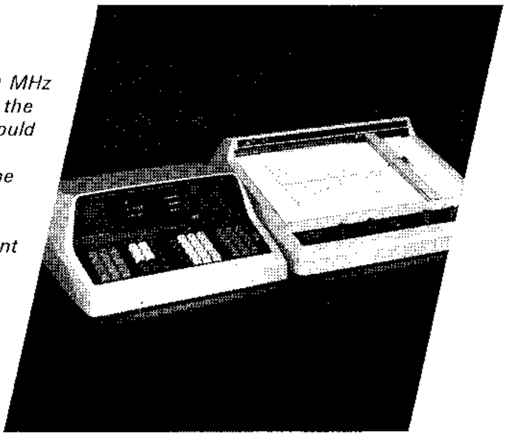
... for better solutions to your measuring problems

1 200 MHz multichannel analyzer
2 Calculator with plotter
3 Computer controlled spectrum analyzer
4 Computer designed for growth
5 Signal analyzer that measures



2 The desk-top calculator that will plot as it computes

As the hp 9100A calculator solves a problem, an X-Y recorder (hp 9125A) automatically converts the results into easily readable graphs. You at once see the interrelation of problem variables. You are only one step from the optimal solution: modifying the variables and recording once more.
Even on its own, the 9100A is unique. You have log and trig functions at your fingertips. You solve transcendental equations as easily as typing your name.



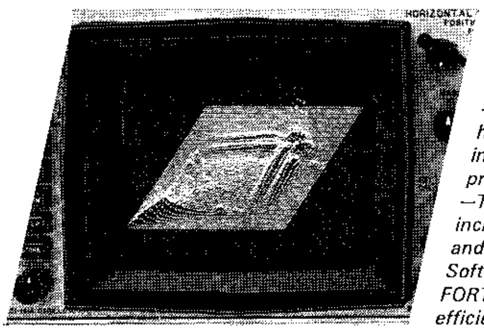
And you obtain solutions with ten significant digits over a 10^{-98} to 10^{99} range.
Need to use a given programme repeatedly? Just record it on a small magnetic card (up to 196 keystrokes), and slip it into the 9100A. Programme changes are made individually. No need to re-enter the entire programme.
Care for a demonstration? Your nearest hp office will be happy to arrange one for you.
9100A: $4,400 fob factory
9125A: $2,475 fob factory

1 Fact or Fiction?

A 4096 channel analyzer with a 200 MHz clock rate? That would be just about the fastest ADC clock rate ever. And it would mean that you could count more than 30,000 impulses per second over all the channels.
It's a fact. It's the 5401A Multichannel Analyzer from hp. This precision instrument offers you a 12-bit ADC (with 4K resolution) and memory expandable from 1024 to 4096 or 8192 channels. Now you can get an extremely high digitizing rate in addition to outstanding linearity and stability specs, I/O flexibility, and multimode operation that hp has already contributed to nuclear and statistical analysis work.
***Linearity**: integral, ±0.1%, differential, ±1% over full range above trigger level.*
***Stability**: baseline and gain are automatically stabilized 30 times per second.*
***I/O flexibility**: easy, with hp quick-change interface cards.*
***Versatility**: Multi-mode operation includes pulse height analysis, multichannel scaling and sample voltage analysis.*
5401A systems are priced from $11,950 fob factory

N 4-CH

3 Adding on-line computation to multiparameter nuclear analysis



Isometric display of Co^{60} coincidence spectra

hp brings increased flexibility to single- and multiparameter analysis, by adding on-line computation. This means you can immediately have meaningful data. Software programmes were developed for pulse height and sample voltage analysis, making these complex systems as easy to use as simple analysers. Keyboard selection from among many subroutines allows you to directly fit the system to your experimental requirements, and to choose optimum resolution and statistical accuracy. You can even insert your own FORTRAN or ALGOL subroutines.

The single-parameter 5405A system consists of a 200 MHz ADC, an hp computer with 4 K memory (expandable to 8 K), teletype input, and a variable persistence display.

The 5406A system operates in multplex (up to 16 ADC's) and multi-parameter modes with up to 4 ADC's in coincidence. Three display modes with markers: isometric (rotate to 20 positions), contour, and x-y slice. Ask for complete specifications.

4 No financial growing pains with this computer system

The hp 2116B computer was designed for natural growth. As you expand capability, improve performance, and increase versatility, your costs rise sensibly and painlessly in a linear way. You are spared the financial surprises that usually accompany the growth of a computer system.

Here's the 2116B's growth potential:

—The 16-bit, high-speed core memory of 8K is expandable to 32K by adding 8K modules.

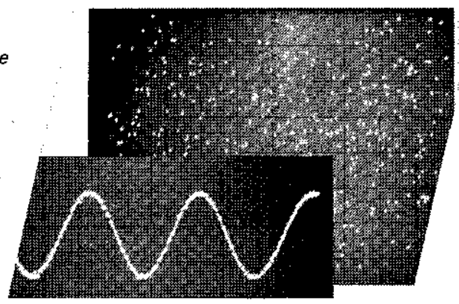
—From 16 I/O channels, you can go as high as 48, with multi-level priority interrupt for each channel. You change priorities by moving plug-in cards.

—The wide range of peripheral I/O devices includes an extended arithmetic unit and 2-channel, direct memory access.

Software capability is outstanding, with FORTRAN/ALGOL and BASIC compilers, an efficient assembler, and executives for data acquisition, time-sharing and real-time multi-programming.

From $24,000 fob factory (8K memory, 16 I/O channels). ***Made in Britain.***

5 Dredging a weak signal from a sea of noise — and measuring it



Let the noise be 1000 times stronger than the buried signal, the 5480A signal analyzer will pick it out. And deliver it to you as a flicker-free, calibrated display.

And when you change experimental parameters? The unique "running average" technique enables the 5480A to follow even a slowly varying signal, selectively de-emphasizing previous information with respect to new data.

You can also obtain time and frequency histograms, perform multichannel scaling, and, with a plug-in unit, auto- and cross-correlation.

An analog output permits direct recording on an X-Y plotter. Digital devices are easily interfaced with an I/O coupler. For further analysis of the signal, the data can be converted into the frequency domain with an hp computer.

With true averaging and steady display, the 5480A adds a new dimension to research in medicine, biology, chemistry and physics. For complete details and data sheets, give us a call.

hp 5480A: $6,950 fob factory

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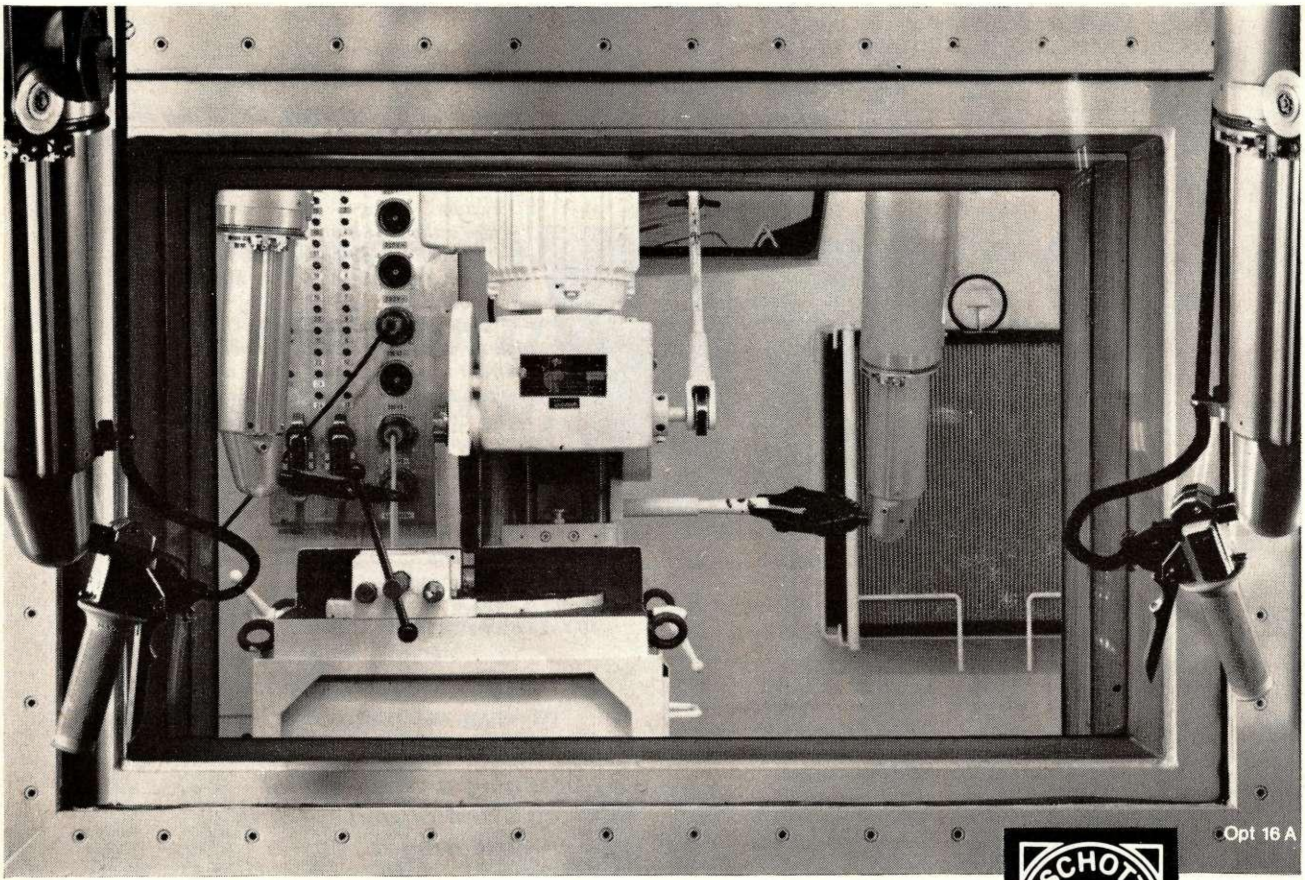
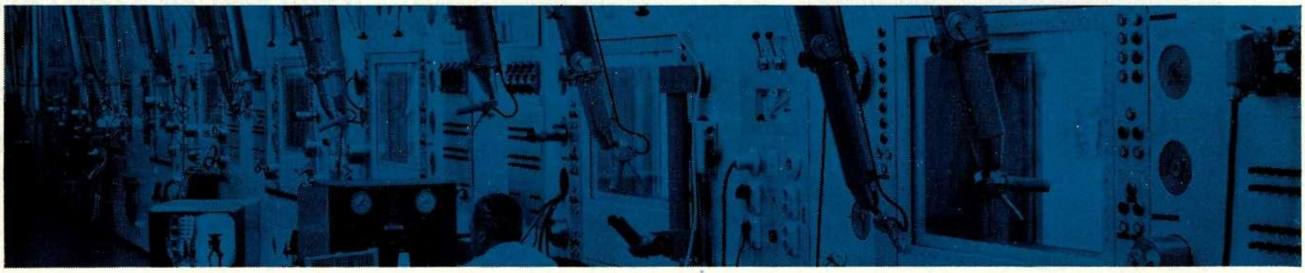
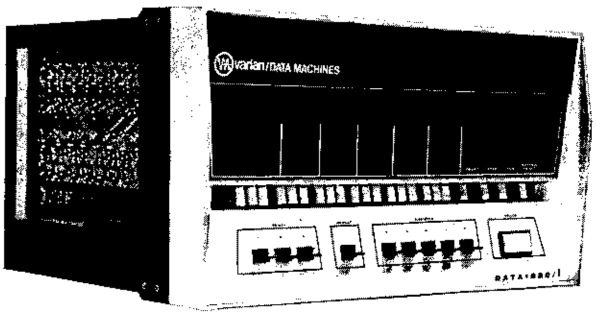

Opt 16 A



High performance/ low priced varian data systems computers.

varian data 620/i.
Over 500 installed.



A third generation system computer with an exceptional price/performance ratio.

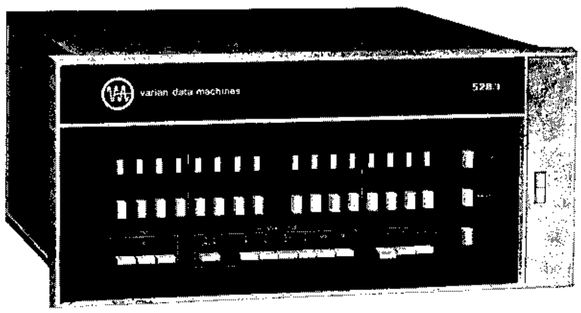
For easy interfacing with your system. Party line communication. Over 100 basic commands. Directly addressable memory—4K to 32K words. 16 or 18 bits with a 1.8 microsecond cycle time.

Multi-level priority interrupts. 9 hardware registers; 6 addressing modes.

Micro EXEC addressing option—handles instructions at submicrosecond speeds, giving a 10 to 1 speed advantage over stored programs. 10½" of rack space; 67 pounds, including power supply.

Field proven software. Cost: only $13,900 with ASR 33 TTY.

varian data 520/i.
New $ 7,500
dual-environment computer.



Dual-environment eliminates the need to save-and-restore routines each time an interrupt occurs.

Single-instruction transfers control between environments. For example, between processing and I/O programs.

Memory expandable from 4K bytes to 32K bytes with 1.5 microsecond cycle time.

11 interrupt lines; 12 hardware registers. Functions arithmetically in 8, 16, 24, 32 bit lengths within same program.

50 basic instructions with over 500 register-to-register operations. Monolithic integrated circuits.

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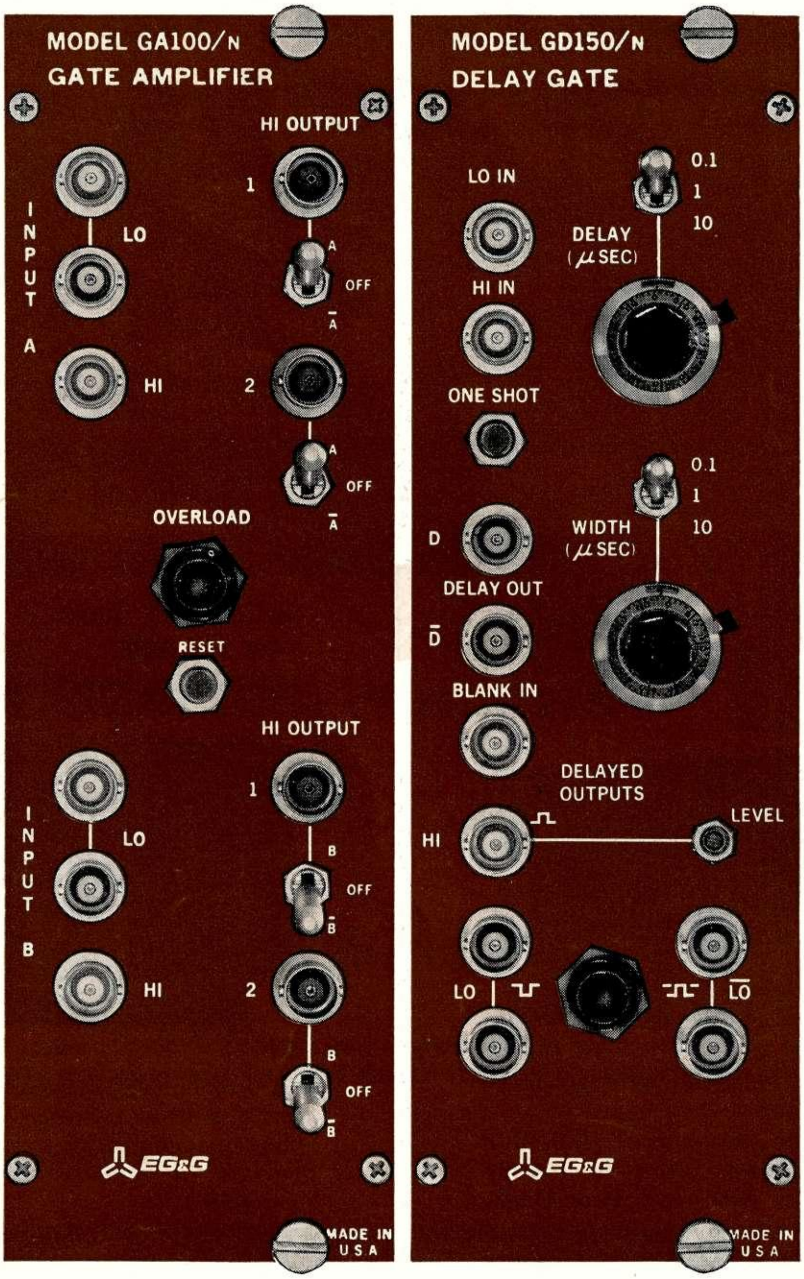
Gate problems stop here

The GA100/N
First gate amplifier module with built-in power supply to conserve premium bin power.

Inputs:
Lo In:
Direct-coupled "bridging" input for NIM-standard fast logic or complement logic signals.
Hi-In:
Direct-coupled for NIM-standard slow data transmission signals. Also accepts negative signals (−4 to −12V).

Outputs:
Fanout:
Two independent outputs per section.
Levels:
Normal or complement.
"1" = + 10V at 250 mA max.
"0" = sinks up to 200 mA at output voltage <1 V.
Width:
Approximately same as input width.
Risetime:
100 nsec (can be changed to a minimum of 50 nsec).



The GD150/N
Precision delay and gate functions provided in one module.

Inputs:
Lo In:
NIM-standard fast logic signal of width wider than 2 nsec.
Hi In:
NIM-standard slow data transmission signals (+3 to +12V). Also accepts negative signals (−2 to −12V).
One Shot:
One and only one output per switch activation.
Blank In:
NIM-standard fast logic signals of width greater than 5 nsec. Delayed outputs are blanked for duration of blanking input.

Timers (delay and width):
Range:
0.1 μsec to 110 μsec.
Accuracy:
10 nsec or ±5% of setting.
Random jitter:
< 1 part in 10^4.

Outputs:
Delay:
One normal and one complement NIM-standard fast logic output for duration of delay interval.
Hi Out:
+2.5 to +10V, adjustable; for duration of width interval.
Lo Out:
One "dual" normal and one "dual" complement; for duration of width interval.

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Make the most of the gating features of each — or combine them for greater fanout and more flexibility. For additional information on the solution of your gate problems, contact EG&G Inc., Nuclear Instrumentation Division, 36 Congress Street, Salem, Massachusetts 01970. Phone (617) 745-3200. Cable: EGGINC-Salem. TWX: 710-347-6741. Telex: 949469.