CERN

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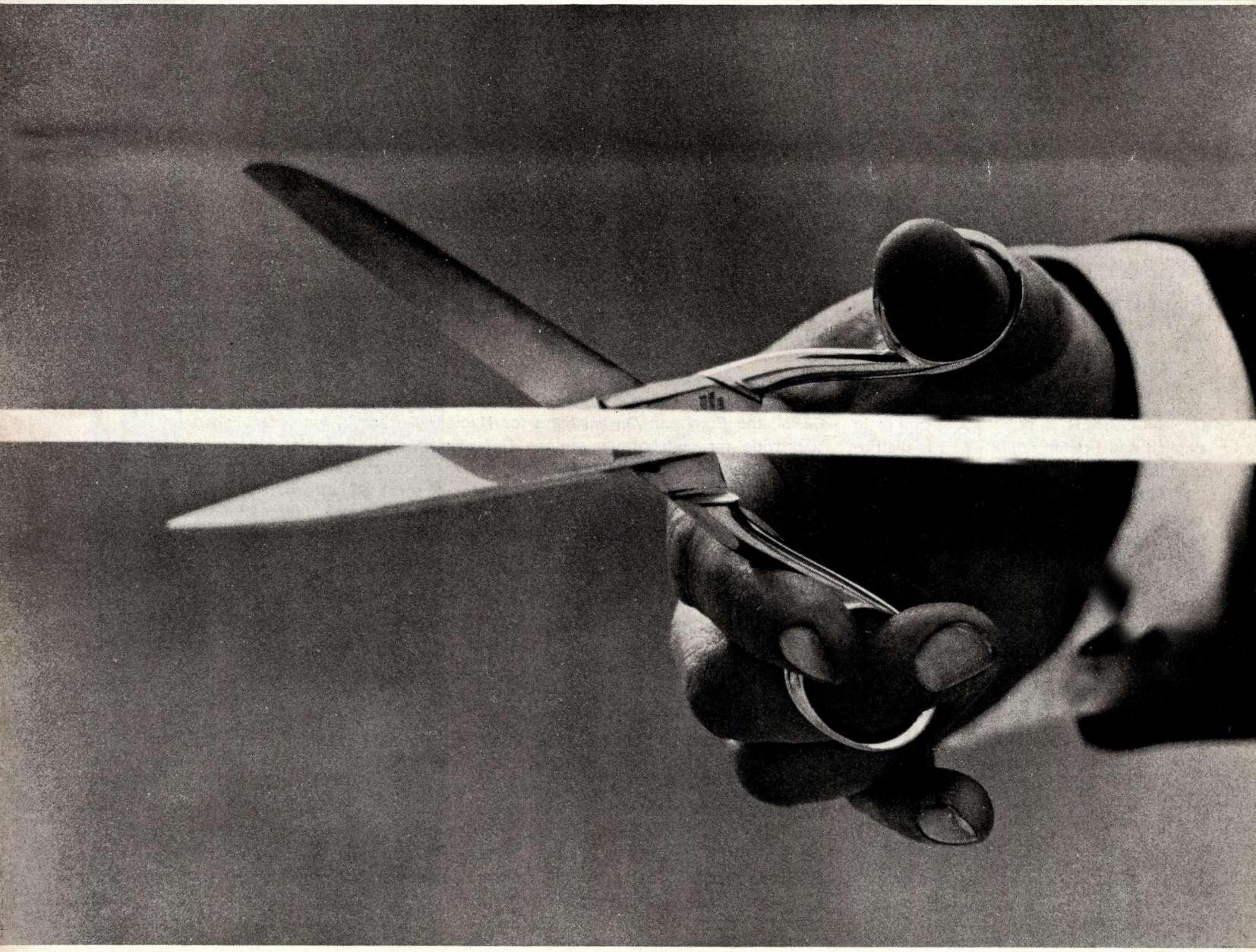
European Organization for Nuclear Research



The cover photograph was taken at a small ceremony on 22 May when a new road was opened across the Franco-Swiss frontier inside the CERN site.
For many months now, civil engineering work has been in progress on the French half of the CERN site where the intersecting storage rings are under construction.
Communication between the two halves has, however, been via the main road running alongside the site, passing through the customs posts.
There is now internal access between the two halves of the site and CERN can operate 'across the frontier' in true manner.

Contents

Comment

A group of scientists from the Laboratory for Nuclear Studies, at Novosibirsk in the Soviet Union, visited CERN for two weeks at the end of April. The party was led by the Director of the Laboratory, Dr. A. Budker. While they were at CERN, news came that Dr. Budker, together with colleagues Sidorov, Naumov, Skrinski and Polasuk, had been awarded the Lenin prize — one of the highest awards in Russia — for their contribution to 'the study of the colliding beams method for high energy physics research'. At Novosibirsk, they have already built two electron storage rings — one to study the problems of beam storage and the other for experiments. They are now engaged on a complex project to provide colliding electron-positron beams at an energy of 3 to 5 GeV and colliding proton-antiproton beams at an energy of 25 GeV.

The News from abroad section (page 88) reports two seminars given by Dr. Budker during his stay and, in addition, the visitors had many discussions with the scientists and engineers involved in the large intersecting storage rings project at CERN. The particular attraction of this visit, which causes us to single it out from the steady flow of visits to CERN, lay in the great fund of new and daring approaches to the problems posed by accelerator technology, which have stemmed from this Novosibirsk team.

The starting point in the design of their equipment has often been 'what can we make in our own workshops' and from there they have developed, by novel approaches, a most intricate scheme for high energy proton-antiproton colliding beams. The unconventional ideas involved include gas-jet ionization to achieve injection into minute iron-less synchrotrons, special magnets to give very short focal lengths at targets to yield controllable, intense anti-particle beams, and (most imaginative of all) synchrotron re-cycling and 'electron cooling' for beam stacking. All of these features of the Novosibirsk project are outside conventional accelerator technology.

Ideas fly from this group like sparks from a grinding wheel. Almost certainly, not all of them are destined to create a fire, but it has been a refreshing experience to encounter these unorthodox ideas.

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

The experimental programme is based mainly 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), which will allow experiments with colliding proton beams to be carried out, are under construction. Scientists from many European Universities and national Laboratories as well as from CERN itself take part in the experiments and it is estimated that some 700 physicists outside CERN are provided with their research material in this way.

The Laboratory is situated at Meyrin, Canton of Geneva, Switzerland. The site covers approximately 200 acres about equally divided on either side of the frontier between France and Switzerland. The staff totals about 2300 people and, in addition, there are over 360 Fellows and Visiting Scientists.

There are thirteen member States participating in the work of CERN. The contributions to the cost of the basic programme, 172.4 million Swiss francs in 1967, are in proportion to their net national income. Supplementary programmes cover the construction of the intersecting storage rings and preliminary studies on a proposed 300 GeV proton synchrotron for Europe.

CERN News

Start of neutrino experiments

The first data-taking run in the new series of neutrino experiments took place in the week 8-16 April preceding the PS shutdown. (The experiments and the equipment involved are described in CERN COURIER vol. 6, page 211.) 90 000 photographs were taken in the CERN heavy liquid bubble chamber. This was less than had been hoped for, due to the necessity to dismantle the chamber to change the membrane which transmits the pressure to the working fluid. A crack developed in the membrane during the run, perhaps due to the higher temperature at which the chamber is operated when filled with propane. However, all the intricate components of the neutrino beam-line worked successfully and a number of neutrino interactions were photographed in good conditions for measurement. The first scanning of the film has been completed and analysis of the data is in progress.

The fast ejected proton beam, drawn from straight-section 74 of the proton synchrotron, was matched to the target by a pulsed beam transport system. A series of tests had been made before the run to select the most efficient target configuration for the production of the 'neutrino parents' — pions and kaons. Targets of beryllium oxide, tungsten, sapphire, boron-carbide and copper were tested.

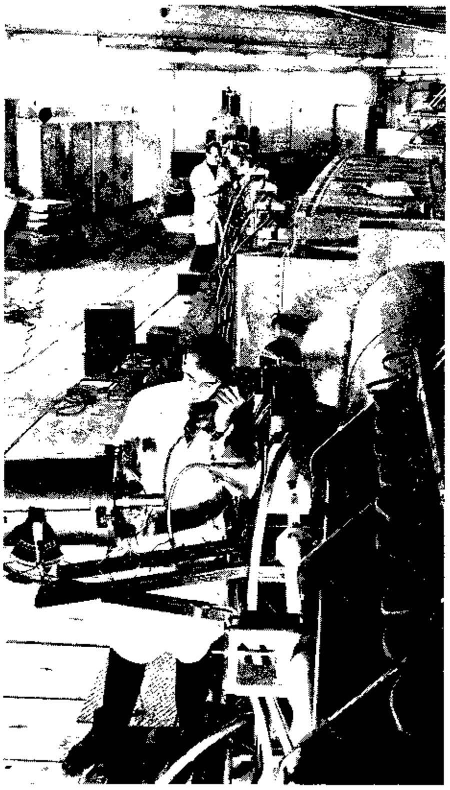
The new magnetic horn and the two large reflectors, which serve to converge the neutrino parents towards the detectors, worked throughout the neutrino run despite preliminary problems with the solid-state power supplies which supply a current of 360 kA to the reflectors.

The elaborate arrangements to measure the spectrum of muons (produced at the same time as the neutrinos in the decay of the neutrino parents) have shown that the shielding had been carefully packed so that its stopping power corresponded with the design value. Knowledge of the muon spectrum gives an additional means to infer the neutrino spectrum, which is vital in any attempt to measure the cross-sections of neutrino interactions.

The shielding is thicker than is necessary for the bubble chamber experiments since it has been adjusted to accommodate a spark chamber experiment which has more stringent requirements for the elimination of muons coming through the shielding. The spark chambers, which are set up in front of and behind the bubble chamber, recorded data which will test the conservation law that in an interaction a muon neutrino always transforms to a negative muon. The spark chamber experiment will also attempt to determine whether the cross-section of the neutrino interactions depends upon the size of the nucleus in which nucleons are bound. In strong interactions in a nucleus, the rate of interactions is dependent on the number of nucleons, because the force between the incoming particle and the target nucleon is influenced by the strong forces acting between all the nucleons. For the neutrino, which is involved only with the weak forces, it is important to determine whether there is any effect on the interaction cross-sections on a nucleon due to the proximity of other nucleons.

About 20 % of the bubble chamber operating time was given to a test of the feasibility of an experiment on inelastic muon interactions. By draining mercury from a pipe in the shielding, muons could pierce the shielding and be recorded in the chamber. These muon pictures have already been analysed and the experimentors are enthusiastic about the results of their test.

The next run for the neutrino experiments is scheduled to take place in July and this year's experiments will be concluded with a further run in September.



CERN/PI 40.12.66

A photograph taken in the synchrotron ring tunnel at the point (straight section 74) where the fast ejected proton beam is taken out for the neutrino beam-line. The proton beam passes through the tunnel wall (top centre) and is directed onto a target. The positive pions and kaons produced in the high energy collisions are converged by magnetic lenses towards the heavy liquid bubble chamber. They decay after a very short time producing the required neutrino beam.

Below are two remarkable photographs taken in the neutrino beam-line.

The one on the left shows the ejected proton beam emerging from the end of the vacuum pipe (on the right of the picture) and flying through the air towards the target. The narrow pencil of light is produced as the high energy protons raise the electrons of some of the air molecules in their path to higher energy states from which they return to lower energy states by emitting light.

To record this photograph, the camera was left in the tunnel of the neutrino beam-line and, by remote control, a single frame of the film was exposed during 200 synchrotron pulses. About 5 × 10^{11} protons passed in front of the film per pulse at this position in the beam-line. This is one of the few photographs ever taken of a high energy proton beam in air.

On the right, is a photograph of the light produced by the ejected proton beam in a Cherenkov counter. The camera is looking at a ground glass screen on the end of the counter, in a direction at right angles to the proton beam. The light has been reflected towards the camera by a thin aluminium foil placed in the beam at an angle of 45°.

The counter was filled with argon gas under pressure. As the high energy proton beam passed through it caused light to be emitted at an angle to the direction of the proton beam which depended on the velocity of the protons and the pressure of the gas in the counter. (This is the operating principle of Cherenkov counters.) The foil intercepted this emerging cone of light and reflected a cross-section of the cone — a ring of light — to the ground glass screen.

Again, one frame of the film was used to record 200 pulses and during this time, the pressure of the gas in the counter was gradually increased so that the light emerged at wider angles, giving a succession of rings of increasing diameter on the ground glass screen.

This Cherenkov light can be used to measure the intensity of the ejected proton beam by placing a photomultiplier over the end of the counter. This technique has been used to make relative intensity measurements and the system may be calibrated in a slow ejected proton beam to give absolute measurements.

Foils coated with a fluorescent material, zinc sulphide, can also be left in position in the beam and the beam profile observed on the foil by a closed-circuit television camera. The zinc sulphide burns off rather quickly, however, if the foil is left permanently in the beam. Just before the target in the magnetic horn, there is a coated foil which can be flipped in the path of the beam by remote control.

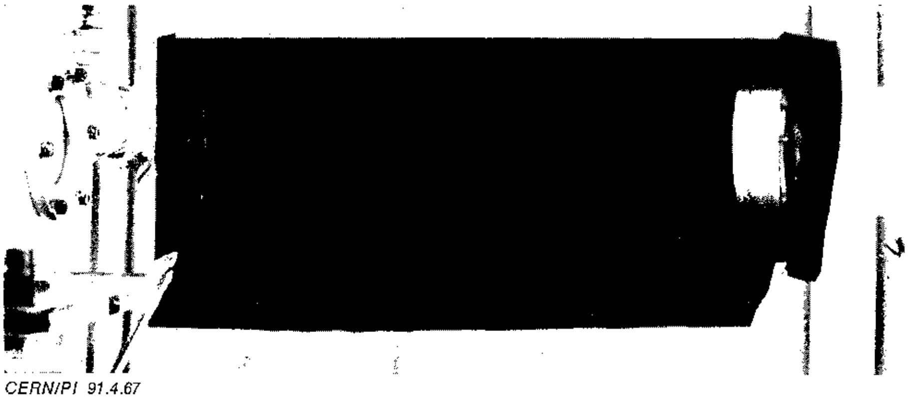
Another method, which has been used in the neutrino beam-line to observe the beam profile and also to measure the distribution of proton intensity over the cross-section of the beam (which the zinc sulphide coated foil does not give) is to insert a mesh of aluminium wires, with wires aligned horizontally and vertically, in the path of the beam. The high energy protons induce radioactivity in the wires. The radioactivity induced in each wire, which is proportional to the number of protons incident on the wire, can be measured when the mesh is later withdrawn.

CERN - USSR discussions

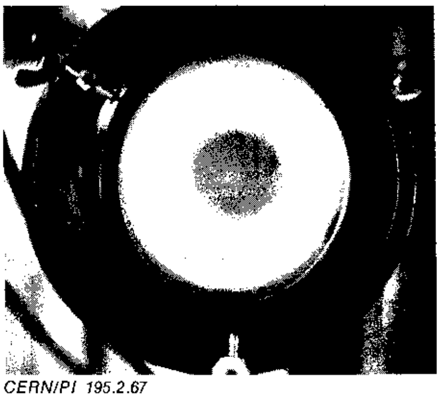
On 10 April, Professor B. Gregory, Mr. G. H. Hampton and Dr. O. Lock went to the Soviet Union to continue talks on the present and future collaboration between CERN and the USSR in the field of sub-nuclear physics. In particular, meetings were held with the State Committee for the Utilization of Atomic Energy (headed by the Chairman, Professor A. Petrosyants) on scientific and technical co-operation at the 70 GeV proton synchrotron nearing completion at Serpukhov.

This visit followed the approval by the CERN Council, at the Session in December 1966, of the possibility of collaboration and the authorization, then given to the Director General to negotiate a Convention between CERN and the State Committee. The latest contacts were very fruitful and the two parties have come to a common opinion on the possibility of conclusion of the Convention.

The CERN representatives also visited the Institute for Theoretical and Experimental Physics, the Lebedev Institute, Dubna, and Serpukhov itself. At Serpukhov, they had discussions with the Director of the Laboratory, Professor A. A. Logunov, and other senior staff. They were able to see the present state of progress in the construction of the 70 GeV machine, the highest energy accelerator in the world. It is hoped to have the first high energy beams accelerated in the synchrotron before the end of the year.



CERN/PI 91.4.67

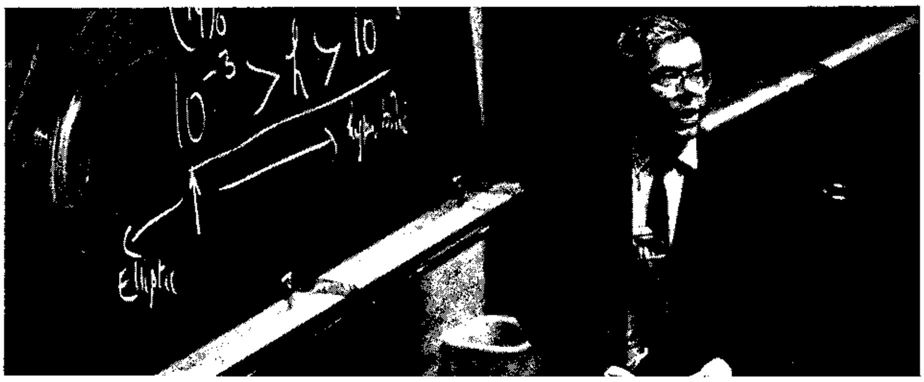


CERN/PI 195.2.67

CERN/PI 70.5.67

The Emperor of Ethiopia, H.M. Haile Selassie, visited CERN on 9 May. The Emperor was accompanied by three of his children and grand-children and by the Ethiopian Ambassador to the Federal Republic of Germany. The visitors were welcomed by the Director General and by the Director of Administration, Mr. G.H. Hampton. This photograph was taken in the proton synchrotron control room during a tour of the site. Dr. K.H. Reich (on the left) is describing machine operation. Mr. Hampton is on the right.

Other visitors in May included the AERIEL Foundation, UK, on 1 May; the Science Research Council, UK, on 18 May; and the Institut des Hautes Etudes de la Défense Nationale, France, on 19 May.



CERN/PI 339.4.67

Professor F. Hoyle from Cambridge University, UK, gave a colloquium on 'Nuclear reactions in a universal fireball', to a packed auditorium at CERN on 27 April.

Academician V.A. Kirillin, Chairman of the State Committee of the USSR Council of Ministers of Science and Technology, paid a brief visit to CERN on 8 April. He was welcomed by the Director General.

The robots are coming?

A remotely-controlled manipulator has been installed at the proton synchrotron during the shutdown. It will be used for a series of tests on remote handling techniques, which are becoming increasingly important at accelerators. The principle aim behind the use of such a manipulator is to carry out maintenance and modification work in 'hot' areas of the machine (where the radiation levels make it impossible or very difficult for personnel to work). It could also make it possible to carry out some work on the machine while it is in operation, without the necessity to shut the machine down to enter the magnet ring tunnel.

On the synchrotron at present, the hot areas are concentrated particularly at the regions where internal targets are installed. A significant proportion of the scattered protons and the secondary particles produced in the high energy collisions in the targets do not emerge down the beam-lines into the experimental halls, but hit the walls of the vacuum chamber, the magnets etc. in the region of the target. Other hot areas are those around the magnets used in the ejection systems. The efficiency of the slow ejection system, in particular, is not yet very high and a considerable percentage of the accelerated proton beam is not ejected but is lost inside the magnet ring. High levels of radioactivity are produced in these regions, and when it is necessary to carry out work (such as changing a target) great care has to be taken to ensure that no one receives a radiation dose in excess of the maximum permissible.

These problems have only recently developed to serious proportions on the CERN PS but it is obvious that in the coming years, especially when the repetition rate and the intensity of the machine are increased in the course of the improvements programme, special measures will have to be taken to safeguard components and to ensure that servicing in hot areas can be carried out. One approach, which has been under study at CERN for several years, is to make a remotely-controlled robot capable of carrying out work in these areas. The manipulator now installed in the PS ring is the result of this study.

The manipulator is suspended from a crane bridge which can be moved around the synchrotron ring on rails above the level of the magnets. Another, independent, bridge carries lights and closed-circuit television cameras to observe the work in progress. The actual observation and control is carried out from a control point 100 m away at the centre of the magnet ring.

Three cameras are used; one observes a general view of the environment where the work is taking place, and two (capable of providing two views at right-angles if necessary) observe the work in close-up detail. The position of each camera can be controlled remotely (using motors to drive the cameras with four degrees of freedom) and their positions are indicated back at the control point.

The crane bridges can be moved into place over 40 m of the circumference of the ring. They move from place to place at speeds up to 0.5 m/s and are manoeuvred into their precise position at 4 mm/s. Five cables, each with 44 conductors, carry signals between the bridges and the control point. The cables emerge from a fixed point on the wall of the magnet ring tunnel and special methods are used to wind the cables in and out according to the position of the bridges.

Prior to installation at the PS, this prototype manipulator has carried out such tasks as changing a special target unit, locating vacuum leaks, and connecting and disconnecting electrical cables.

The experience with this manipulator at the PS will be a very useful guide to the techniques which need to be employed more and more at high energy accelerators.

A more detailed description, by W. Richter, M. Ellesplass and R. Horne, can be found in 'Industries Atomiques' Nos. 1-2, 3-4, 1967.

Colloquia

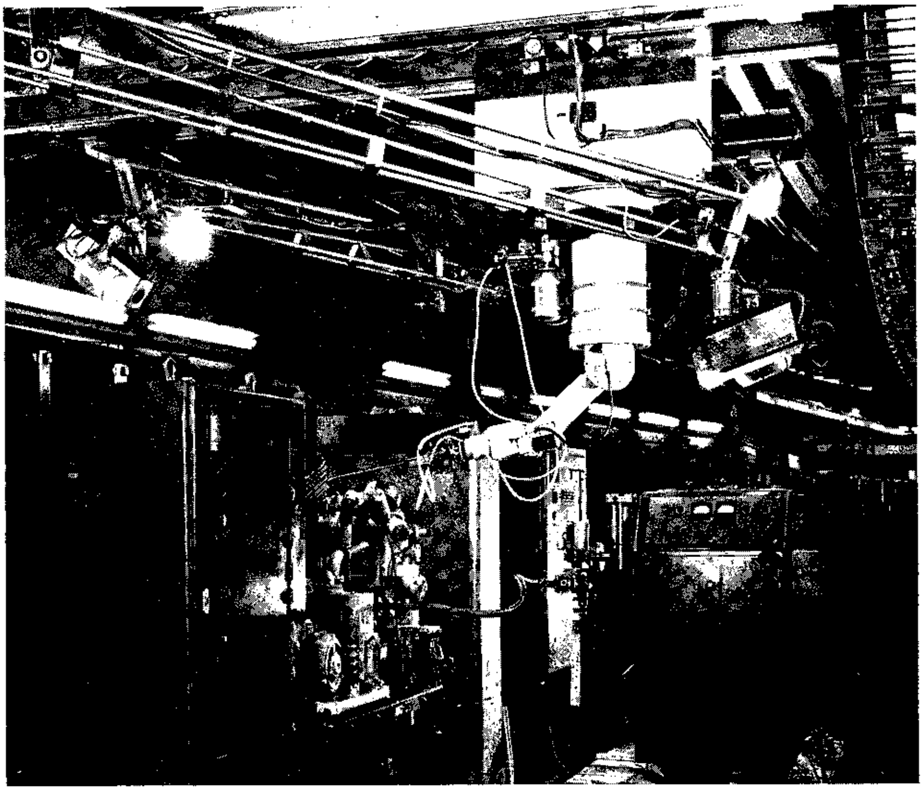
Two colloquia have been arranged for June:

8 June: Dr. H. Coblans, previously head of the Library services at CERN who is now with ASLIB in London, will talk about 'The computer, the information problem and all that'. The colloquim will cover the achievements and limitations of mechanization in documentation, automatic indexing and machine translation, and the implications of the man-computer partnership in the handling of information.

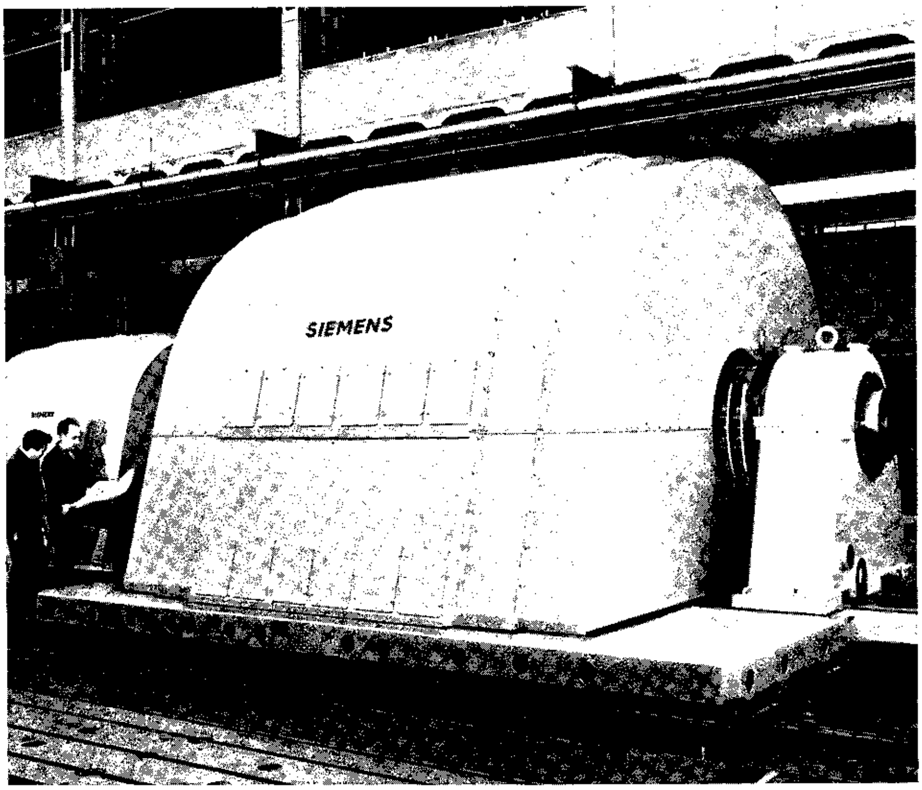
22 June: Professor U. Schmidt-Rohr from the Max-Planck Institut at Heidelberg, will talk about 'Nuclear structure studies with 52 MeV deuterons'.

The remotely controlled manipulator which was installed in the synchrotron ring during the machine shutdown. The operating arm (centre of photograph) is suspended from a crane bridge which can travel around the ring. The lights and television cameras used to observe the operation being performed can also be seen.

The motor-alternator set of the new synchrotron power supply photographed at the factory before leaving for CERN. The set arrived at the site on 19 May.



CERN/PI 112.5.67



(Photo Siemens)

Power supply arrives

Another important stage in the programme of improvements for the 28 GeV proton synchrotron was reached in May when some of the major components of the new main-magnet power supply were delivered to the site. The base plate and the bearings of the alternator and motor arrived on 1 May and installation has already begun in the new power supply building. The motor-alternator set arrived on 19 May.

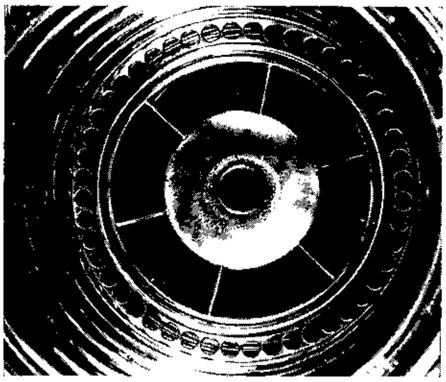
Construction of this large new power supply began at the Siemens factories in Berlin at the beginning of 1966. At the end of March 1967, CERN experts went to the factory to be present at a stringent series of acceptance tests designed to ensure that the plant would meet its specification.

Some of the parameters of the new supply are as follows — It consists of a 1000 rev/min alternator driven by a 6 MW asynchronous motor. The total weight is about 216 t including an 88 t rotor. The mean power is 46 MVA with peak power 95 MVA. The current fed to the coils of the synchrotron magnet is rectified by a converter set with 48 mercury arc rectifiers.

The power supply acts as a buffer between the electricity grid and the magnet, smoothing out the effect of the great surges of power (with the new supply these will be up to 6400 A at 11 kV) which are required for each pulse of the synchrotron. About 5.5 MW of power will be drawn continuously from the mains by the asynchronous motor to make up the losses which occur in the magnet coils and the power supply itself.

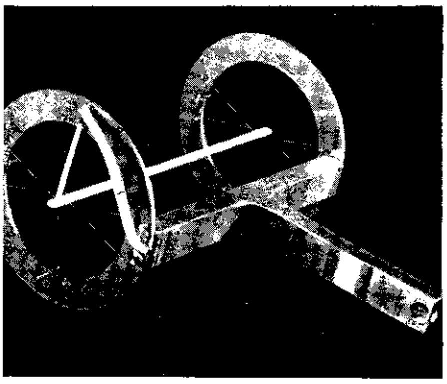
The new supply will make it possible to operate the proton synchrotron at two or three times its present pulse repetition rate. It replaces the existing supply (which will, however, stay in commission as a spare) which has now provided over 50 million pulses.

Delivery of the whole plant will be completed in August. It is hoped that installation of the supply will be finished by the end of October. Tests at CERN, without the PS magnet as load, will then begin. Actual connection to the magnet will probably take place during the main shutdown of the synchrotron early in 1968.



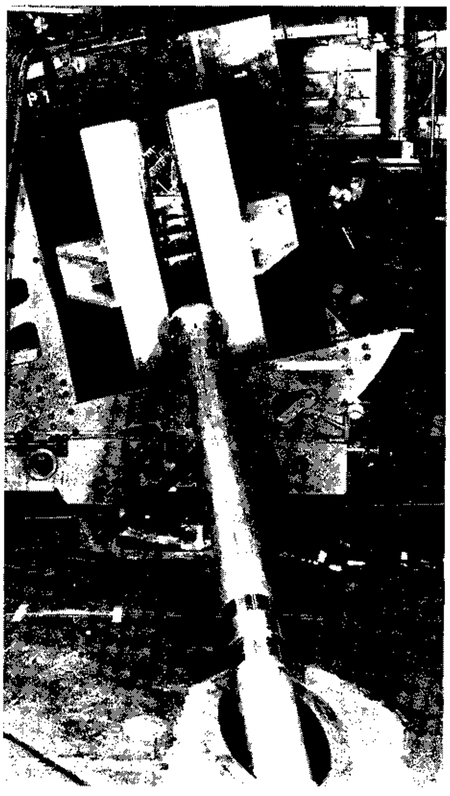
1 CERN/PI 110.5.67

1. After being in operation for a year, the new 500 kV accelerating column, at the input of the linear accelerator which feeds the proton synchrotron, was opened for inspection during the shutdown. This photograph of the inside of the column was taken looking from the position of the proton source. The beam passes through the circular aperture at the centre of the electrode (called the intermediate electrode; it carries a potential of 250 kV, half the total potential across the column).
The electrode is constructed of titanium, which is an excellent material from the point of view of high voltage properties in vacuum. Electrical breakdowns do occur, however, from time to time and the small pock marks, which can be seen surrounding the aperture, were produced by the sparks.



2 CERN/PI 88.4.67

2. A typical target used in ejected proton beams at the synchrotron. The target proper is the copper rod 1 × 2 × 100 mm^3, (the axel of the two wheels) supported by thin wires. When the proton beam (whose cross-section is of the order of 2 × 3 mm^2) hits the target, a large amount of charge is ejected, mainly as 'knock-on' electrons, and this effect is used for 'burst-intensity monitoring'. The target is simply electrically insulated and connected to a charge measuring instrument. The amount of charge removed from the target gives information about the number of interactions (primary and secondary) that have taken place.
External targets are usually set up in air and not in a vacuum enclosure. The free charges in the heavily-ionized air surrounding the target could therefore partially neutralize the required signal. However, this difficulty is largely overcome by coating the target surface with a thin layer of aluminium oxide, which prevents the low-energy charges in the air entering the target.



3 CERN/PI 313.4.67

3. A view of the first bending magnet in the beam-line from the synchro-cyclotron to the ISOLDE laboratory. The magnet steers the beam down through a hole cut in the floor of the SC hall, to the underground tunnel leading to the target room. The magnet frame was specially designed in the SC drawing offices so that the magnet can be rotated around the axis of the beam. The short shutdown of the SC, when the major components of the beam-line where installed, finished on 14 April. Before the end of the month, beam had been taken as far as the target. Intensities of 3 × 10^{11} protons per second have been achieved, with a beam cross-section (containing 90 % of the protons) of 3 cm diameter. Tests were carried out to ensure the adequacy of the installed shielding and the results are now being analysed.

News from abroad

Novosibirsk

For two weeks at the end of April, the Intersecting Storage Rings Department was host to a group of scientists from the Laboratory for Nuclear Studies, Novosibirsk, USSR. (See also Comment, page 82). The party consisted of the Director of the Laboratory, Dr. A. Budker, his wife, Dr. B. Sidorov and Dr. B. Chirikov.

Dr. Budker gave two seminars during his visit, entitled 'Current electron-electron and electron-positron colliding beam experimentation at Novosibirsk' and 'The construction of colliding beam machines for 25 GeV proton-antiproton and 3 to 5 GeV electron-positron experiments at Novosibirsk'.

The first talk was concerned with the storage rings already built: VEP 1, an electron-electron device built principally to study the problems of particle beam storage but which, with difficulty, has been used for some experiments; and VEP 2, an electron-positron device (2 × 700 MeV) designed for experiments, at which some significant physics with colliding beams has already been done.

Two fascinating short films were shown of the synchrotron radiation coming from the orbiting particles. The synchrotron light enables the beam behaviour in the rings to be observed in detail. It is easily possible to follow with the naked eye the effect of induced instabilities on the beam profile by observing the light. Conversion of radio-frequency power fed into the beam, to synchrotron light emitted is practically 100 % efficient. Indeed, Dr. Budker said that one electron could be traced from the light it emits. Since the storage rings hold the particles in orbit for many hours, it is possible to watch a single electron, go home to bed, and return next morning to see the same electron still turning round the ring.

The second talk concerned the very ambitious storage rings project for which building is now well under way at Novosibirsk. The intricate system is designed to make possible electron-positron experiments at 3 to 5 GeV per beam and proton-antiproton experiments at 25 GeV per beam.

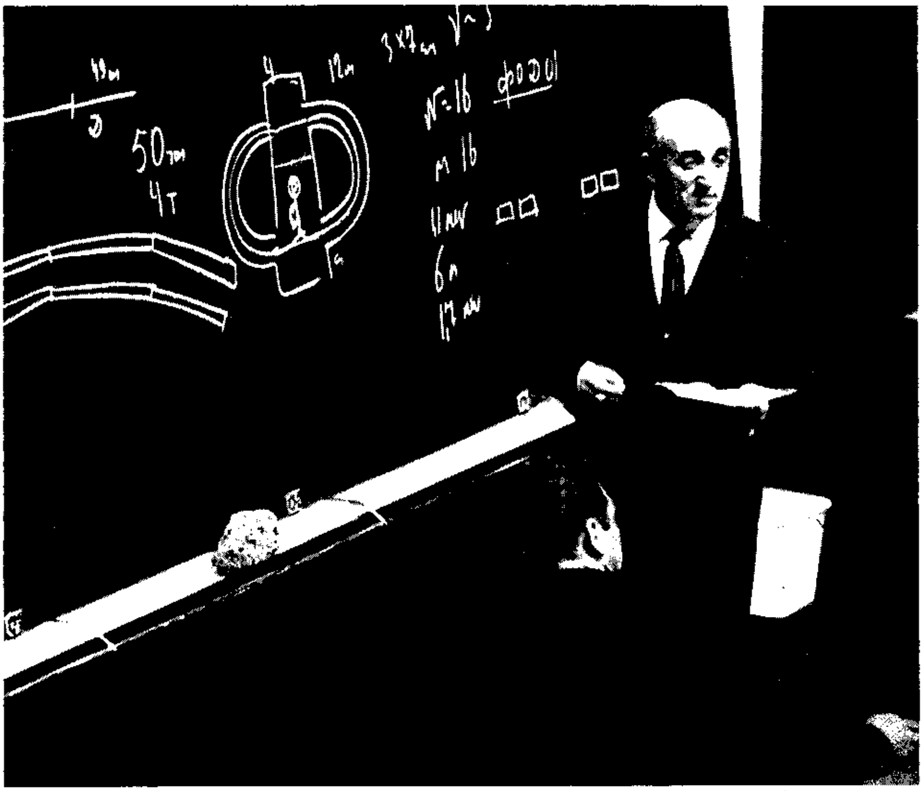
The electron-positron device for energies up to 3 GeV is a small oval shaped magnet 'ring' with ends of 8 m radius and straight sections of 12 m. The vacuum vessel cross-section is 3 × 7 cm and the magnets, to give a field up to 18 kG, are cast in 50 ton blocks each block giving one FODO sequence. Electrons are injected after acceleration to 650 MeV in a small ironless synchrotron of 1 m radius. They are directed onto a target to produce positrons.

New techniques have been developed to achieve a high and controllable yield of positrons. They involve the use of a special magnet lens system (an x-x lens — so called because of the shape of the pole profiles) which gives extremely high magnetic field gradients resulting in a very short focal length for the particle beam. The target sits at the focal point between two of these x magnets and the beam approaches the target with such wide angles that scattering in the target does not add much to angular spread and the second magnet catches a high intensity positron beam.

A further refinement, known as 'the dollar system' from the shape it had in its initial conception, introduces an omega shaped loop in the beam. In the loop the beam traverses wedges of triangular cross-section — the faster particles, at greater radii, pass through more of the wedge and are slowed down most. This system compresses the energy spread to about 1 % before the beam is directed onto the target giving an increase of a factor of four in the yield of positrons, though involving some increase in the angular divergence of the positron beam.

The positrons are captured in the ring and their oscillation amplitudes are damped by radiation. There is then room for the injection of more positrons and injection proceeds until the desired beam intensity is obtained. Electrons are then fed in and the electron and positron beams are simultaneously accelerated to the desired energy for colliding beam experiments.

They hope to complete the electron-positron ring by the end of this year and to start experiments with it by the end of 1968.



Dr. Budker photographed during one of his seminars given at CERN on the Novosibirsk plans for particle-antiparticle colliding beam experiments.

CERN/PI 356.4.67

In preparation for the proton-antiproton system, experiments have been carried out on the use of gas jets for charge exchange injection into accelerating rings. In the experimental set-up, a 1.5 MeV Van de Graaff machine produces negative hydrogen ions. These are converted to neutral ions by being passed through a fairly low velocity jet which strips off one electron, and then injected into a small diameter betatron ring. There, another gas jet, with a velocity of twelve times the speed of sound, converts them into protons which can be accelerated to 600 MeV.

This use of jets is another novel development at Novosibirsk. Efficiencies of 75 % in particle conversion are achieved and the very fast jets in the accelerating rings do not cause much disturbance to the high vacuum. Good injection of charged particles into very small rings would be practically impossible.

The proton-antiproton system starts by charge exchange injection into an ironless synchrotron of 1 m radius. It is expected that 3×10^{11} protons can be accelerated to 3 GeV in this ring.

The protons are then injected into a large oval with ends of 45 m radius and 36 m straight sections, around which the experimental halls are built. Acceleration continues in the large oval to 25 GeV and the protons are then directed onto a target to produce antiprotons. It is hoped to achieve about 10^{-7} antiprotons per pulse.

The antiprotons are stored in the smaller oval used for the electron experiments and there they are 'electron cooled'. This new technique was described in CERN COURIER vol. 6, page 219. It serves to take the random motion out of the antiproton beam which then reduces to 1 mm diameter. The whole cycle, as described above, will be repeated about 1000 times to accumulate an antiproton beam of 10^{10} particles.

A further 120 pulses of 3 GeV protons are injected into the big oval and will build up a proton beam of 10^{14} particles.

When the large oval is filled with protons, the magnet fields in the two ovals are equalized and the antiproton beam is brought into the big oval and the energy of the protons and antiprotons is raised to the desired value for colliding beam experiments. An interaction rate of 2×10^4/s has been calculated which is ample for experiments, allowing a large safety factor if all the complicated processes do not operate as efficiently as expected.

Construction of one large experimental hall and of the tunnel for the big oval is complete. They hope to have all the components of the big oval installed by the end of 1968 and to be ready for experiments by 1970.

Stanford

Two articles in the April issue of 'Physics Today' report on the performance of the 20 GeV electron linear accelerator and on the experimental programme coming into effect at the Stanford Linear Accelerator Centre.

In January of this year, the design energy of 20 GeV was achieved. (High energy beams (10 GeV) first travelled the full length (3 km) of the accelerator in May 1966.) The beam current is between 15 - 30 µA at a pulse repetition rate which can increase to 360 per second. About 90 % of the beam current measured close to the injector can be accelerated along the full length of the machine. It is possible to accelerate simultaneously at least three time-interlaced beams to different energies and with pulse-length and intensity independently controlled — thus experiments can proceed at the same time in several physically separated areas.

A positron beam is required to emerge about $^2/_3$ along the accelerator length for the proposed electron-positron storage ring to be built in association with the linear machine. A converter can be introduced about $^1/_3$ along to produce positrons and it is hoped that positron beams of 2.5×10^{11} particles with an energy spread of about 1 % can be accelerated.

For the experimental programme, electron, positron, photon and muon beams in particular will be available. Detection equipment will include three large spectrometers (the largest weighs 1700 t and is 50.2 m long); two magnet spark chambers (one using a magnet of 500 t with a field of 15 kg) and a streamer spark chamber 2.4 × 1.2 × 0.6 m in volume; and two hydrogen bubble chambers (one of 1.02 m diameter and one with an effective length of 2.08 m).

The approved experiments include elastic electron-proton scattering to continue the examination of the electromagnetic structure of the proton; photoproduction experiments (including the photoproduction of antiprotons and of strange particles), a search for new particles (particularly those having only electromagnetic or weak interactions); and muon-proton elastic and inelastic scattering.

Frascati

The electron-positron storage ring, ADONE, with a maximum energy of 1.5 GeV per beam, is nearing completion at the Frascati Laboratory, Italy.

The injection system was completed in Autumn 1966. It provides pulses of electrons of up to 100 mA peak current within an energy spread of 2 %, at an energy of 350 to 400 MeV. Pulses of positrons are produced at up to 1 mA peak current. The linac injector can operate at 250 pulses per second and can send beams direct to an experimental hall as well as feeding the storage ring (only 2 or 3 pulses per second are needed for the storage ring).

Acceleration to 1.5 GeV takes place in the storage ring itself where two r. f. cavities are installed to accelerate the particles and to make up the energy lost by synchrotron radiation. The ring has a mean diameter of 16.7 m (the radius of the magnet sections is 5 m) with four beam intersection regions. The cross-section of the vacuum vessel is 14 × 7 cm. It is hoped to store 2×10^{11} particles per beam.

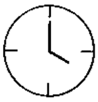
Japan

The Japanese Government has approved the construction of a 40 GeV alternating-gradient synchrotron. This was recommended by the Japanese Science Council in the 'First-Five-Year Plan' for long range research projects, presented in October 1965.

Switching on the PS

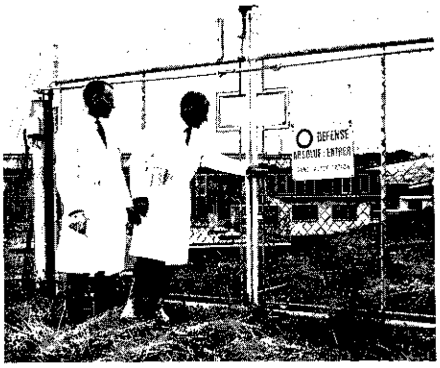
After a month's shutdown the proton synchrotron was started up again on 18 May to enable the various teams of physicists working at CERN to begin a new phase of their experimental programme. This shutdown provided an opportunity for carrying out maintenance work, inspections, and certain improvements to the machine.

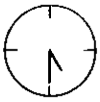
We thought it would be interesting to take part as a spectator in the standard sequence of operations involved in switching on the machine after a shutdown and have tried to describe the main steps in the PS start-up procedure.



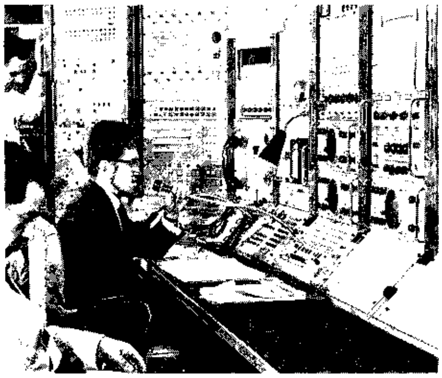
A safety patrol of two men sets out to ensure that all is in order in the magnet ring tunnel itself and in the surrounding areas outside the PS.

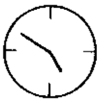
At the same time, a second patrol inspects the basement of the ring tunnel. After this inspection the entrances to the basement are locked.





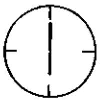
In the main control room myriads of little lights are already flickering, the operators are at their stations and the first warning is broadcast over loudspeakers in the ring building: 'Operation will begin in half an hour. The ring building will be cleared of all personnel in 20 minutes time'. This announcement is made in four different languages.





The second warning is broadcast, again in four languages:

'Operation will begin in 10 minutes. All persons must leave the ring building now'.



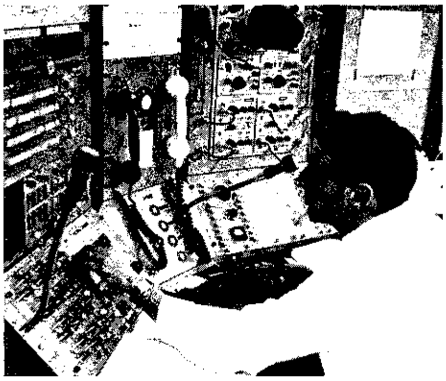
All doors leading to the inside of the ring are locked electrically. Sitting at the control desk in the main control room, an operator may nevertheless authorize entry in an emergency. He can observe the access doors on a series of television screens.

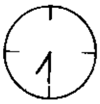
In the meantime, two magnet operators have entered inside the ring tunnel to make sure, visually, that the magnets are in order and that nothing has been forgotten or moved to a dangerous position.

Three other operators from the control room, accompanied by two watchmen, also go on a tour of inspection round the ring to make quite sure that everything is normal; that, for example, no one is still inside. A few moments later, the magnet operators ask for the magnets to be fed with power and carry out a second inspection, this time to listen for any abnormal noises, caused, for example, by metal objects moving in the main magnetic field.

After these various inspections, the operators leave the ring watched by the closed-circuit television cameras trained on the doors, and the machine is ready to start up.

Inside the main control room, an operator checks the innumerable controls and dials and takes over control of the linear accelerator, the injector of the proton synchrotron, which has been running for four or five hours already.





All the safety systems having been checked, the operator presses a button to switch on a recording which will be broadcast over the loudspeakers in the ring tunnel in four languages all the time that the PS is running: 'Attention. You are in danger. Push an emergency stop'.

After waiting a further two minutes, the operator presses the beam stopper button which lets the beam from the linear accelerator into the synchrotron ring. The accelerator is then in operation: the first pulse of protons has started on its journey of nearly 300 000 kilometres inside the vacuum chamber.

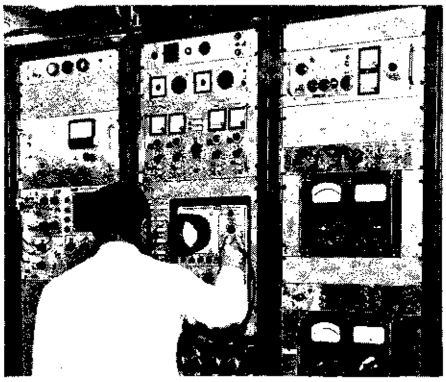
In the main control room, the nerve centre of the accelerator, the flickering lights begin to fade. The various steps to develop a good proton beam, to be used for the programme of experiments, begin.

One of the technicians adjusts the controls, another carefully follows the traces on a 'scope'. Then comes the moment they have been waiting for: all eyes turn to a series of illuminated numbers indicating the number of particles accelerated. The figure reached causes various reactions according to whether it corresponds to the expected value or not.

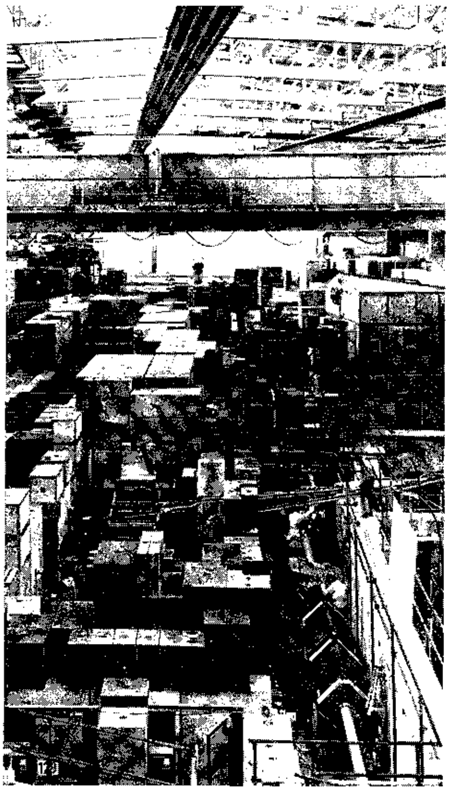
A technician also carries out measurements on the 'closed-orbit' of the beam and makes any necessary corrections to the magnetic fields. This is to try to obtain the best possible beam.

There is still a lot to do. For example, the accelerated proton beam has to be directed on to internal targets or ejected from the machine according to a programme often drawn up long before.

From 8 p.m. onwards, the machine is given over for twelve hours to the engineers, technicians and operators responsible for its running. This time will be used to carry out a number of tests to obtain the optimum performance from the accelerator before making the various beams available to the experimental physicists.



From now on and during the whole PS running time, the operators on duty, led by an engineer, will watch the performance of the machine and make any corrections that may be required. They will also, among their other duties, have to answer the requests of the experimenters who may wish a target to be moved, the beam intensity to be changed, etc.



Book Reviews

Axiomatic Field Theory

Brandeis University Summer Institute in Theoretical Physics, 1965, Volume 1 edited by M. Chretien and S. Deser (New York, Gordon and Breach Science Publishers, 1966, $ 35).

This is the first of two volumes containing the proceedings of the Brandeis University Summer School 1965. The title 'Axiomatic Field Theory' is somewhat misleading, since only three of the five contributions deal with that subject. They will be reviewed first.

'Axiomatic field theory' has fallen into disrepute with many theoreticians because it obstinately refuses to yield numbers. The disrepute is undeserved. Those who are interested in understanding, rather than in computing, will still find field theory useful and the inclusion of the subject in the programme of a summer school is therefore commendable. It is doubtful whether this volume will contribute greatly to the dissemination of field theoretical knowledge among the unbelievers, since two of the three contributions are so highly technical in character that they are not likely to find many readers among those who do not firmly intend to become active in the field themselves. The authors cannot be blamed for the technicality, which is, to a large extent, enforced by the subject matter of their courses. For the interested student these articles will be of great value.

H. Epstein's contribution deals with the recent developments in our knowledge of the analiticity properties of the field theoretical Green's functions, both on and off the mass shell. As yet the most important result of these researches (to which Epstein has contributed significantly) is the proof of crossing symmetry for the two particle scattering amplitude in the general mass case. The subject is not an easy one. It involves methods of handling analytic functions of several variables which are not familiar to the average theoretician. Indeed many of these methods have only been developed in the course of this work. Epstein succeeds in presenting the problems as clearly as possible, but even so, a serious effort on the part of the reader is needed to understand them. The article contains a great deal of material that is not easily accessible elsewhere and is therefore of interest not only to the student but also to the expert.

The LSZ-formulation of field theory has traditionally been considered to be less rigorous mathematically, but more useful physically, than the Wightman formulation. K. Hepp reports in his lectures on the progress that has recently been made, mainly by himself, in removing the mathematical objections to the LSZ results by deriving them in a rigorous way from the Wightman axioms. After a short review of Wightman's theory, he starts with Ruelle's, by now, classical proof of Haag's asymptotic condition, then goes on to prove the LSZ asymptotic conditions on a dense set of states, as well as related facts like the Yang-Feldman equations, the reduction formulae for the S-matrix, and dispersion relations. The cluster properties and the one-particle structure of the S-matrix are discussed. The proofs are given in detail, and in most cases for particles of arbitrary spin. This is a welcome deviation from the customary attitude of axiomatists, who tend to regard spin as a mere nuisance without fundamental significance. The author manages to cover a lot of ground in some 100 pages. The style is correspondingly terse.

D. W. Robinson's contribution on the algebraic aspects of field theory is, in contrast to the two reviewed above, refreshingly understandable even to the uninitiated. Especially recommended is the lecture of Chapter 4, which contains an account of the general ideas underlying the algebraic approach to quantum mechanics in general, and field theory in particular. This approach seems to have many advantages over the conventional point of view and deserves the attention of a wide audience. The earlier chapters are on the Poincaré group and its representations, and on some basic facts of conventional field theory.

While pedagogically on a high level, these chapters do not go beyond what can be found in numerous other summer school courses on the same topics. The notes have been prepared by a student rather than by the lecturer himself. As a result this contribution suffers more than the others from the disadvantages of the informal summer school style, i.e. careless formulations, and, sometimes, ambiguous and misleading statements.

The two contributions not on field theory are by L. Michel and R. G. Newton. Michel's course 'Relativistic Invariance and Internal Symmetries' deals in its main part with some mathematical aspects of group theory which are not known to most physicists, despite the recent wave of interest in group theory. In particular, he discusses applications to groups and algebras of the methods of homological algebra and the theory of homogeneous spaces. The emphasis is on mathematics ; physical applications are given somewhat incidentally.

The final chapter gives a useful, though not very systematic, account of a covariant spin description and its connection with various internal symmetries.

Newton's contribution is by far the shortest of the five (30 pages). It describes the application of the familiar nonrelativistic scattering formalism to the scattering of a single particle on a bound state of two particles, discussing the derivation of Lippman-Schwinger equations for this problem and methods for their solution — in particular, an adaptation of Faddeev's method. The treatment is formal and existence problems etc., are not discussed.

O. Steinmann

Atomic and Nuclear Physics

by D.L. Livesey (Massachusetts, Blaisdell Publishing Company, 1966, $ 10.50).

This book is an excellent introduction, at undergraduate level, to atomic and nuclear physics and, for all but the specialist in topics from these fields, can sit very usefully on the shelf as a general reference book.

Its first chapters cover the atomic theory of matter, kinetic theory, charged sub-atomic particles, and atomic interactions with radiation. The approach is partly to follow the historical development of the subject and there are neat, simple descriptions of some of the famous experiments which changed our conception of the structure of matter early in this century.

In moving on to chapters covering photon mechanics and relativity, the nuclear atom, quantum mechanics, the quantum theory of solids, and nuclear physics, the treatment becomes more mathematical until we are deep in worked-out examples of the application of the Schrödinger equation. A useful, short description of the operating principles of the various types of accelerator is given in the chapter on nuclear physics. This is an example of the emphasis which the author gives to the development of experimental techniques.

The final chapter steps outside the mandate of the title of the book to provide an introduction to sub-nuclear physics. The coverage is well up-to-date at the time when the book was written, including for example CP violation in long-lived neutral kaon decays.

Presentation of text, mathematics and illustrations is a delight throughout. Books for further reading on the topics covered in a chapter are listed at the end of the chapter and there is a thoughtfully-produced index.

This is not a book for the specialist, but for its intended undergraduate audience and for those physicists, no longer steeped in the field, who one day need to recall what the Lamb-shift, the Sommerfeld theory of metals, or Bose-Einstein statistics, is basically about, it is an excellent source of easily assimilated information.

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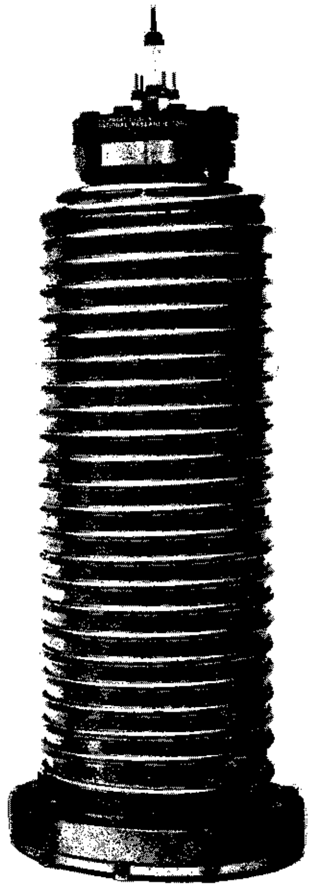

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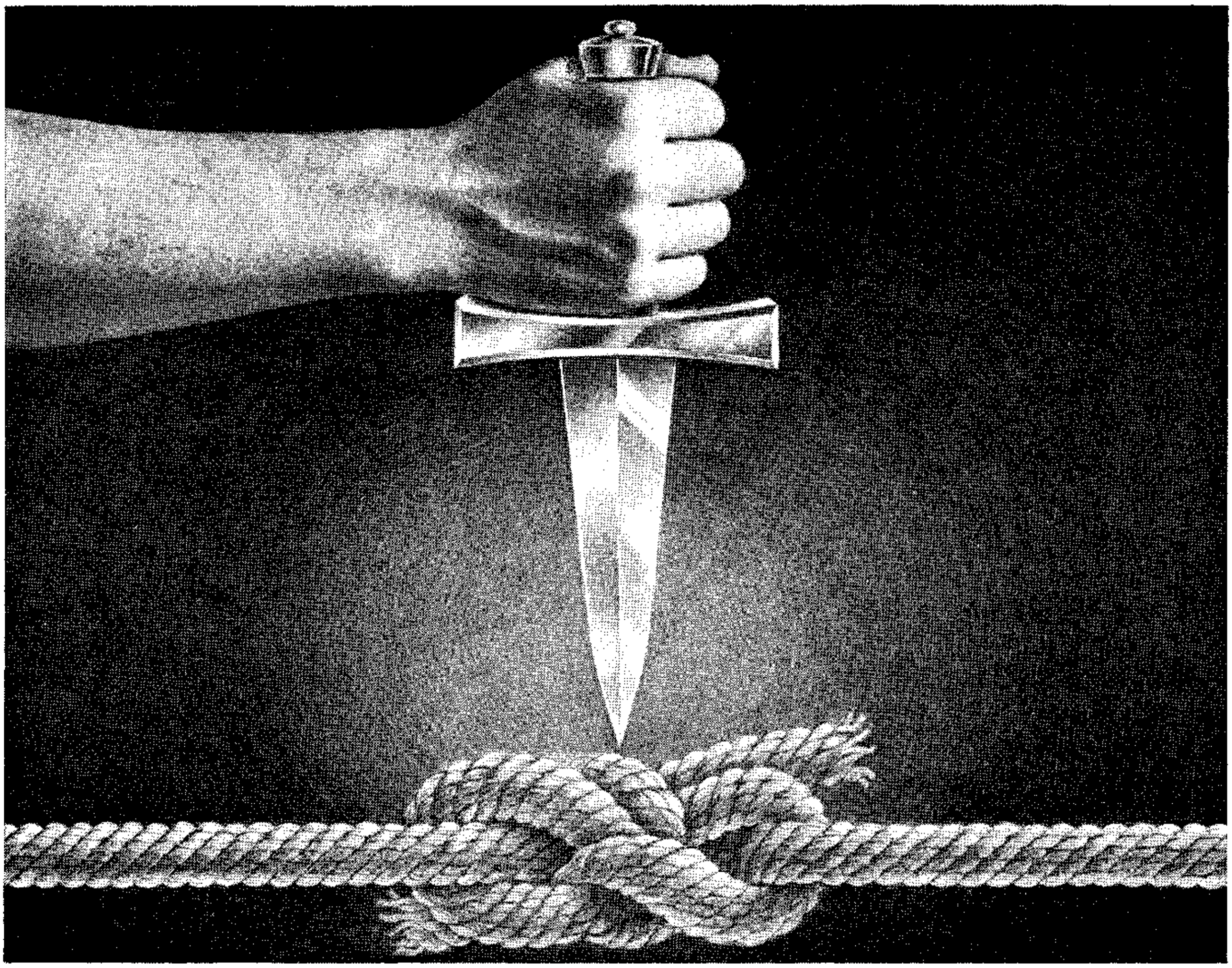

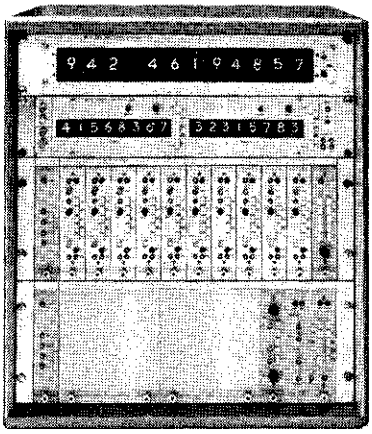

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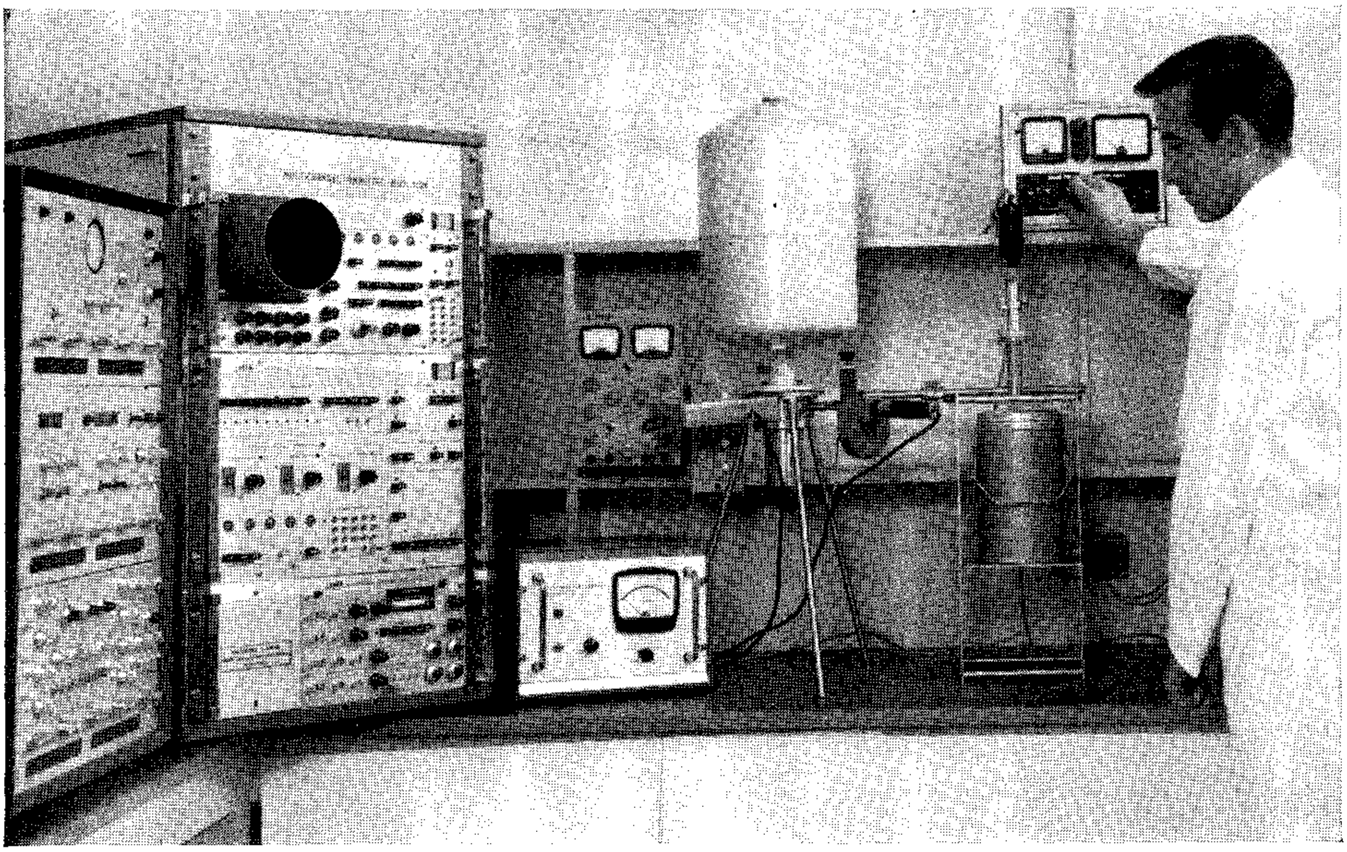

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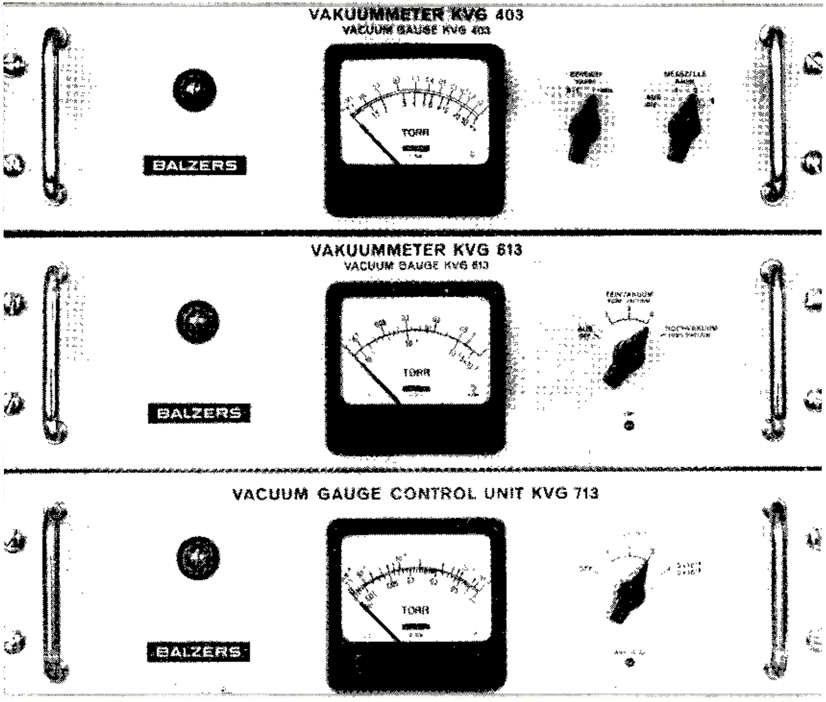

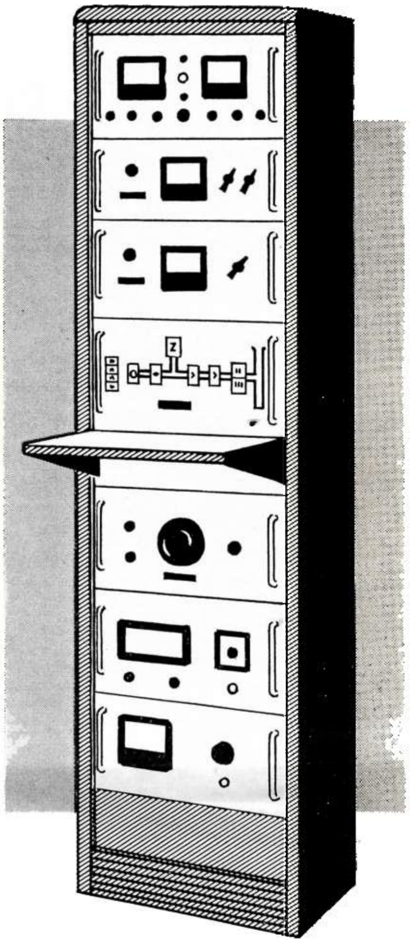

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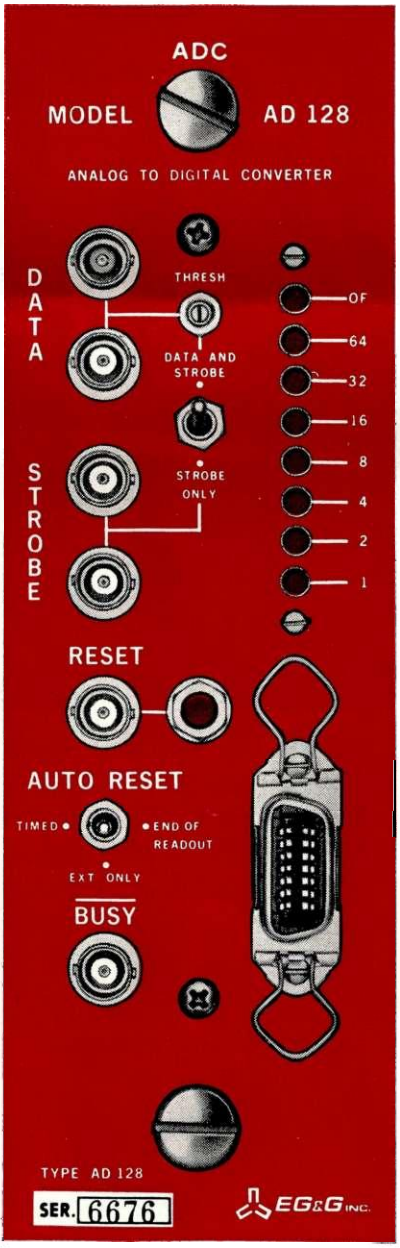

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