CERN COURIER

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Cover photograph : The scope traces recording, on 1 March, one of the first pulses reaching a beam energy of 200 GeV in the proton synchrotron at the National Accelerator Laboratory, Batavia ... surrounded by the signatures of some of the accelerator builders.

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1200 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3000 people and, in addition, there are about 850 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 371.4 million Swiss francs in 1972.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of hundreds of GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1972 is 95 million Swiss francs and the staff will total about 300 people by the end of the year.

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Comment

Our opening article in this issue celebrates the first operation, on 1 March, of the proton synchrotron at the National Accelerator Laboratory, Batavia, at its design energy of 200 GeV. The article gives a short description of the machine and some of its building and commissioning story. It is a great achievement to reach the highest energy in the world from a particle accelerator and NAL have done it in a style which is all their own.

When they started work on the design of the machine in the summer of 1967 there were already in existence, in Europe and the USA, design studies for accelerators to give several hundred GeV energy. Those design studies in their essential philosophy were extrapolations of the great alternating-gradient machines, built in the 1950s, which have performed so well at Brookhaven and at CERN. NAL did not take over these designs but rethought the problem and came out with a radically different scheme. Not many of the new underlying ideas actually originated at NAL but certainly the incorporation of the ideas in the design of a big machine was first done at NAL.

When, after a few months of intense work at Oakbrook, the design for a 200 GeV machine capable of extension to higher energies was presented to the accelerator community at the Cambridge Conference in September 1967 (see vol. 7, page 199) the new ideas were not well received. By now, however, many of them — such as the concept of 'extendible energy' for the accelerator, the choice of separated-function lattice for the main ring, the choice of window-frame magnets, the belief that it is possible to achieve high ejection efficiencies — are completely accepted. Others — such as the 'tightness' of the magnet design, the use of the machine itself as the test bed (rather than rigorous pre-testing of components prior to installation) — have not been a convincing success.

When tackling the design of such a major project there is a narrow path to be trodden between attitudes which we might express in the words of Dean Inge as 'This is old, therefore it is good' and 'This is new, therefore it is better'. The NAL machine builders would probably be the first to admit that they did not win them all — taking new approaches, some valid experience was rejected and part of the baby went out with the bathwater. Nevertheless Bob Wilson and his team re-opened the windows on accelerator design and let some fresh air blow in. As a result of their imagination and freshness of approach the design of large accelerators has been revitalized.

It is appropriate to use the expression 'Bob Wilson and his team' because the personality of the Laboratory Director, Professor R.R. Wilson, has been dominant in setting the style of the National Accelerator Laboratory. His influence can be seen everywhere — in the design of the machine, in establishing the rapid pace of construction, in the political negotiations that sustained support in a time of financial stringency (as perhaps no-one else could), in the flair for publicity, in the design of the Laboratory (the building complex is becoming a striking work of architecture). He inspired tremendous enthusiasm and won tremendous hard work from his team. They are likely to look back with memories of blood, sweat and tears but also with memories of enjoyment and statisfaction from the years they spent building the synchrotron at Batavia.

The ultimate test of a good accelerator is the quality of the physics programme it is able to support. Up to now, the criterion might be expressed as 'a machine which sustains the research of the maximum number of physicists for the maximum amount of time with maximum versatility'. But this may not be the only criterion of excellence.

As the NAL team continue their work to bring their accelerator fully into operation to feed experiments, the high energy physics community will wish to congratulate them on their achievement in reaching 200 GeV and on the vigour and enthusiasm with which they have brought it about. It has been an exhilarating experience to follow the progress of the project and we look forward with even more interest to the start of the experimental programme.

First pulses at 200 GeV

Commissioning of the proton synchrotron at the National Accelerator Laboratory, Batavia.

The National Accelerator Laboratory came into being in the summer of 1967 with the mandate to build and operate a proton synchrotron of 200 GeV energy. The Laboratory is operated for the United States Atomic Energy Commission by Universities Research Association — a consortium of 51 USA universities plus one from Canada.

On 15 June 1957 design work started at Oakbrook, a suburb west of Chicago. The design team stayed there for over a year until they had access to the site which was made available by the State of Illinois (a roughly square-shaped site with a 5 km side around the former village of Weston). The move to the site was completed in September 1968. On 1 December 1968 ground was broken for the first permanent Laboratory building (to house the linac) and construction was under way. The aim was to have the accelerator operational by 1 July 1972 and to build it within a budget of $ 250 million.

The machine design

The design is of a three stage machine — a 200 MeV linear accelerator feeding an 8 GeV fast-cycling booster synchrotron feeding the 200 GeV main ring. Work on the linac was simplified by taking over, for the most part, a design developed at Brookhaven as part of the conversion project of the 33 GeV AGS. It has a total length of 145 m with a 750 kV Cockcroft-Walton preinjector and nine accelerating tanks containing 286 drift tubes fed with r.f. power at 201.25 MHz. The design intensity is 75 mA in pulses 100 μs long and a pulse repetition rate of 15 per second. The linac produced its first beam on 1 December 1970 only two years after the ground-breaking ceremony and is now performing reliably.

The fast-cycling Booster has a diameter of 150 m. It is designed to operate at a repetition rate of 15 pulses per second of which 13 pulses will be used in filling the main ring during 0.8 s. The design intensity is 3.5×10^{12} protons per pulse using four-turn injection from the linac. The magnet system is 'combined-function'. Design energy was reached for the first time on 21 May. Up to now it has been operated mainly at 7.2 GeV peak energy, rather than 8 GeV, so that there will be some safety margin in the r.f. accelerating system. It provides an intensity of about 10^{11} protons in one pulse to the Main Ring. During commissioning of the accelerator this has been sufficient to tune the whole complex and avoids the build up of induced radioactivity. Eventually, four-turn injection and 13 pulse ejection will raise the intensity per second.

The Main Ring is obviously the major stage of the accelerator and it is the stage which has seen most innovations. The ring is 2 km in diameter with six long straight sections (54 m) — one of them is taken up by the r.f. accelerating system, one for injection from the Booster and ejection towards the experimental areas. The magnet system is 'separated-function'. The tasks of holding the beam in the ring and of keeping the beam focused are performed by different magnets — bending magnets and quadrupole focusing magnets respectively.

The bending magnets (each about 6 m long) are of two types with different apertures (12.5×3.75 and 10×5 cm^2) adapted to the beam profile around the ring. They are of the 'window-frame' type with coil on the median plane of the beam. There are 774 bending magnets and 180 quadrupoles distributed around the 6 km circumference of the ring. The ring is so packed with magnet that a field of only 0.9 T in the bending magnets is needed to hold beams accelerated to 200 GeV. Tests on the magnets have indicated that it should be possible to retain sufficient 'good field region' at field levels as high as 2.25 T to accelerate some beam. Thus it was announced, in April 1970, that 500 GeV beams at much reduced intensity would be tried with the accelerator as it has been built. Sufficient power supply for 500 GeV acceleration has been installed (since power supply costs came out lower than anticipated) but the installed water cooling capability will hold the pulse rate down. A detailed description of the magnets can be found in vol. 10, page 180.

The power supply is of the static compensator type with sixty units taking power direct from the electricity grid without the intervention of rotating plant (motor-generator set). The machine cycle for 200 GeV requires 0.8 s for injection from the Booster, 1.6 s for acceleration up to 200 GeV (16 r.f. cavities providing 3.5 MeV energy per turn) and 0.6 s to return to injection field levels. Thus with a 1 s 'flat-top' the total cycle time will be 4 s. Higher energies will obviously lengthen the cycle time. The design intensity is 5×10^{13} protons per pulse at 200 GeV.

We will return to commissioning of the Main Ring later.

There is one ejected proton beam subsequently split to serve three experimental areas. The slow ejection system involves the use of a wire-plane electrostatic septum (see vol. 11, page 320) which should yield very high ejection efficiencies. The ejected beam can be directed in a proton switchyard to the right to feed the Proton Laboratory, to the left to feed the Meson Laboratory or allowed straight ahead to the Neutrino Laboratory. In the few days following first acceleration to 200 GeV the ejection system sent a low intensity beam at 75 GeV into the proton switchyard.

1.

1. The ground breaking ceremony for the first permanent building (to house the 200 MeV linac) on the NAL site. The date was 1 December 1968. At work with the spade are the then Chairman of the U.S. Atomic Energy Commission Glenn T. Seaborg (right) and the Laboratory Director, Robert R. Wilson.

2.

2. The 1014th magnet of the main ring being slotted into place to complete the circle on 16 April 1971 (though many had to be unslotted again and refurbished before the accelerator achieved design energy). This closing of the ring took place in the presence of visiting scientists from the Soviet Union. In the picture are (left to right) N. Ramsey, C. Larson, M. Petrosyants, A.G. Laveroff, R.R. Wilson, G.T. Seaborg, V.F. Gordeyev and N.A. Prozorov. The two last named Soviet scientists were at NAL to participate in preparations for the initial experimental programme.

The Proton Laboratory is designed to provide flexible facilities for experiments at very high energies (beamlines, etc., are likely to be specific to a particular experiment rather than serving a long series of experiments). It is subdivided into three areas (East, Central and West). Charged particle beams (including an electron beam) are already designed and the first experiments are being prepared. The Meson Laboratory will have, as its first phase beams, a diffracted proton beam, a neutral kaon beam and a neutron beam. The building is complete and internal installation will continue for a few more months. Most beam-line components are in place but not aligned. The Neutrino Laboratory will house the world's largest bubble chamber — a 15 foot chamber scheduled to be ready for experiments at the beginning of next year. In the meantime a 30 inch bubble chamber, previously operated at Argonne, is ready to take beam. High energy neutrino and charged particle beams will be available in the Laboratory.

Commissioning of the Main Ring

The Main Ring was brought to a state where acceleration could be tried in June 1971. This was in response to a decision, taken in the course of construction, to try to advance the first operation date by a year (reducing total design and construction time to four years). It was, however, always anticipated that the running-in of the NAL machine would take longer than is usual on accelerators since a lot of time had been saved by cutting corners on component testing prior to installation with the intention of using the machine itself as the test-bed.

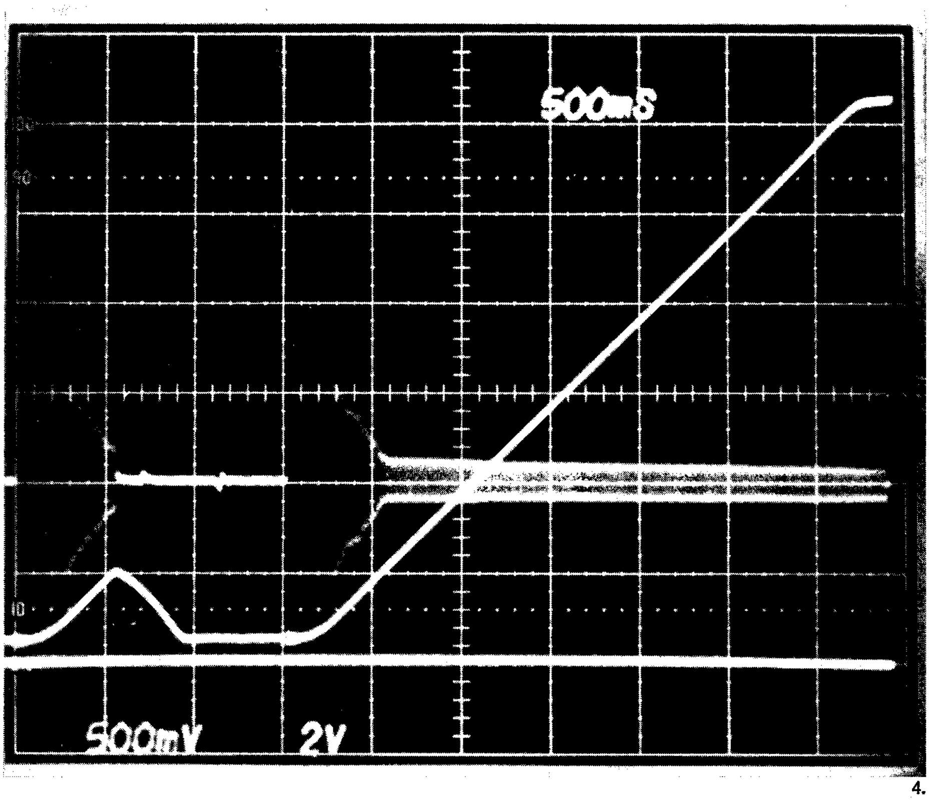
The first circulating turns were achieved on 1 July 1971 but for several months following this date a series of major problems required attention. The most difficult one concerned the bending magnets and has been covered at length before (vol. 12, page 13). Moisture in the ring tunnel found flaws in the magnet insulation and made it impossible to bring the volts up. Many magnets had to be removed and re-insulated. The cutting out of the magnets introduced a further complication because small curls of metal fell into the vacuum chamber and stood up to impede the beam when the magnetic field was brought on. The vacuum chamber had to be swept out — no easy task given the dimensions. The r.f. system and the magnet power supplies also required doctoring.

However the problems were steadily overcome and early this year serious attempts at acceleration could begin again. The break-through (in several senses) came on 22 January when, after twentieth harmonic corrections and sextupole fields were brought to bear in the machine, beam was accelerated through transition energy (17.4 GeV) to 20 GeV. The next important dates were 4 February, when 53 GeV was reached, and 11 February, when the NAL accelerator took over from the 76 GeV machine at Serpukhov as the highest energy accelerator in the world by accelerating beam to 100 GeV.

These energies followed the mastering of the difficult tuning of the magnet power supplies. It is necessary to bring on the supplies successively

3.

3. 'There it is'. On 1 March 1972 happy faces cluster around the screen in the NAL Main Control Room to see the scope trace extending out to the 200 GeV mark. At the scope itself are (left to right) Frank Cole, Jeff Gannon and John Clarke with, immediately behind them, Dick Cassel, Ryuji Yamada, Bruce Strauss and Paul Evan.



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4. The scope traces. Operation of the accelerator was 'bi-modal' to avoid the need for water-cooling the magnets — thus the photograph shows first a 30 GeV pulse and then a 200 GeV pulse. The top trace shows the intensity (falling steeply at lower energies up to about 30 GeV but then extending without much further loss out to 200 GeV). The lower trace shows the magnetic field (climbing and falling from the 30 GeV level and then climbing up to 200 GeV level).

in a pattern around the ring and several days work have been required to get the synchronization right when moving to a new energy. The tracking between the quadrupoles and bending magnets — making sure that the focusing fields and bending fields are in step — needed careful power supply control. In fact 53 GeV and 100 GeV were reached with the supplies to quadrupoles and bending magnets in a single series circuit. (200 GeV was reached with them separated, as designed.) A few magnets have tended to fail each time a higher energy level has been reached but this has not occurred to the magnets refurbished with the latest techniques.

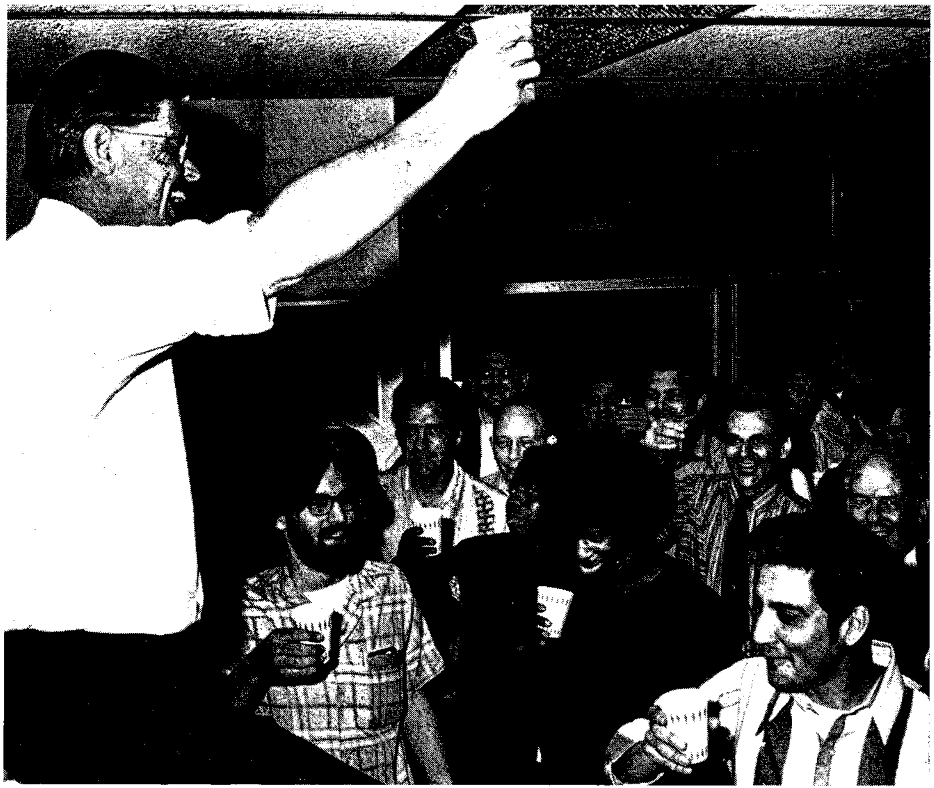
On the morning of 1 March there was a pep talk at the Laboratory from Bob Wilson, who had been reporting at budget hearings to the Joint Committee on Atomic Energy the day before, and from Ernie Malamud reviewing commissioning progress. In the Main Control Room, Frank Cole was leading the new attack on design energy with Jim Griffin at the other end of the inter-com in the R.F. Building. Don and Helen Edwards had worked during the night to tidy up the tracking between bending and quadrupole magnets which was a possible source of beam instabilities at energies over about 30 GeV.

At 11.00 h a stable beam was achieved after injection of about 10^{11} protons per pulse from the Booster at 7.2 GeV. By 11.30 h the beam was through transition and a steady climb to higher energies began. The machine was being operated in a 'bi-modal' fashion. In order to simplify the removal of magnets which failed (and also, perhaps, because of an understandable phobia about moisture) the magnet water cooling circuits were not operating and the pulse rates had to be kept low to avoid overheating. The cycle sequence was forty pulses at 30 GeV each

5. One of the bottles of chianti with which 200 GeV was celebrated. They bore the same label as the bottle which was opened to celebrate the operation of the first atomic reactor at the University of Chicago in 1942 under the leadership of the famous Italian physicist Enrico Fermi. The bottles for NAL were given by A. Wattenberg of the University of Illinois who had been present in 1942 and had saved the Chianti bottle (now in the Chicago Museum of Science and Industry).

6. Bob Wilson offers a toast to his fellow machine builders.

(Photos NAL)

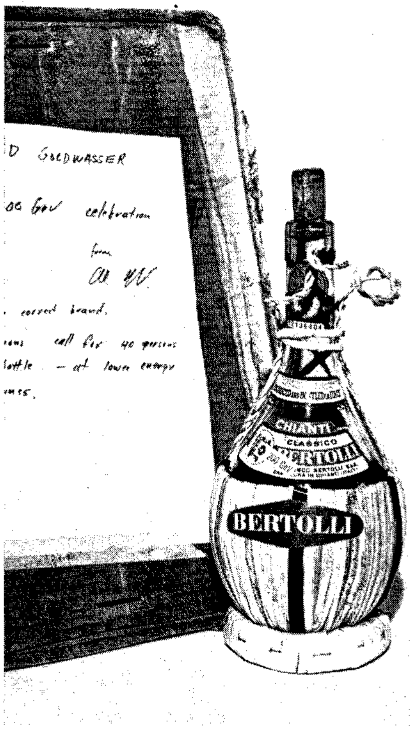


6.

taking 1 s (this took the beam beyond transition and made it possible to continue tuning) followed by a single pulse to 200 GeV field levels taking 5 s (3 s rise time).

At 12.30 h the scope trace indicating accelerated beam crept out to 167 GeV. The intensity fell rapidly up to about 30 GeV but then remained constant at a few 10^{-9} protons per pulse. Excitement was growing and the Main Control Room became a crowd scene. A huddle of heads peered at the screen crowding round Ed Gray who was operating the main control console. At 13.08 h the shout went up 'There it is !'; the trace went all the way out to 200 GeV.

After a cheer and a few more pulses to rub the 200 GeV home, the celebrations began. Champagne which had been lurking hopefully in the refrigerator at the cafeteria for several months was brought into the open and was joined by bottles of chianti with historic associations (see the photograph caption). Design energy had been achieved several months ahead of the initial schedule and within the forecast construction budget.



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Coming months

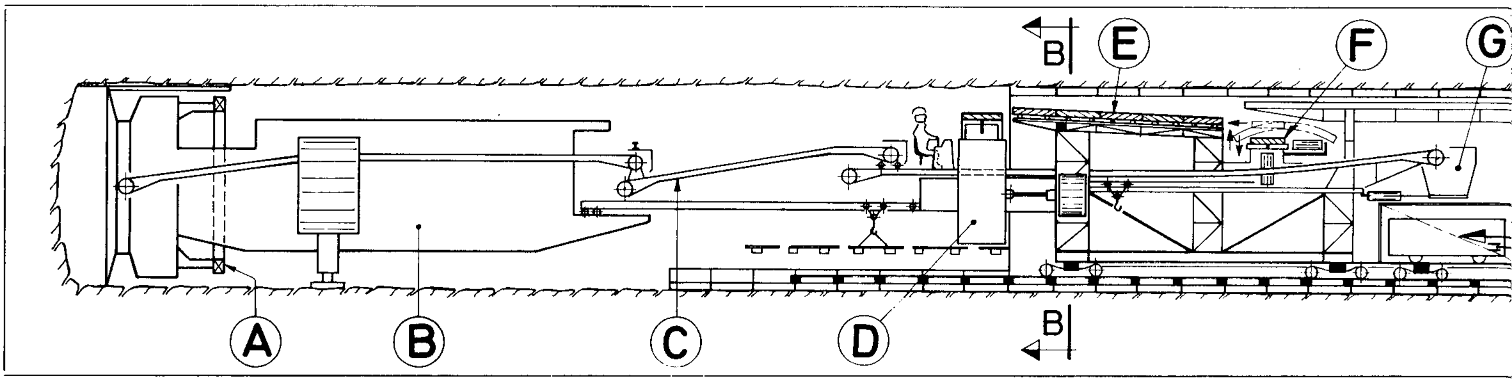
The main tasks of the coming months are to bring the accelerator into reliable operation at high energy levels and to operate the ejection system. The ejection septum has been powered without disturbing the circulating beam and when ejection was tried at 75 GeV, during the days following first acceleration to design energy, a low intensity beam was detected in the proton switchyard, as mentioned above. Also in the coming months acceleration to higher energies may be tried.

Physics began at the accelerator on 6 March when a Rockefeller, Rochester, Dubna, NAL team, using an internal polyethylene target, collected data on elastic scattering of protons at small angles. They measure the angle and energy of slow recoil protons by means of semi-conductor detectors positioned from 79 to 90° to the beam direction inside the vacuum box. The aims are to measure the differential cross-section and the real part of the nuclear scattering amplitude. Their preliminary data have been assembled with proton energies from 21 to 57 GeV and beam intensities of about 2×10^{10} protons per pulse at a 3 s repetition rate.

The accelerator was switched off on 11 March to bring in the water cooling so that normal repetition rates for high energy operation will become possible. Also there will be moves to higher intensity per pulse. Eventually multi-turn injection into the Booster from the linac and multi-pulse injection into the Main Ring will be necessary to approach design intensities. Further tuning of the Main Ring will also be needed. A computer-simulation programme of magnet alignment, which worked very well for the Booster, has started and more refined adjustments of the correction magnets (sextupoles, etc.) will be implemented as the performance of the machine becomes better known.

As the accelerator is progressively mastered more attention will be given to bringing in the experimental areas. Before long it is hoped to be able to provide the high energy physicists with beams of adequate energy, intensity, and reliability for the initial experimental programme. Information on particle behaviour at energies of hundreds of GeV (supplementing the results at extremely high energies but of limited variety coming from the Intersecting Storage Rings at CERN) will then become available in a controlled way for the first time.

CERN News



1. Boring the main tunnel and fitting the lining : The 'Mole' (B) is on the left. It is immediately followed by the device for mounting steel rings (A) which provide a temporary support for the tunnel wall until the concrete lining is in place. Then comes the device (D and F) for fitting the prefabricated concrete lining (section BB) which locates and then holds the six concrete sections (E) forming the first lining against the wall. A wedge is then inserted between two of the lateral sections in order to press the lining against the wall. A conveyor belt (C) removes the spoil (G) to wagons (I) and also keeps the work area supplied (H) with rails and lining materials. The railway is also laid semi-automatically. Very precise geodesic measurements are made on the surface in order to determine the position of the shafts with an accuracy of several millimetres. The accuracy is less in the tunnel itself but the Mole is guaranteed not to deviate by more than ± 7 cm from its projected path between the shafts, this path being defined to within ± 3 cm.

Boring the SPS tunnel

In February, excavation began of two of the shafts through which the equipment to be used to bore the SPS machine tunnel will be lowered to the necessary depth. The boring operation is the most spectacular item in the civil engineering programme for the new machine. The ring tunnel itself has a circumference of about 6.9 km. The tunnel diameter to be cut out is 4.8 m and it will be bored at an average depth of 40 m.

The Batavia tunnel was dug by the cut-and-fill method. At CERN preference has been given to underground boring as used for Alpine tunnels. There are two decisive reasons why this method has been chosen. In the first place, there is the desire to keep the surface of the land intact to preserve its present character as far as possible. Secondly, there is the considerable variation in altitude of the land above the tunnel (45 m between the highest and lowest points) which, if we are to have a minimum covering of about 20 m to provide radiation protection, would involve digging at a depth of 65 m below the highest point on the surface. In addition, the bedrock of mixed molasse gives adequate stability for underground boring in good conditions.

Tunnels are often blasted out but this could adversely affect the stability of the ground causing the alignment of the magnets to vary with time. The choice was then between mobile-head tunnelling machines, where the boring head moves at the end of an articulated arm, and full-face machines where the operating component is circular and of the same diameter as the tunnel to be bored. The latter was preferred, although mobile-head machines will be used to bore the transfer tunnels which are not circular in cross-section but shaped like an inverted horse-shoe and certain parts of the main tunnel where the cross-section is increased to bring in transfer tunnels or shaft connections.

The full-face machine, constructed by Robbins (USA), has been nicknamed 'The Mole'. As the drawing across the top of the page shows, the Mole is far from being the only component in the tunnel. It is followed by a 'train' 40 m long which removes the spoil and brings shoring and lining equipment to the working face. The lining is installed as boring progresses.

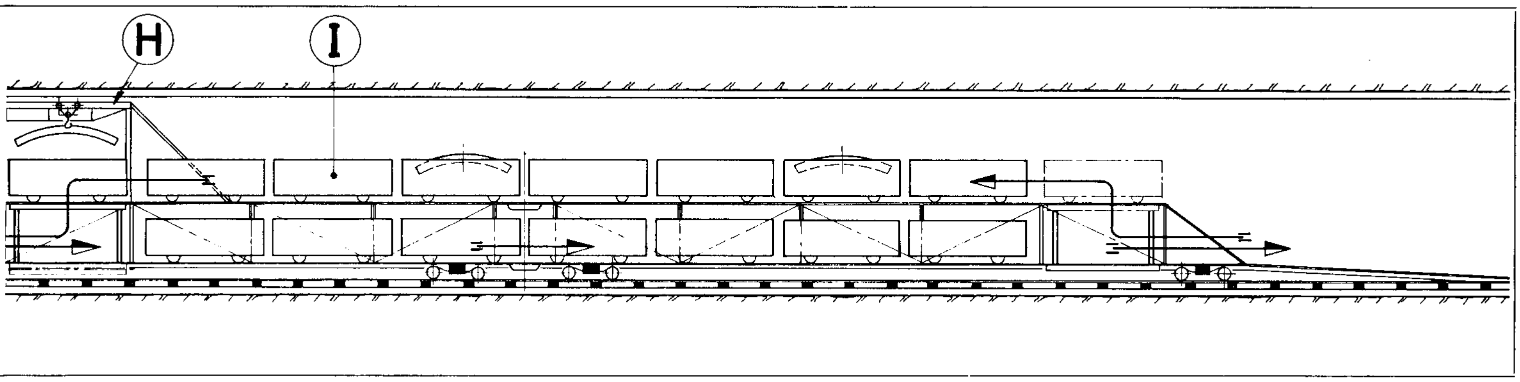
The simplest way to explain the operation is to refer to the drawing. Top left can be seen the machine. Its boring head consists of a single rotary plate fitted with a large number of cutters which, actuated by a force of 400 tons applied by an axial ram, dig into the rock and pulverise it. The thrust force is counteracted by friction applied via huge radially moving pads pressed against the walls by means of rams. When the axial ram is at the end of its stroke, the lateral supports are retracted. The body of the machine then advances by about a metre and begins a new cycle. It is hoped that the rate of progress, which depends on the rock, will reach 20 m per day. The Mole will be guided from one shaft to the next by a sophisticated topometric system giving an accuracy of ± 3 cm on the theoretical axis of the tunnel over a distance of 1 km.

The spoil from the working face is picked up by scoops incorporated in the periphery of the plate and so shaped that they empty at the top of their travel on to a conveyor belt which takes the spoil back to the skips. The skips are carried on a conveyor with two tracks, one above the other. They are used to remove the spoil and to bring shoring material, consisting of I-section steel rings temporarily fitted behind the machine head until curved prefabricated concrete sections, forming the first layer of the final tunnel lining, are installed. The concrete sections are fitted automatically, the only job which has to be done directly by human labour being the keying of the lining by means of wedges securing the sections against the wall of the tunnel.

The other layers (one of metal for sealing and a further coating of concrete moulded with the aid of shuttering) will not be applied until later, *2. A cross-section at position B-B which shows the device for putting the six prefabricated concrete sections in place as the first step in lining the tunnel.*

3. A typical section of the tunnel lining. The prefabricated concrete sections (A) are each 1/6 of the tunnel's circumference. The sections are pressed against the tunnel wall by means of pinning wedges (D) and then cement is injected between the rock and the sections in order to fill any gaps and bond the sections to the rock. The inner lining (B) consists of an envelope of moulded concrete. The tunnel floor (C) is then cast on an inverted prefabricated concrete section. Finally, concrete is injected between the sections and sealing plates and the whole lining is made leak-proof and secure. The tunnel is bored 4.80 m in diameter but the final internal diameter is only 4.14 m.

Photograph taken on 18 April of the digging out of the access shaft PP1 where the Mole will be lowered to tunnel level. The hole is being dug 6 m in diameter and 45 m deep (about 15 m were excavated when the photograph was taken).

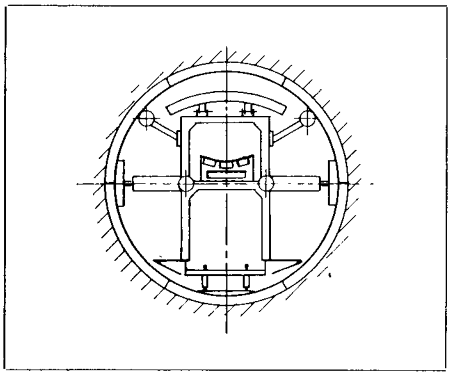


when more than half the tunnel has already been bored. The whole forms a rigid assembly 33 cm thick, bonded to the rock.

This great subterranean factory, which will run twenty-four hours a day, will need a crew of only six people to operate it.

As mentioned above, the tunnel cross-section will be widened in those areas (the long straight sections) where the transfer tunnels and the access tunnels to the shafts join it. Two mobile-head machines made by Alpine (Austria), travelling on caterpillar tracks and capable of being fitted with various boring tools to suit the type of rock, will be used for these widened sections and for boring the transfer tunnels. In the wider parts of the tunnel, the lining will consist of steel rings welded together with concrete sprayed on top of them. The remainder of the work is substantially the same as for the ordinary parts of the tunnel.

The transfer tunnels totalling about 2 km in length, have several types of lining, depending on whether they have been built by the cut-and-fill method (entrances and exits near the surface) or bored into molasse, good moraine or unstable moraine. Welded steel rings are used in all cases, together with sprayed-on or injected concrete, and shuttering for the pouring of a second concrete coating.



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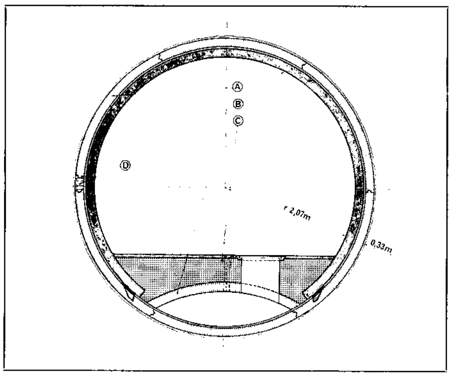

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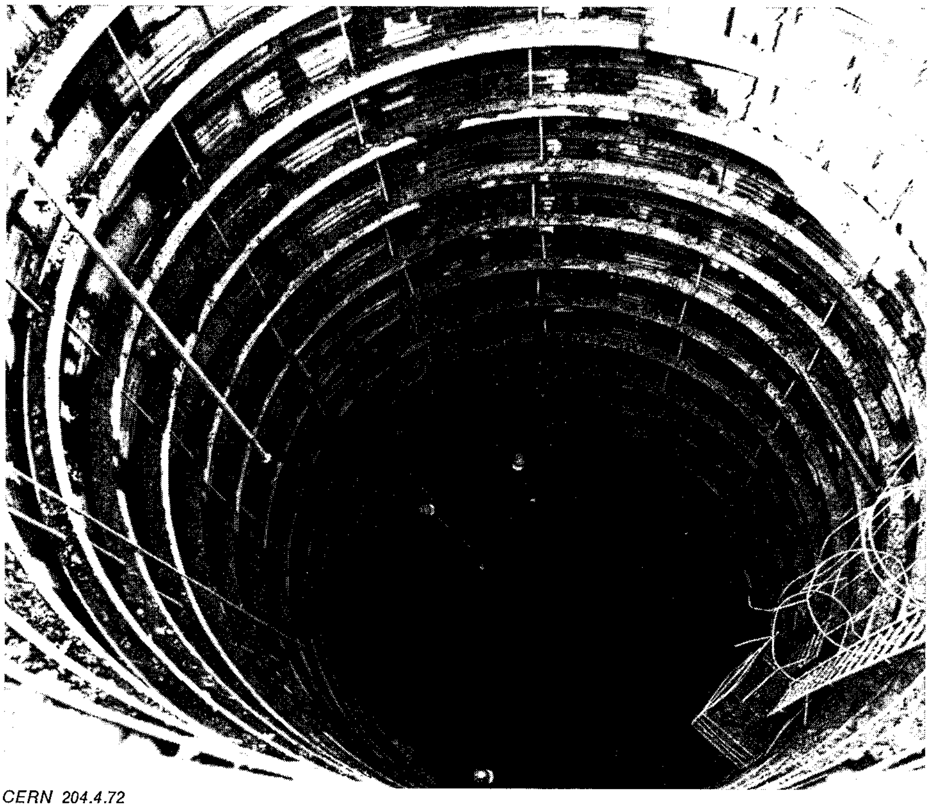

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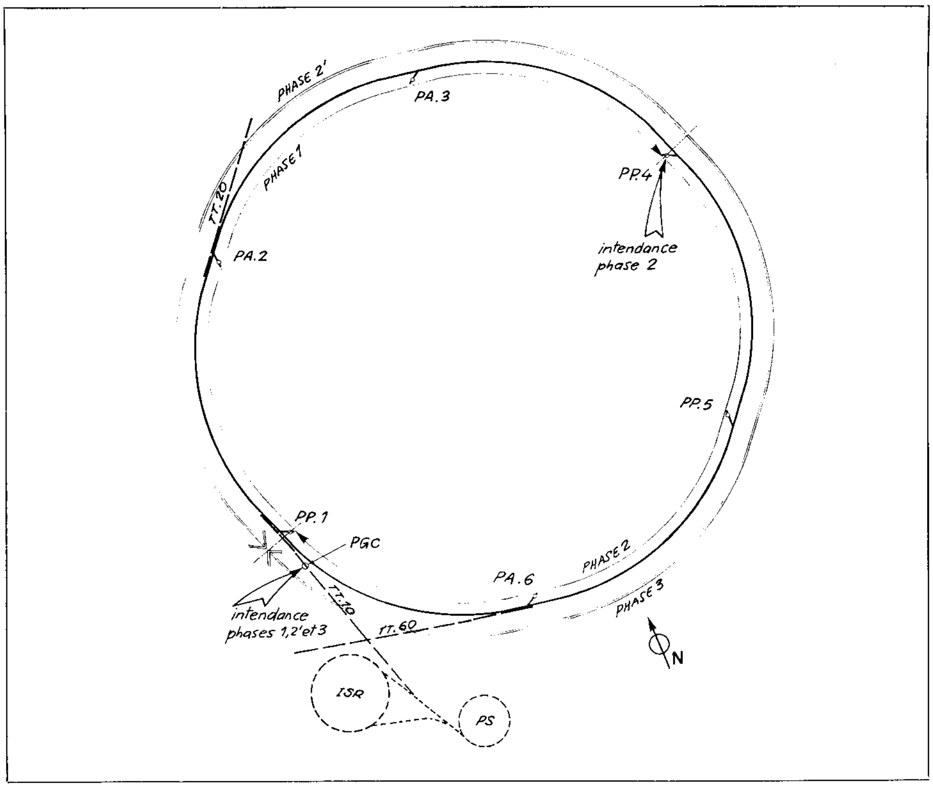

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4. Boring of the SPS tunnels will be done in three phases :

1) From September 1972 to mid-1973 the Mole will work from PP1 to PP4 the support facilities (removal of the spoil and fitting the first part of the lining) being provided through the PGC shaft ;

2) From mid-1973 to March 1974 the Mole will complete the work from PP4 to PP1 continuing round, the support facilities being transferred to shaft PP4. At the same time, the final tunnel lining will be fitted in the half already bored, from PP4 towards PGC, the latter being used for the movement of the required materials (March to October 1974);

3) When the Mole has completed its run, it will be withdrawn through shaft PP1 and the final lining will be fitted in the second half of the tunnel, working from PP4 towards PA6 and continuing to use the PGC shaft for the support facilities.

Work on the transfer tunnels will be from February 1972 to December 1973 for TT20 (North ejection tunnel), from July 1972 to October 1974 for TT10 (injection tunnel) and from February 1973 to September 1974 for TT60 (West ejection tunnel). Some of the tunnelling work (in the shallowest sections) will be done from the surface.

The access shafts

There are seven shafts — six of them distributed around the tunnel and one located to the right of the tunnel linking the PS to the SPS. They will be used to introduce the boring machine, for the extraction of spoil and for the entry of equipment. The shafts will be as follows :

PGC (civil engineering shaft): 9 m in diameter used to introduce the support facilities, the concrete sections and to remove spoil. It will be fitted with a 14 tonnes lift.

PP1 and PP5 (personnel shafts): 5 m in diameter, PP1 used to introduce the Mole.

PP4 (personnel shaft): 9 m in diameter used as a service shaft instead of PGC when the Mole has bored out more than half of the tunnel.

PA3, PA6 (access shafts): 9 m in diameter containing 25 tonnes service lifts to be used for the introduction of heavy equipment (magnets).

PA2: identical to the two above, but with a lift with a capacity of only 10 tonnes.

The 5 m shafts will be sunk with the aid either of small explosive charges or pneumatic drilling. The 9 m shafts will be bored by an Alpine machine working together with a loading machine at the bottom of the shaft. The depth of the shafts will vary depending on the land contours (22.5 m for PP5 and 61 m for PA3). Work on sinking shafts PP1 and PGC began in February. A few weeks later, shaft PA2 was started and excavation of the 'cut-and-fill' parts of the North ejection tunnel commenced.

The shafts will be sunk in numerical order, and boring of the injection tunnel will start around the middle of this year. A start will not be made on excavating the West ejection tunnel, however, until the beginning of 1973. Work on the final sextant of the ring tunnel should be completed in autumn 1974, at the same time as the tunnel to the West Hall.

The Mole, which will be lowered through shaft PP1 in September, will resurface through the same hole in spring 1974, after a journey of about 7 km. The whole of the underground work is scheduled for completion at the end of 1974.

Denmark joins

The Danish Minister of Education has informed the President of the CERN Council that Denmark wishes to participate in the 300 GeV programme. This brings to eleven the number of Member States contributing to the eight year construction programme of the new accelerator. The States are Austria, Belgium, Denmark, Federal Republic of Germany, France, Italy, Netherlands, Norway, Sweden, Switzerland and UK.

ISR: peak currents, peak energies and a leak

By mid-April the peak current in Ring I of the ISR had been taken to 11 A and in Ring II to 9 A. The beams are sufficiently stable for experiments up to levels which are getting proportionally closer to the peak figures than they used to be (about 9 A now in Ring I, for example) and physics runs have been carried out with currents of about 5.5 A in each ring.

Climbing to higher currents still seems to be impeded only by beam-induced out-gassing causing a deterioration of the vacuum conditions in the rings. It is interesting to think that, had it been known about seven years ago just how dependent stored currents would be on vacuum, the project might never have got off the ground for the vacuum figures that were then put forward (10^{-9} torr in the rings and as low as 10^{-11} torr in the intersection regions) were regarded as being at the very limit of what technology could cope with in such a large vacuum system. In fact those figures have been comfortably exceeded. Now, around the rings in general, we are at 10^{-10} levels and a few times 10^{-13} levels are possible in an intersection region using cryopumps.

It is still possible to tidy things up a little more; sublimation pumps are being installed and they should be in

A view of BESSY, the scanning table designed specifically for use on film from the 3.7 m European hydrogen bubble chamber, BEBC. A prototype has been delivered to CERN and many units will go to European research centres in the coming months.

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place all around both rings by the end of the year. Also, as mentioned some months ago, laboratory tests on outgassing properties of surfaces are under way and methods are being studied of pulling the liberated ions in the vacuum vessel to places where they will not cause serious outgassing.

In March there were some brief experiments during a machine development period to test the ISR magnet performance at higher energies. A 50 mA beam, coming into Ring II from the PS, was nudged slowly up to higher energies by the ISR r.f. system, keeping the magnet fields in step. This resulted in a beam accelerated to the highest energy yet achieved at CERN — 31.4 GeV. However the purpose of the exercise was not to set records or to make higher energy beams available for experiments in the immediate future. It was simply to take a first look at the magnet properties at field levels equivalent to higher energies. Closed orbits and Q values were measured at 31.4 GeV. When the ISR becomes serious about higher energies, the acceleration will be done by phase displacement. This will involve computer control and the necessary computer programs are not yet developed.

A comforting sign of fallibility at the ISR came in March when one of the sections in the rings was misaligned and the beam left its preordained path and collided with the walls of connecting bellows in intersection region I-6. The edge of the beam burned a series of holes a few millimetres in diameter on the top of the convolutions.

The vacuum pressure monitors reacted to the sharp rise in pressure and the beam was immediately dumped. Within 20 ms, fast acting valves slammed shut, followed by isolating sector valves so that the damaged part of the ring was sealed off extremely rapidly. The pressure in the rest of the vacuum system never rose above 10^{-10} torr.

In the following 36 hours, the physics experiments around I-6 were dismantled sufficiently to give access to the damaged bellows which were replaced and checked. Pump down and bake out (for 24 hours) followed and, when a pressure of 10^{-11} torr had been reached again, the experiments were reinstalled. Within four days of the accident, the ISR were back in full action.

BESSY

Scanning and measuring devices are becoming more numerous and various as the time approaches when Gargamelle, Mirabelle and BEBC will all be feeding film to European laboratories. Recently a new machine, known as BESSY (BEBC European Scanning SYstem) has appeared on the scene.

Although rather classical in design, there has been a search for economy by optimising the specifications to the needs of BEBC only. The orders from numerous European laboratories indicate that this approach was what was needed.

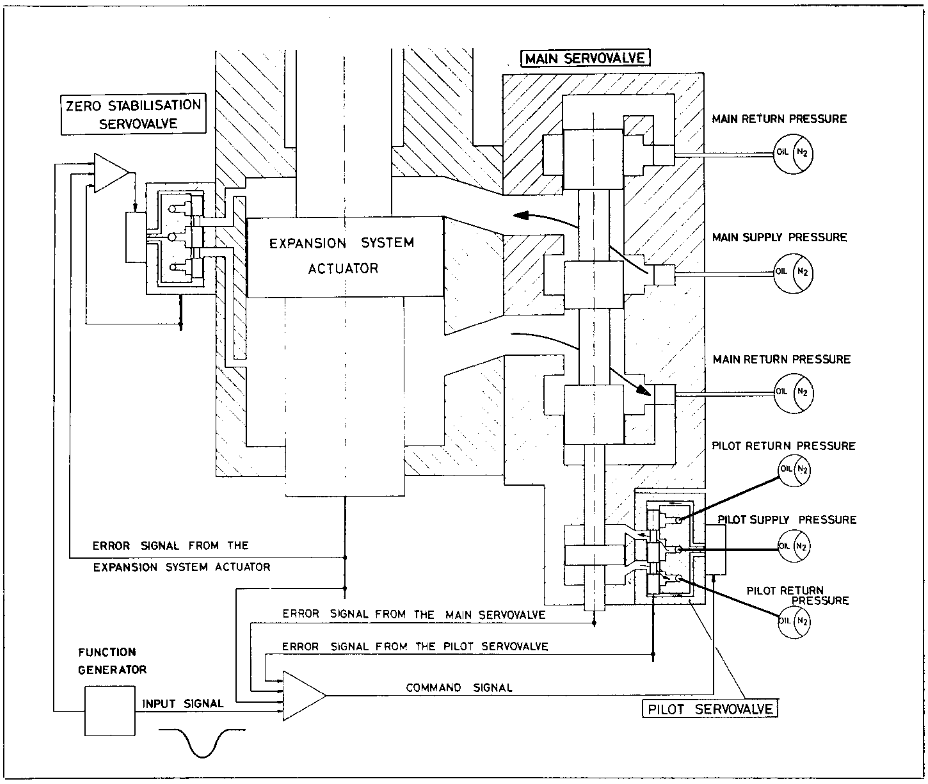
In 1969, when the question of the processing of the BEBC films was tackled, it became clear that existing devices such as the HPD, PEPR, and LSD (spiral reader) would be retained for a long time to come. But for these devices to operate at their optimum rate, the regions containing interesting events have to be roughly identified in advance. For this reason, scanning and preliminary measuring devices not involving high precision are needed.

In May 1970 a small team was set up to establish the specifications to meet the above requirements, and soon after, 25 European firms were contacted. It was made clear to the manufacturers that they would have the benefit of new ideas from CERN to help reduce the price. SFAT (France) sent in a tender matching the specifications for the lowest price of all the firms contacted.

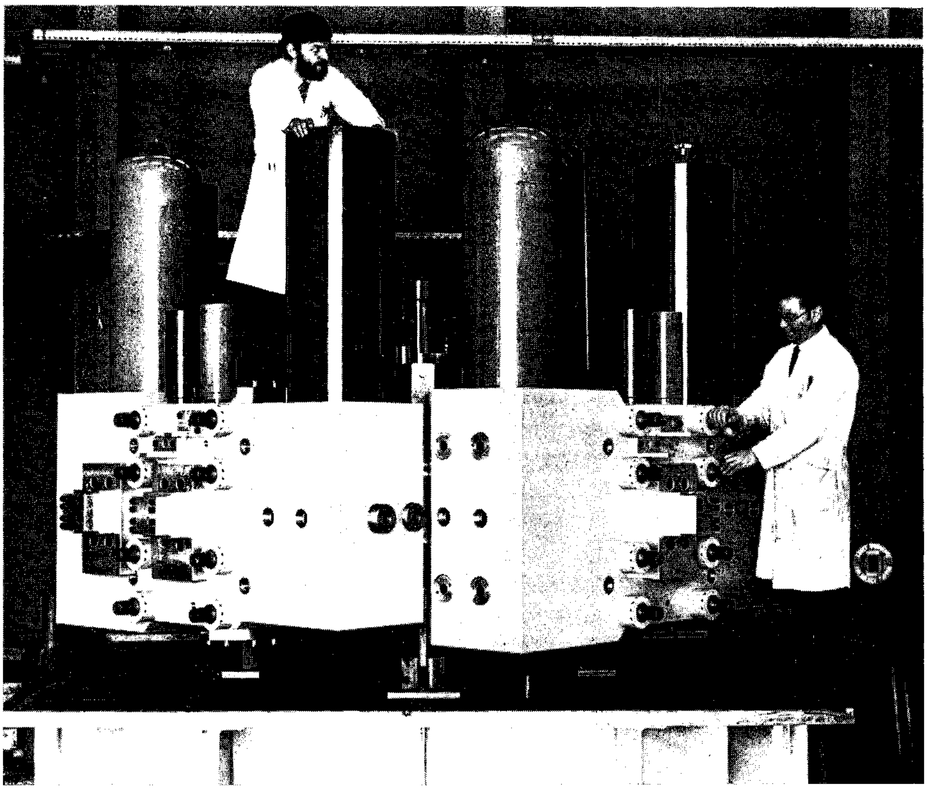
The result is BESSY, the prototype of which was delivered to CERN in December 1971. It is a scanning and preliminary measuring table intended for BEBC film. For an order of 43 units its price has been brought down to 41 500 SF, less than half the price of a table produced using conventional methods throughout. Close collaboration and a grouping of the buyers helped to achieve this price.

BESSY has a mirror fixed to the machine, a projection table 1.3 × 1.6 m^2 and four projection lenses on a single plate giving a total magnification of 17x. The preliminary measuring can be carried out in the image plane with a precision of $\pm$ 170 μm (equivalent to $\pm$ 10 μm in the film plane).

Diagram of BEBC expansion system indicating the relation of the units referred to in the article.



The expansion system units photographed in April. The cylinders are the high pressure (small diameter cylinders) and low pressure (large diameter cylinders) accumulators. It will be positioned below the bubble chamber.



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The tricks which helped bring the price down concern the film driving motors, lenses, film pressure plates, mirrors, projector and condenser. The driving motors are very sturdy car windscreen wiper motors ; the speed, though sufficient for view by view movement and 1/5 view steps, does not allow fast winding. There are twelve of them at a price of about 50 SF each — a considerable saving compared with low-inertia printed circuit motors. Special lenses were made by Jos. Schneider, Germany, for this purpose at a price of 1000 SF per unit. The distortions caused by the film pressure plates are corrected by these lenses. A precision mirror is used which has only been polished once. The quality is adequate and the price is less than a fifth of a high precision polished mirror. The lamps with incorporated mirror are commercially available units from movie projectors. The condenser is made from a plastic Fresnel lens costing a few tens of Swiss francs.

The long list.of deliveries will be spaced over the period from December 1971 to the end of March 1973. Tables will go to CERN (2), Rutherford (2), Birmingham (2), Imperial College London (2), Cambridge (2), Liverpool (2), Glasgow (2), Durham (1), Westfield College London (1), Hamburg (3), Heidelberg (3), Munich (1), Aachen (6), Bonn (1), IPN Paris (2), Ecole Polytechnique (1), Nijmegen (2), Amsterdam (1), Stockholm (1), Turin (2) and Lisbon (4).

BEBC expansion system

The impressive size of the 3.7 m hydrogen bubble chamber, BEBC, is complemented by the equally impressive power of its expansion system — the peak hydraulic power climbs to 100 MW.

Several factors governed the design of the expansion system. Firstly, the expansion-recompression cycle must be highly reproducible since any variation results in a change in the density and size of the bubbles. Secondly, the use of Scotchlite and wide-angle lenses means that the bubbles must be large (500 μm in diameter) while, at the same time, spurious boiling must be kept to a minimum. To cover these requirements, a flexible system has been adopted, which allows the form of the expansion-recompression cycle to be optimized. Finally, the system must allow liquids other than hydrogen to be used in the chamber. It must be capable of bringing about the desired expansion-recompression cycle independent of the thermodynamic conditions in the chamber.

A resonant system would not satisfy this requirement because the form of its pulse cycle is closely linked to conditions in the chamber. However, a forced closed-loop servo-system does

Below: The BEBC piston which arrived at CERN in March.

From 10-14 April, CERN was host to the First European Conference on Computational Physics, which had as its theme 'The Impact of Computers on Physics'. The Conference attracted some 270 physicists and computer specialists in addition to participants from among the CERN staff. It was sponsored by the Computational Physics Group of the European Physical Society. The photograph shows H.B.G. Casimir, the new President of the EPS, in the course of giving the concluding talk at the Conference.

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allow this type of independence between the expansion system and the chamber and the desired reproducibility and cycle shape, although such control is obtained at the cost of higher power consumption.

The chosen system is therefore of the closed-loop servo-controlled electro-hydraulic type. The control force is obtained by means of a double-acting actuator driven by four 4-stage servo-valves. The servo-loop is obtained by comparison between the position of the control actuator and the input signal provided by a function generator which sets the shape of the desired cycle.

Main servo-valves: The problem with such a system concerns the servo-valve power spool. In spite of the fact that four servo-valves are used in parallel, each spool is impressively large — 140 mm in diameter, maximum output 500 l/s per 100 kg/cm^2 pressure drop. The spools are the largest of their type ever made and were built in the CERN Main Workshop with advice from MOOG.

Actuator: A symmetrical double-acting actuator, 470 mm in diameter, is used. The piston-rod assembly is made of titanium.

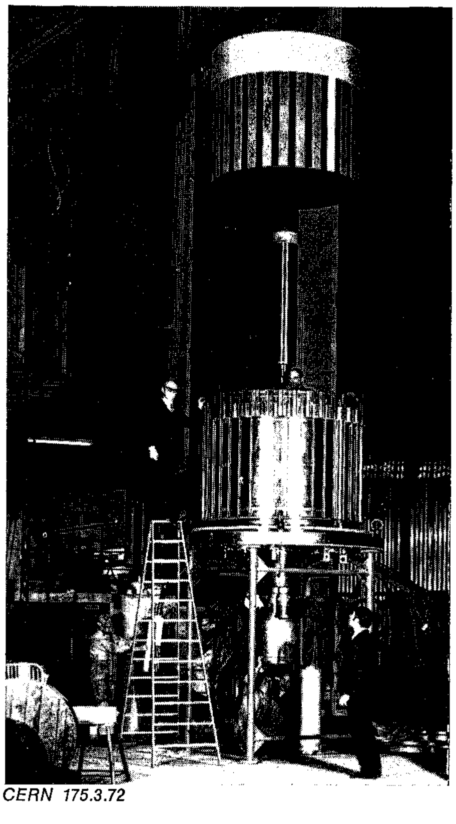
Hydraulic power: The high peak hydraulic power requires that energy be stored in eight hydro-pneumatic accumulators, each with 100 l capacity at a pressure of 210 kg/cm^2. Taking losses into account, the average power needed to trigger the actuator with a chamber expansion ratio ($\Delta V/V$) of 0.7% at two cycles per second is 1500 kW. The hydraulic set manufactured by HML comprises five motors, each driving two gear-type pumps with a unit output of 250 l/m.

Performance: The expansion system must be capable of two 40 ms cycles per second with 100 ms interval between cycles at an expansion rate of 1% (stroke 145 mm). With the chamber filled with hydrogen, the moving mass will then be 1700 kg. During the first dynamic tests in January and February this year the system, fitted with two servo-valves (out of a total of four), carried out 10 000 cycles satisfactorily.

Piston: The last of the large BEBC components, the chamber piston, manufactured by the VFW FOKKER aircraft works in Bremen, arrived at CERN on 3 March. It is a highly original structure in many respects. Since it is subject to enormous acceleration forces (a maximum of 230 g), the piston must be extremely light while at the same time very rigid. Since it operates in a magnetic field of 3.5 T it must also contain as little metal material as possible.

The structure adopted was developed during tests on the 1 m model chamber. It is laminated with glass fibre and epoxy resin sandwiching a phenolic resin honeycomb. The only metal components are in the piston rod, and consist essentially of titanium alloy parts insulated from one another to avoid eddy currents. Thus, a component was constructed weighing only 1170 kg with unusual structural rigidity for its diameter of 1.80 m and length of 4 m. Static tests were successfully carried out at CERN at the end of March. These consisted in applying a hydraulic pressure of 10 kg/cm^2, equivalent to a tractive force of 250 tons on the piston rod, to the lower surface of the piston.

The piston was fitted inside the chamber at the beginning of April and the first cool down of the chamber is scheduled for May.



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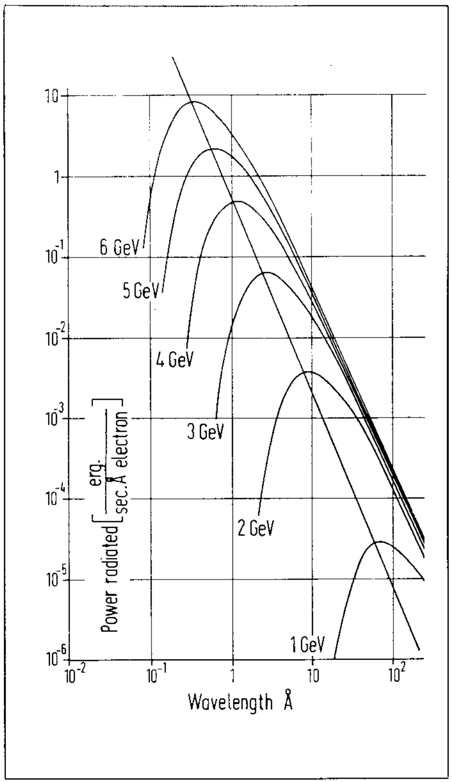
Synchrotron Radiation Facilities

Below: Variation in power radiated by an individual electron over a range of wavelengths as the energy of the accelerated beam in the synchrotron is changed. These particular curves are from the DESY machine.

Right: Diagram of the radiation facility at the DESY 7.5 GeV electron machine where some of the leading work in this field has been carried out. The indications are : EO - electron orbit, CH-chopper, M 1-3 - mirrors, B 1-2 - beam shutters, X-DIFF - X-ray diffractometer, UHV S - UHV sample chamber, S - sample, FM - focusing mirror, R 1-3 - Rowland spectographs, PG - DESY spectograph, X-MONO - X-ray monochrometer, S M-VAP - metal vapours, W 1-4 - Wadsworth monochromator.



Particularly in the past few years, interest in using the synchrotron radiation emanating from high energy, circular electron machines has grown considerably. In our February issue we included an article on the synchrotron radiation facility at Frascati. This month we are spreading the net wider — saying something about the properties of the radiation, listing the centres where synchrotron radiation facilities exist, adding a brief description of three of them and mentioning areas of physics in which the facilities are used.

Inevitably, an electron forced to follow a curved trajectory will emit radiation. For relativistic electrons, those travelling close to the speed of light, the total power radiated per revolution in a circular machine is proportional to the fourth power of the energy and inversely proportional to the radius of the machine (E^4/R). This is a major problem in attempting to push the peak energy of electron synchrotrons or storage rings higher because the machine's r.f. accelerating system has to put back all the radiated energy. However it is an ill wind that blows no-one any good ... the synchrotron radiation has features which makes it an excellent experimental tool for many applications.

Properties of the radiation

A particular property of synchrotron radiation from high energy machines, which gives an additional useful handle in the understanding of some experiments, is that it is emitted with a high degree of polarization (100% on the plane of the synchrotron orbit and high close to the plane). Also, due to the relativistic effect, all the radiation is strongly forward focused emerging in a very narrow cone tangent to the beam.

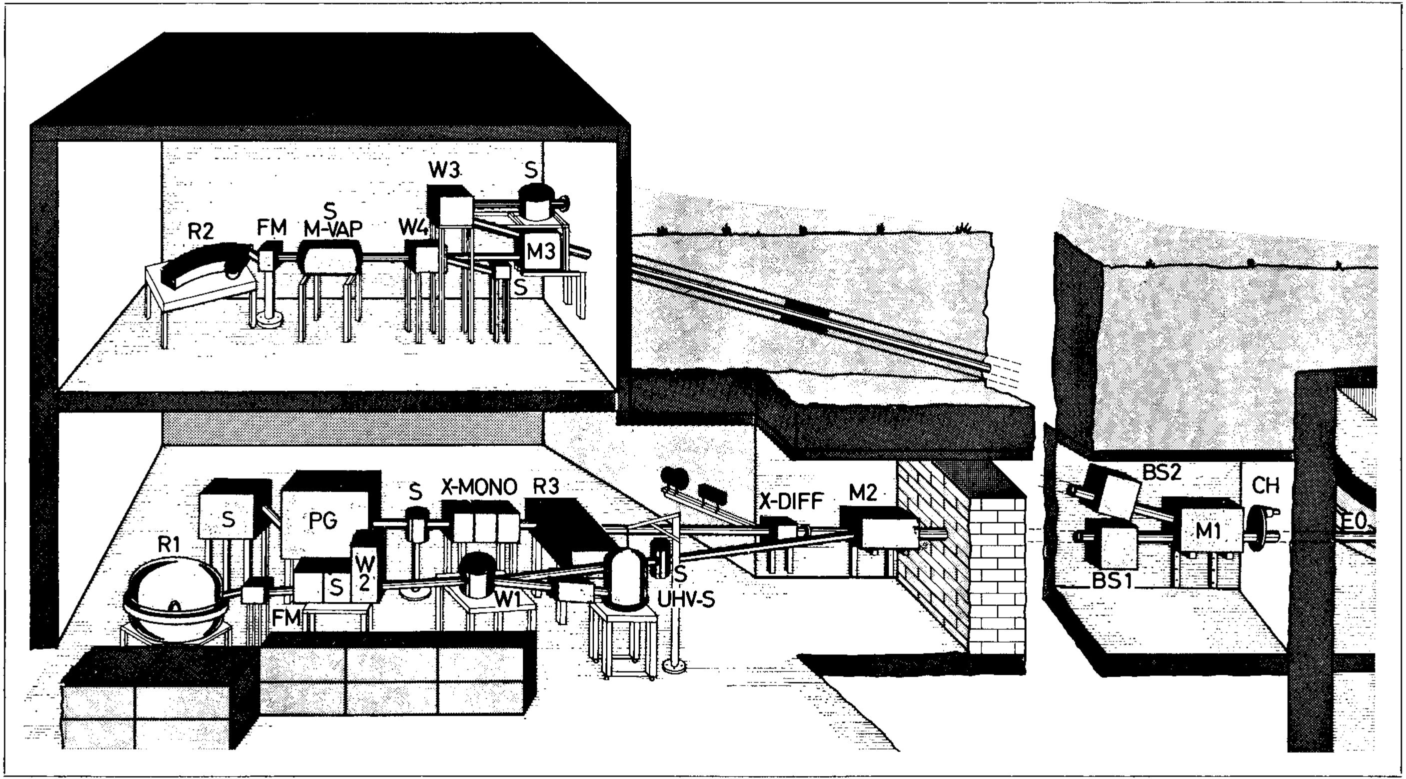
The radiation is a continuum covering a wide spectrum of energies (usable intensities extending from 10^{-1} to over 10^3 angströms are obtained at existing machines). The wavelength at which peak intensity occurs is reduced with increasing accelerator energy as is illustrated in the curves recorded at the DESY synchrotron shown in the figure. Note that the spectrum is like that of a 'blackbody' but peak radiated intensities correspond to blackbody temperatures of well over a million degrees. Only very high temperature plasmas or nuclear explosions provide comparable terrestrial radiation sources and the later is not a particularly practical experimental technique.

Synchrotron radiation is especially useful in the wavelength range from about 1 to 1000 angströms where it covers the gap between X-ray levels and short wavelength transmission limits.

The radiated intensities depend on such things as the accelerated electron beam intensity and, of course the electron beam energy. In the synchrotron therefore the emitted radiation pattern follows the accelerator cycle. Storage rings have the advantage of a constant energy and virtually constant intensity. Apart from being affected by such accelerator parameters, however, the physicist using synchrotron radiation can 'parasite' on a high energy particle physics programme without disturbing it or being disturbed by it.

List of Synchrotron Radiation Facilities

The following list of research centres where synchrotron radiation facilities are in action, or planned, will indicate how interest in this field has blossomed from virtually nothing about five years ago. At the electron synchrotrons: DESY, using the 7.5 GeV machine, has led the way being the first in time and the first in quantity and quality of experimental results (more information below). Daresbury, using the 5 GeV NINA, are currently bringing a new facility into action (more information below). Bonn with the 2.3 GeV machine have a small synchrotron radiation programme. Tokyo INS have one at their 1.3 GeV machine. The Frascati facility at the 1.1 GeV machine was reported in the February issue (page 42). There are also programmes at smaller machines such as the 330 MeV at Glasgow and the 180 MeV at the National Bureau of Standards, USA. At storage rings: The pioneering work has been done at the 240 MeV ring (known as Tantalus) of the Physical Sciences Laboratory, Wisconsin, which has run a programme of synchrotron radiation research for several years. There are also plans for facilities on storage rings at ACO (Orsay), the Lebedev Institute (Moscow) and a large one on DORIS (DESY).



The drawing shows the scope of the existing facility on the DESY synchrotron and the instruments currently in use. The facility is divided into two floors (the upper floor coming into full operation in 1971), the beams being split by mirrors, and there is a further division on the lower level so that several experiments can run simultaneously. The facility has been used almost from the time that the synchrotron came into action and a high proportion of the papers resulting from research at the machine have involved the use of synchrotron radiation. In 1971 there were 25 scientists (from DESY, Hamburg, Munich and Freiburg) working full time at the facility as well as part-time visitors from Heidelberg, Helsinki and Sendai.

A second synchrotron radiation laboratory is being built at the DESY machine for the European Molecular Biology Organization, EMBO. The building itself is complete and installation of the beam pipe, detectors etc. has begun. In addition, a facility will be established at the electron-positron storage rings, DORIS, scheduled for operation at the end of 1973.

The facility at Daresbury is now being commissioned. It is divided into three sections — two areas (operationally independent) each fed by a beam-line and a control area where a Honeywell 316 computer is stationed with a fast data link to the Laboratory central computer (IBM 360/65). There are also three independent branch highways in CAMAC whereby the H 316 provides interactive links between the data collected and the apparatus.

Instruments include a horizontally dispersing Wadsworth monochrometer (covering the range 500 to 3500 angströms with a resolution of a few angströms), a grazing incidence monochrometer (40 to 350 angströms with a resolution better than 1 angström) and a vertically dispersing monochrometer which should be able to exploit the polarization property of the radiation (400 to 5000 angströms with a resolution better than 0.5 angström). The experimental programme will involve scientists from Cambridge, Daresbury, Manchester, Medical Research Centre, National Physical Lab., Oxford and Reading.

The facility at the PSL Wisconsin storage ring is, at present, the most extensive in terms of the number of beams (six outlet ports) and experimental groups (fourteen in 1971) that can be supported. The total number of groups using or intending to use the facility is now 25. PSL was also the venue for a 'Synchrotron Radiation Users Group Conference' in November 1971.

This year the National Science Foundation is funding the construction of two additional beam-lines and the University of Wisconsin has approved the building of additional experimental area (to provide four times the previous area) so that the new beam-lines can be exploited and the existing beam-lines extended. The shutdown for the modifications is planned for early Autumn. It is hoped that a microtron will then be installed as injector (microtrons can give lower emittance and energy spread than the FFAG machine used at present).

Operation of the storage ring as a radiation facility has proved very efficient; only 2% of scheduled research time was lost due to equipment failures in 1971. Three computers (PDP 8e, PDP 12 and IBM 1401) are in use for data acquisition and some control functions. Experimental equipment includes a Pruett-Lien normal incidence monochrometer which was commissioned in 1971 and several other monochrometers. A wavelength shifter will be installed during the shutdown.

An improved version of the storage rings is under study (Tantalus II) to make research at shorter wavelengths possible. The peak energy of the new ring would be 1 GeV; it would be fed by a 35 MeV microtron. Such a ring would radiate a continuum from infrared to the X-ray region with a peak around 10 angströms and with radiated intensities generally several orders of magnitude higher than from Tantalus I.

Around the Laboratories

Experimental Programmes

The experimental programmes at synchrotron radiation facilities have extended into a number of fields not normally associated with the research at accelerator Laboratories. An example is the interest of EMBO for molecular biology research (structures of biological systems) which led them to invest in the facility at DESY mentioned above. Work of this nature is already under way at DESY and will start at Daresbury also. Another use is by research workers concerned with establishing standards who study synchrotron radiation, which has a predictable, calculable spectrum, to establish, for example, spectral emission standards in the ultraviolet.

The physics of the earth's atmosphere and of stellar atmosphere gains from studies of the interaction of high energy photons with atoms and molecules so that processes of photo-ionization and auto-ionization are better understood. In astrophysics similar work is important and the synchrotron radiation phenomenon itself has been at the root of the most successful attempts to explain the observations of the pulsars which give out regular bursts of radiation just like what is experienced from a bunch of electrons orbiting a machine.

There is a lot of research going on and still to be done in solid state physics, the study of crystals and thin films. Surface phenomena band structures, fundamental optical properties (photo-emission, reflectance) all come under this heading. With growing familiarity in the use of this comparatively new type of research tool, many more types of experiment can be expected to emerge. It may well be that some of the most important contributions of the electron machines to our understanding of the world around us will come from their use as a gigantic light bulb.

STANFORD (HEPL) Superconducting section tested

Construction of the superconducting electron linear accelerator at the High Energy Physics Laboratory of Stanford University has met its fair share of technical difficulties connected, in particular, with achieving anticipated performance from full-scale niobium structures. Encouraging progress was made in March when the first full-length section of the accelerator was operated.

This 55-cell structure, one of the twenty-four identical structures in the planned 140 m long superconducting machine, was operated c.w. at an energy gradient of 3.8 MeV per metre. The test of the full-length section, together with previous tests of the 7-cell capture section and the 23-cell pre-accelerator section, has demonstrated that an intense continuous electron beam can be produced in a superconducting accelerator with exceptional energy resolution.

Last summer in tests of the superconducting capture section and pre-accelerator section, a 50 μA beam at 30 per cent duty cycle was accelerated to 6.6 MeV. Careful measurements of the output beam showed that the accelerating fields in the two superconducting structures were stable to better than one part in 10^4 in amplitude and to better than 0.1 degree in phase. The energy spread of the emerging electron beam was measured to be less than 7 keV. Because the energy spread is expected to increase less rapidly than the electron beam energy as acceleration takes place through the remainder of the accelerator, these tests indicate that the design objective of one part in 10^4 energy resolution and stability in the superconducting accelerator can be achieved.

During tests of the 55-cell structure in March an electron beam was accelerated to 17.2 MeV. All of these tests involved the use of the 1.8 K superfluid helium refrigerator which has been operational for over a year at HEPL. The accelerator tests provided an excellent opportunity to explore the phenomenon of beam breakup in the superconducting accelerator, and minor design modifications are now being incorporated to lower the Q of the beam break-up modes in the structure.

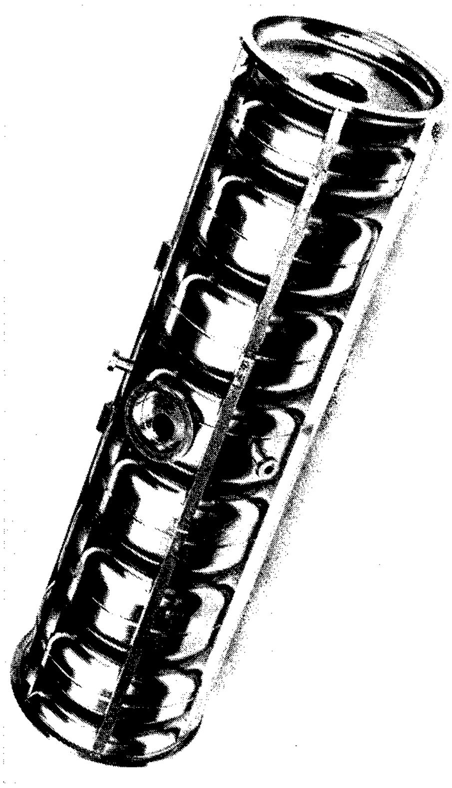
The most critical problem remaining in the development of the superconducting accelerator is that of achieving the high energy gradients hoped for in the superconducting structures. Recent experiments with S-band test cavities which operated at gradients in excess of 14 MeV per metre, however, give hope that the solution to the energy gradient problem in large structures is near.

The aim is to achieve high gradients in large L-band (1300 MHz) structures. Although in early X-band test cavities gradients exceeding 26 MeV per metre were reached, in long L-band structures the highest gradient achieved so far is 3.8 MeV per metre. This compares to the gradient of 14 MeV per metre hoped for in the superconducting accelerator. Both magnetic breakdown (when a part of the superconducting surface reverts to the normal state) and electron loading (caused by field emission) have been found to limit gradients in L-band structures.

The gradient of 3.8 MeV per metre is higher than the design gradients in other new high duty cycle machines but is still way below the figures which make superconducting accelerators, potentially, such an interesting proposition. To attack the gradient problems the HEPL group is collaborating with the Centre for Materials Research at Stanford in a programme

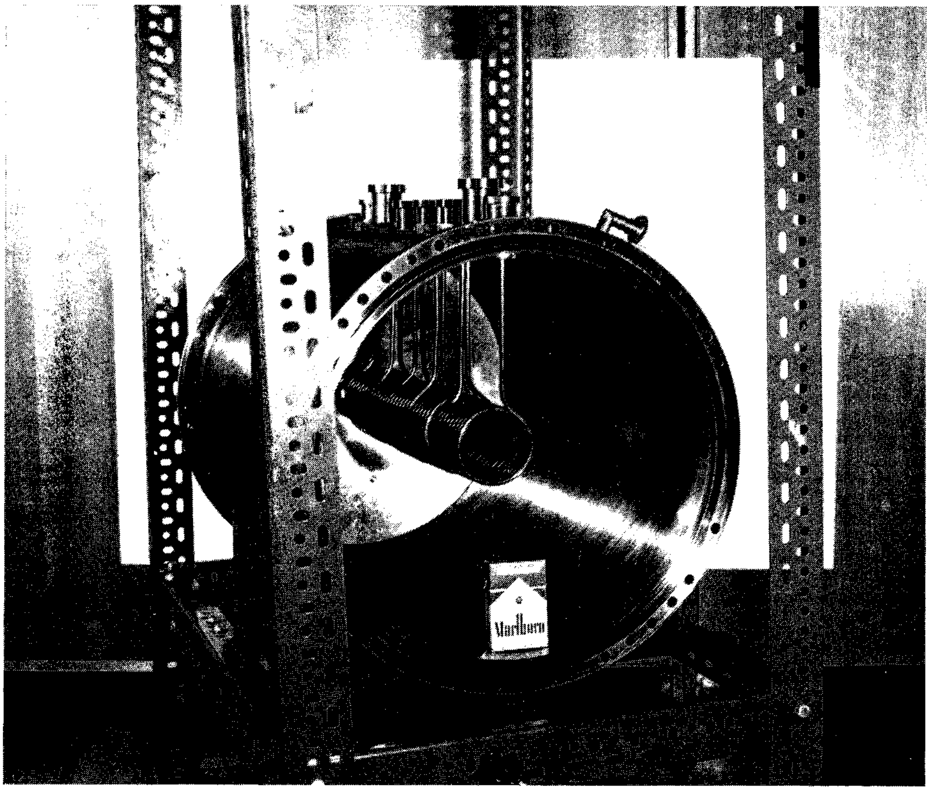
One of the seven sub-structures which comprise the 55-cell superconducting accelerator section tested at the High Energy Physics Laboratory of Stanford University in March. This is the first full-length section (after the pre-accelerator) of the electron linear accelerator being built at HEPL, to operate. The sub-structure is constructed from pure niobium and is operated at a temperature of 1.8 K.

(Photo HEPL)



A view into the first superconducting accelerator section recently successfully operated at Karlsruhe. The tank is of lead-plated copper and has a chain of five niobium-tube helices which are cooled by superfluid helium flowing through their suspensions.

(Photo Karlsruhe)



to investigate, in detail, the techniques used in processing the superconducting niobium structures. These investigations are beginning to yield improved results. Recently, in S-band test cavities, gradients exceeding 14 MeV per metre were reached. With the new processing techniques an attempt will soon be made to produce comparable gradients in long structures.

In the course of the March tests an interesting experiment was accidentally initiated. Concern has often been expressed about the consequences of vacuum failure in a superconducting accelerator since contamination of the carefully nurtured niobium surfaces could be a problem. During the initial cool-down of the 55-cell section, a beam-line vacuum valve was accidentally opened admitting a large quantity of air. The structure was already at a temperature below the ice-point and water vapour condensed on the niobium surfaces. Following the accident, the system was warmed to room-temperature, pumped out, and again cooled down. A Q of 4.5×10^9 and a gradient of 3.8 MeV per metre were achieved in the contaminated structure indicating that a superconducting accelerator could tolerate a fair amount of abuse.

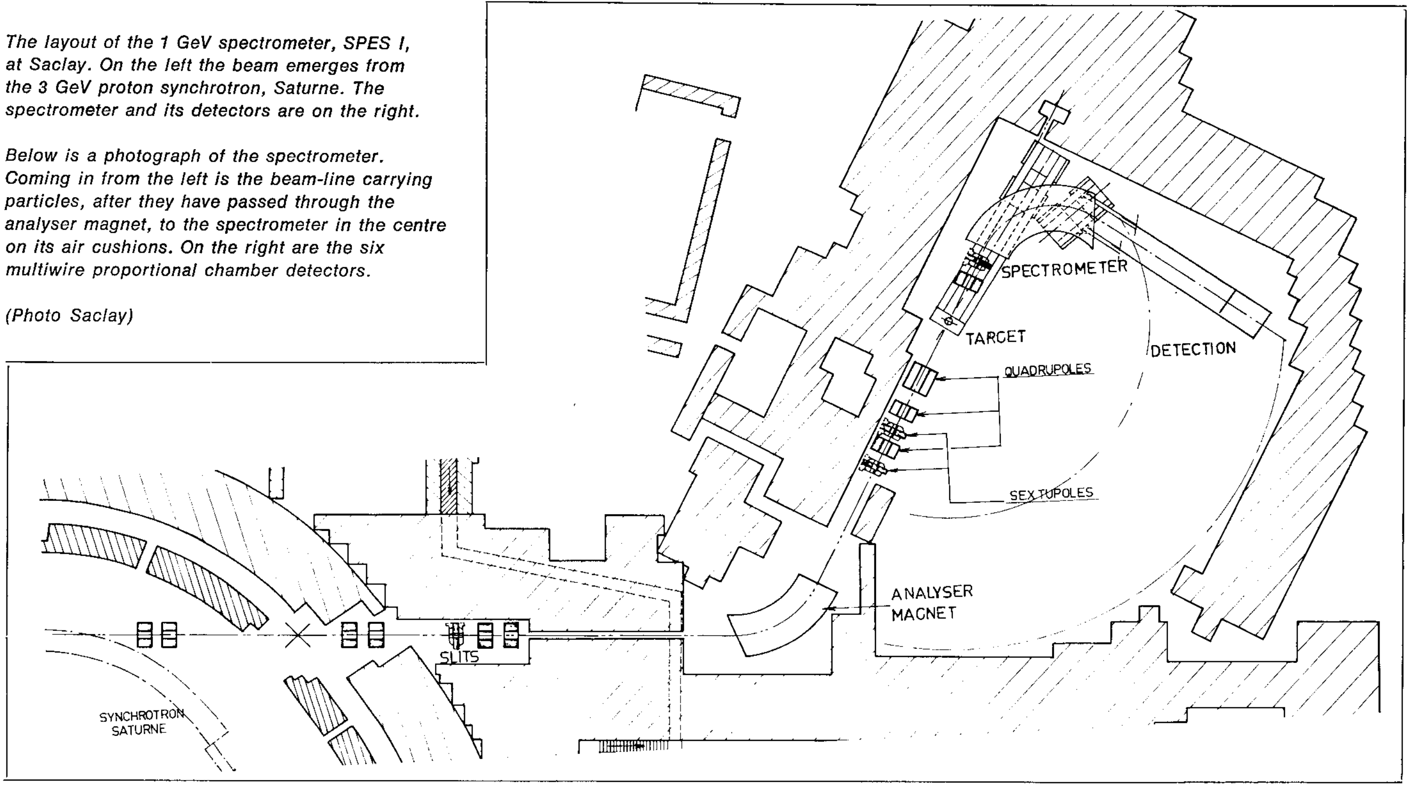
It is hoped that the remaining problems of the superconducting accelerator at HEPL can be resolved by this autumn.

KARLSRUHE Superconducting proton accelerator

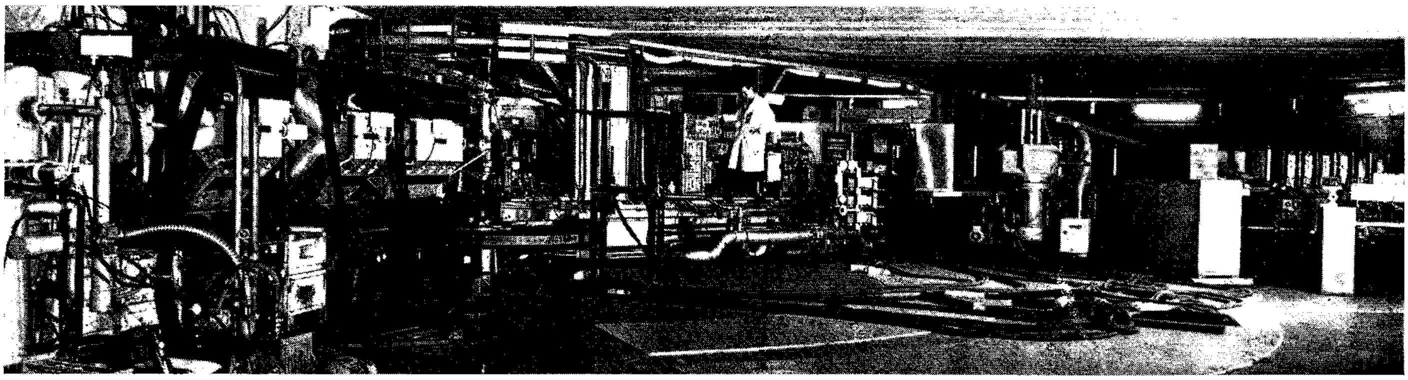
Following appropriately from the HEPL information is news from Karlsruhe that protons have been successfully accelerated in a superconducting linear accelerator. Protons were injected from a 750 keV Cockcroft-Walton set into a cryostat cooled to 1.8 K by a refrigerator with a maximum cooling power of 380 W. The 4 m long cryostat contained one accelerating section, one superconducting quadrupole doublet and a number of dummies taking the place of future accelerating structures and lenses.

The accelerating structure is a cylindrical cavity, 40 cm in diameter and 54 cm long, loaded with five helices in series. The helices are suspended from the cylinder wall by metallic stems and are electrically strongly coupled. The cylinder is made of lead-plated copper and the helices are wound out of 6 mm wide niobium tube through which the cooling helium can flow. The niobium was electropolished and anodized.

The cavity was excited in a π-mode. The dimensions of the helices (diameters between 7 and 9 cm, total length 39 cm) were fixed in collabo-



The layout of the 1 GeV spectrometer, SPES I, at Saclay. On the left the beam emerges from the 3 GeV proton synchrotron, Saturne. The spectrometer and its detectors are on the right.



Below is a photograph of the spectrometer. Coming in from the left is the beam-line carrying particles, after they have passed through the analyser magnet, to the spectrometer in the centre on its air cushions. On the right are the six multiwire proportional chamber detectors.

(Photo Saclay)

ration with the helix group at the University of Frankfurt. They correspond to an accelerating field strength of 1.15 MV/m. A maximum energy gain of about 450 keV was thus expected.

When power was fed into the cavity, two multipacting barriers had to be crossed before the design field could be reached and mechanical vibrations caused the resonant frequency of the cavity to jitter. However, a phase-lock system still permitted power to be fed to the cavity continuously. Instabilities due to electromagnetic forces acting on the helices could be overcome successfully by choosing the operating parameters of the external feedback loop appropriately.

The cavity quality factor at high field was about 3×10^7. The corresponding heat dissipation of about 4 W could be handled by superfluid helium cooling in c.w. operation. The energy gain of the protons, measured behind the cryostat by magnetic deflection, was 400 keV±10% at a field level slightly below the design value. This result is in agreement with calculations based on field profile measurements.

The next aims, to be reached during the current year, are the operation of a strongly overcoupled cavity, to make it possible to accelerate high currents, and the joint operation of two accelerating sections.

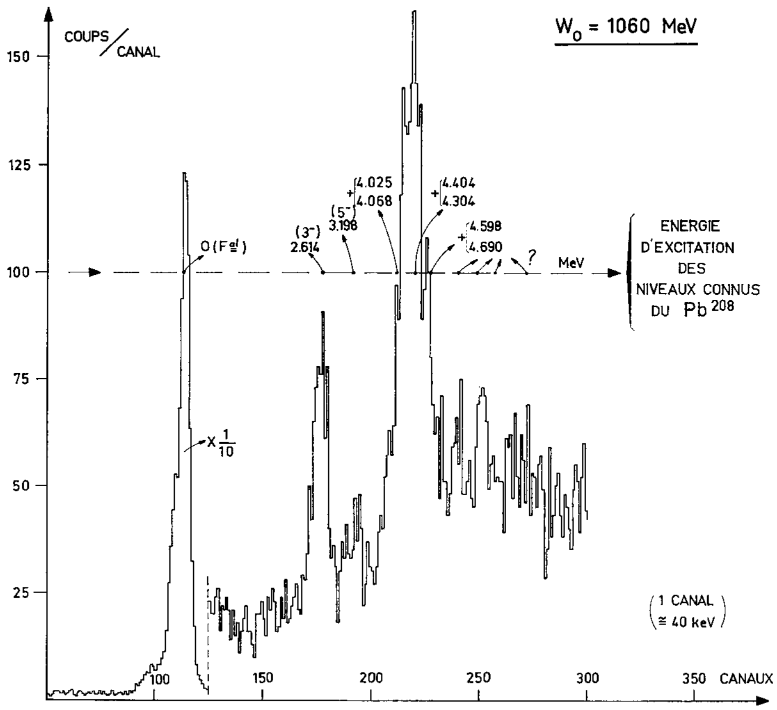
SACLAY/ SPES operational

The 1 GeV spectrometer known as SPES I came into operation at the 3 GeV proton synchrotron, Saturne, in February. Within three days of operation some very encouraging preliminary measurements were carried out, promising much for the future of nuclear physics at Saturne.

The spectrometer project was promoted by J. Thirion and J. Saudinos. It was launched at the end of 1968 and when magnetic measurements and trajectory calculations were carried out at the end of January this year they indicated that a resolution very close to the '100 keV at 1 GeV', which was considered essential for high-precision nuclear research, has been achieved.

The beam-line from the synchrotron is designed to allow the protons to be spread over the target by adapting the dispersion of the incident particles to the dispersion of the spectrometer. The ejected proton beam from the synchrotron was directed onto the target for the first time during the night of 9-10 February. The energy resolution on each pulse was lower than 1 MeV (but the energy varied from pulse to pulse within a range of 2 MeV).

Some data were then taken, with the intensity of the beam turned down,



The inelastic scattering spectrum obtained from lead (^{208}Pb) with 1060 MeV protons using the new spectrometer, SPES I, at Saclay. This spectrum was measured in the first runs and the system was by no means tuned to give its optimum performance.

looking at the scattering of protons at 10° on platinum, lead, aluminium, and a Mylar target. Without any dispersion adjustment, a spectrum was obtained on the Mylar with a resolution of better than 450 keV. Since the heavy bodies have fewer kinematic effects, it was possible by means of rough manual adjustment to obtain a resolution of 160 keV at half-height on lead. No fine adjustment was made, nor was there any compensation for aberration.

The multiwire proportional chamber detectors operated correctly. Four detectors in coincidence, measuring the position of the particles in the horizontal plane, made it possible to find the intersection of the trajectories with the focal plane of the spectrometer; precise angular measurement had to be used to compensate the aberration (the same applies to the two detectors monitoring the vertical plane).

The subsequent experimental run was aimed at raising the quality and intensity of the incident beam in order to optimize compensation for aberration and kinematic effects, and also to take preliminary measurements of the angular distribution of protons scattered elastically and inelastically on a few targets (ranging from carbon to lead) in the region of the rated energy of 1 GeV.

During the year, the experiments will be progressively expanded by using all the facilities offered by the system and the ejection line. They will include measurements as a function of the incident energy from 600 to 1400 MeV (the Saturne ejection system is designed to provide beam up to 1.4 GeV), the detection of pions produced in defined nuclear states, quasi-elastic diffusion on aggregates (deuteron, alpha,...) inside nuclei, etc.

Work has already begun on a second wide-aperture (2 × 10^{-2} steradian) spectrometer known as SPES II which, when coupled with the existing spectrometer, will allow a large number of three-body measurements to be made in the final state. This assembly is due at the end of 1973.

Already, however, the nuclear physicists at Saclay feel confident that, because of its energy resolution, intensity duty cycle and energy range, Saturne (which can be considered among the 'old' machines for particle physics) is a good, 'young' machine for nuclear physics.

ARGONNE
Polarized proton targets

Two recent advances in polarized proton target technology have been reported from Argonne. The first concerns the achievement of a polarization of 90% in a 13 cm^3 target of ethylene glycol, which is believed to be the highest 'hydrocarbon' target polarization attained anywhere up to now. The second concerns the perfection of a method for measuring background when using an ethylene glycol target ; the ability to make an accurate background subtraction bears directly on the precision that can be attained in certain high energy physics experiments using these targets.

Polarized proton target development at Argonne has concentrated in recent years on the use of ethylene glycol as the target material. Glycol targets have been used in several experiments at the Zero Gradient Synchrotron for polarization studies on Kp, πp, and np scattering. An alternative material, butanol, has received much attention elsewhere during this period, particularly at CERN where high polarizations have been achieved (see for example vol. 10 page 112). Although there are advantages and disadvantages with each material, glycol has been favoured at Argonne because of the higher polarizations that can be obtained and because of the relatively greater ease with which target samples can be prepared.

The very high polarization of 90% that was recently achieved was accomplished with a newly built He^3 cryostat, specifically designed to accommodate large volumes of target material for high energy particle scattering experiments. (The substantial increase in polarization that can be gained by going from He^4 to He^3 temperatures was reported by the Argonne group in 1969 and simultaneously at Saclay by A. Masaike and collaborators.) The target material was composed of frozen glycol beads, a method commonly applied at CERN, using a new method of preparation proposed by H. Glattli.

The importance of background substraction in polarization experiments with a single-arm detector is a consequence of the fact that all polarized

The last tank section of the side-coupled cavity part of the Los Alamos Meson Physics Facility, LAMPF, was manœuvred into position in March. This completes the installation of the 352 sections which will be used to accelerate protons to an energy of 800 MeV. LAMPF is scheduled to come into operation this summer.

(Photo Los Alamos)

proton targets have had to use target materials more complex than hydrogen. Although the scattering processes of interest are those that occur off the free protons (hydrogen atoms) in the target material, there is no way of separating these from the 'background' that is the result of scatterings involving the other kinds of atoms which are in the target material.

In order to be able to substract the background scattering from an ethylene glycol ($H_6C_2O_2$) target we have to find some way of estimating the scattering from a mixture of carbon and oxygen atoms in equal proportions. By successfully producing a target of liquid carbon monoxide, CO, which could be substituted for the regular glycol target without disturbing the cryostat configuration, the Argonne group was able to measure directly the background scattering during their recent experiment on polarization in pion-nucleon charge exchange. Though the idea of working with the very toxic carbon monoxide was rather startling at first, the sealed systems that are used in contemporary polarized proton targets provide perfectly adequate containment for the gas and the method was applied with success.

New physics journal

The first issue of a new-style physics journal has appeared. It is entitled 'Adventures in Experimental Physics' edited by B. Maglich and published by World Science Communications. The journal attempts to tell the stories of major discoveries or current experiments in a way which projects their interest, excitement, meaning... all the features which suggest that human minds are involved (a fact which is usually ruthlessly exorcised from scientific literature).

Some five years ago we pulled together an article for CERN COURIER (not published because the disease seemed too well entrenched for treatment) on a closely related theme and it is perhaps a good way to indicate what 'Adventures' is about, to quote a few of the comments we collected at that time :

F.P. Woodford, 'Sounder thinking through clearer writing', Science 12 May 1967 — 'He (the scientist) takes what should be lively, inspiring and beautiful and in an attempt to make it seem dignified, chokes it to death with stately abstract nouns ; next, in the name of scientific impartiality, he fits it with a complete set of passive constructions to drain away any remaining life blood or excitement; then he embalms the remains in molasses of polysyllable, wraps the corpse in an impenetrable veil of vogue words, and buries the stiff old mummy with much pomp and circumstance in the most distinguished journal that will take it... I am appalled by the frequent publication of papers that describe most minutely what experiments were done, and how, but with no hint of why or what they mean.'

John Maddox, 'Is the literature dead or alive ?' Nature 10 June 1967 — 'But why cannot there be some experiments in which reports of scientific work are written deliberately with the objective of bringing enlightenment, pleasure and occasionally excitement to as many readers as circumstances will permit ?'

The first issue of 'Adventures' responds to these criticisms. It includes the stories of the discoveries of the first optical pulsar, quantized circulation in superfluid, the 'blocking effect', muon-induced fusion, two kinds of neutrino and transition radiation, and the experiments in progress on retro-reflection from the moon and the cosmic ray pyramid chamber search. The stories include personal accounts of the researchers, explanatory notes for non-specialists, the original paper as published in the formal literature and subsequent developments since the discoveries.

Much of the issue is a real pleasure to read and anyone who believes that physics has the power to make the intellectual nerve-ends tingle just as much as any other aspect of man's culture, will be glad to take the journal into his hands. It should also prove an excellent method of putting physics before young people in a way which will attract them (a much needed virtue at the present time).

On the negative side much of the presentation (given the style of journal it sets out to be) is clumsy and heavy. Type-faces, page lay-outs etc. could be much more attractive. However, the content is more important than the wrappings and, because we believe the aim is so worthwhile, we wish the journal a very healthy future.

PRINCETON PPA close down

On 12 April the Princeton Pennsylvania Accelerator was turned off and placed in 'standby' condition. Despite valiant efforts to keep the Laboratory in being, particularly for heavy ion research where the machine had pioneered the production of and experimentation with multi-GeV beams, no finance for further operation was available. The final swing of the axe came on 23 March when the National Cancer Institute decided not to finance biomedical research at the accelerator.

In saying farewell to the PPA which began life in 1963 as a 3 GeV fast-cycling proton synchrotron (another bit of pioneering) we should like to pay tribute to the accelerator builders, operators and research workers who have been connected with the machine. Particular tribute should be paid to Milton White, Director of the Laboratory, who sustained the PPA in being over the past year by his inspiration and optimism and by his ceaseless work to secure long-term support. During recent months, important work has been carried out on the accelerator and the fact that this has been possible is largely due to his devoted efforts.

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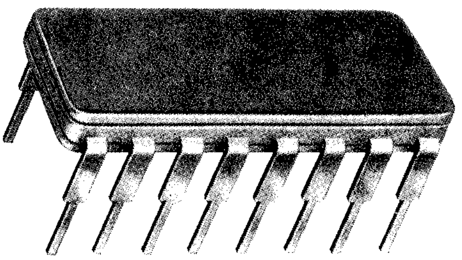

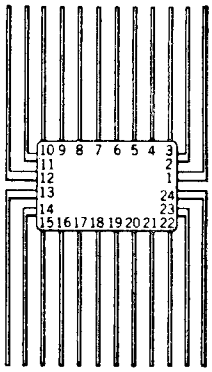

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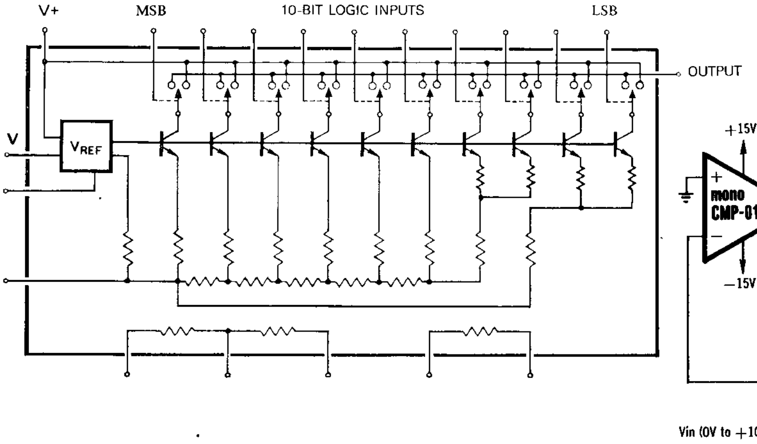
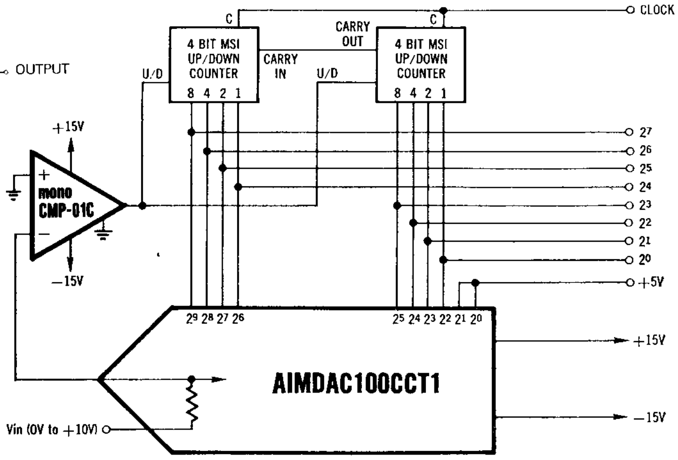
Simplified schematic



8 bit A/D Conversion approach



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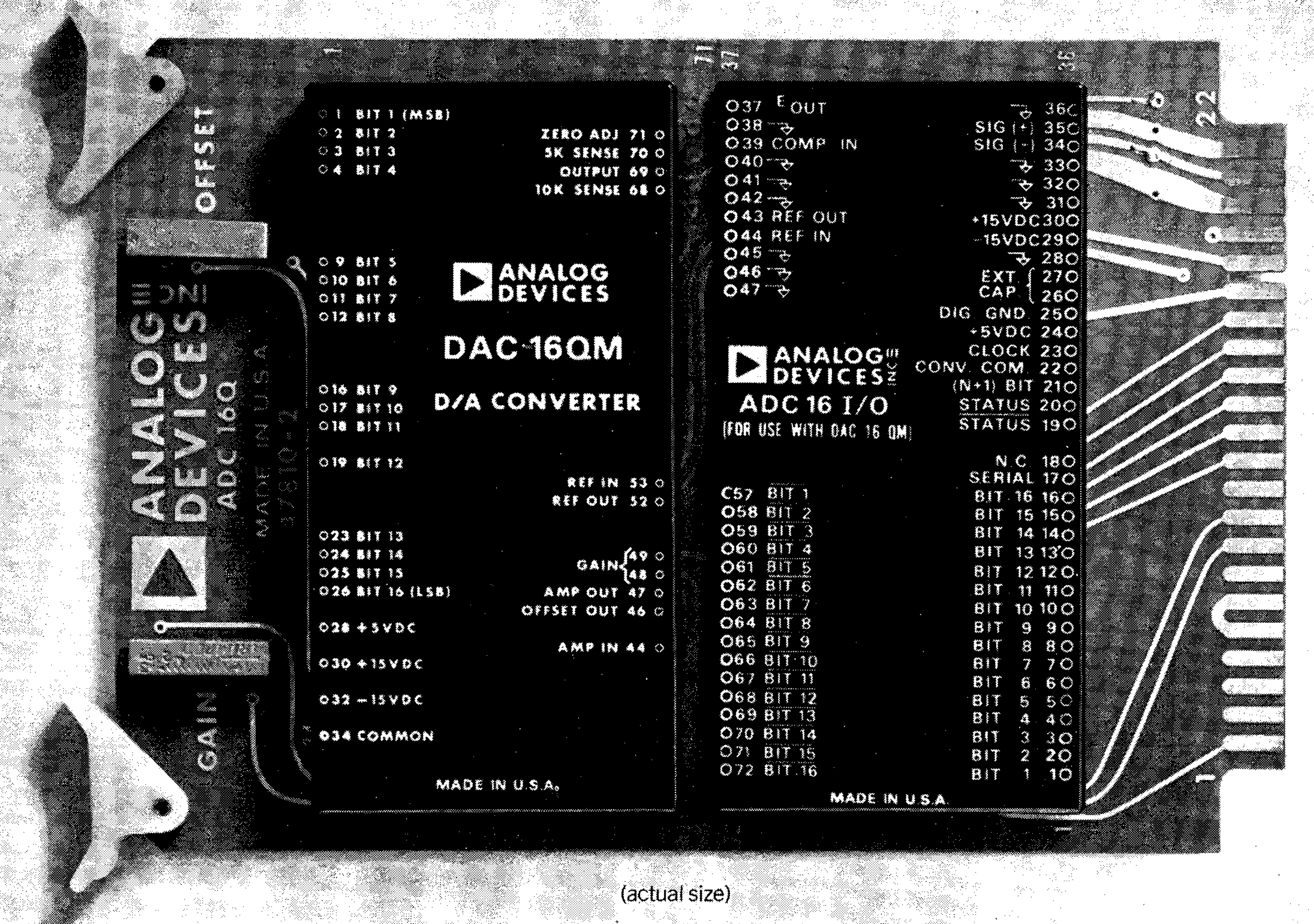

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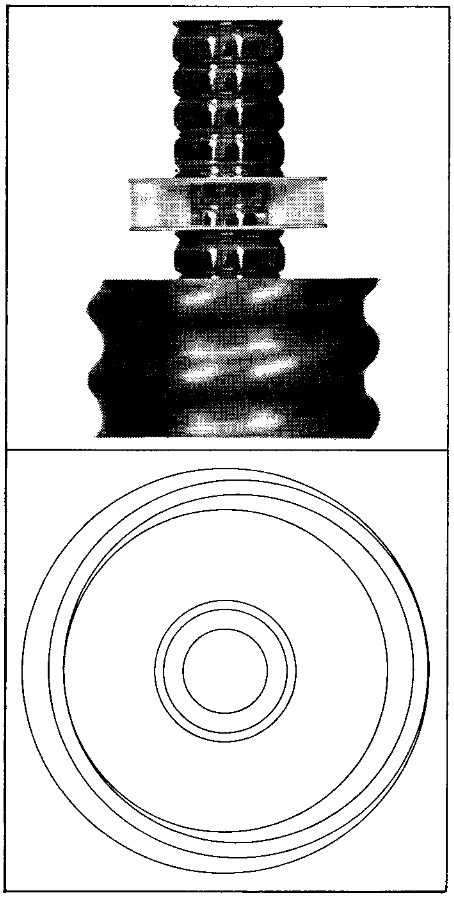

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Video cables are manufactured as coaxial cables with a characteristic impedance of 75 Ω (in exceptional cases 60 Ω with solid insulation and are used, for instance, to connect the camera amplifier to the monitor, intermediate amplifier, radio or television transmitter.
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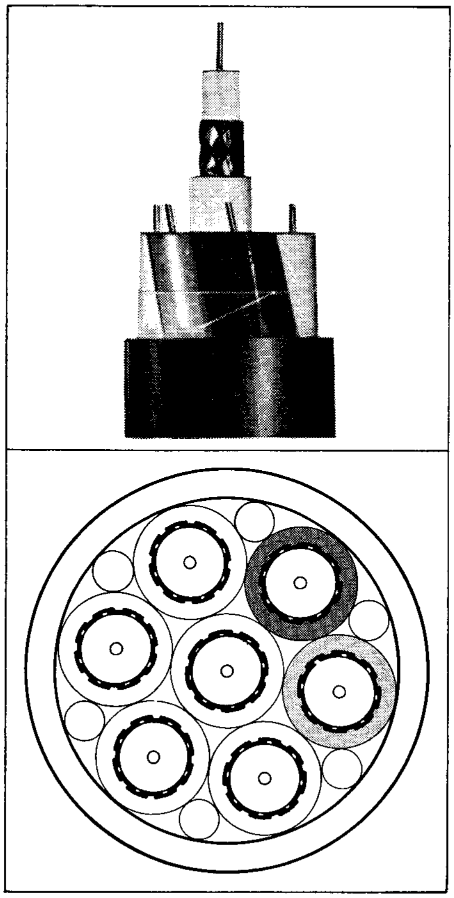

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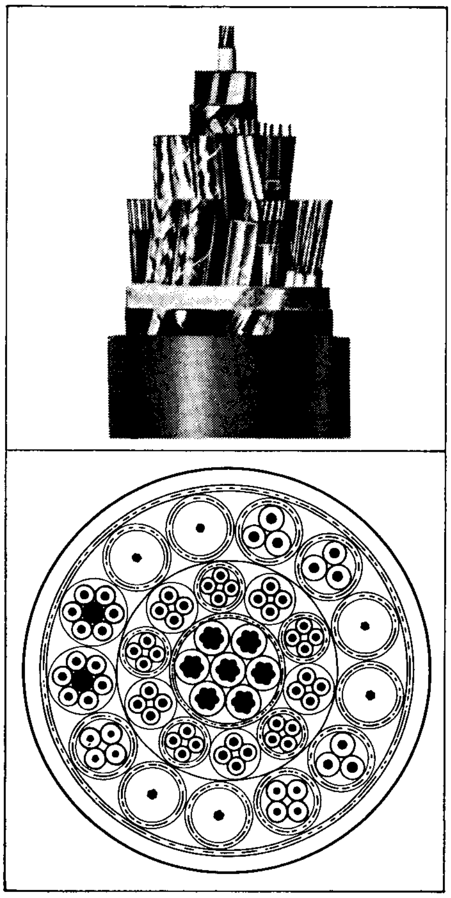

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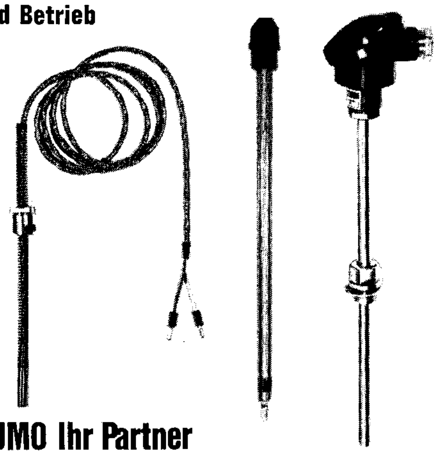

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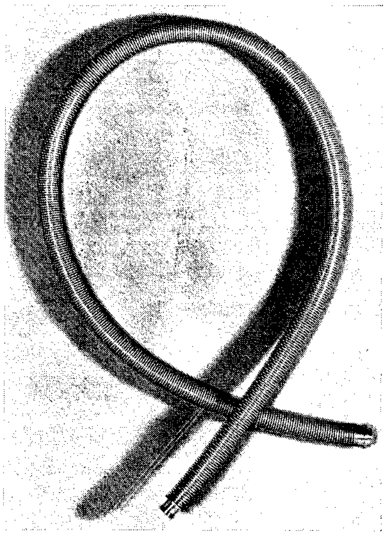

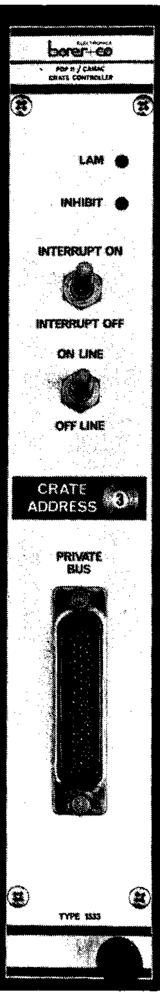
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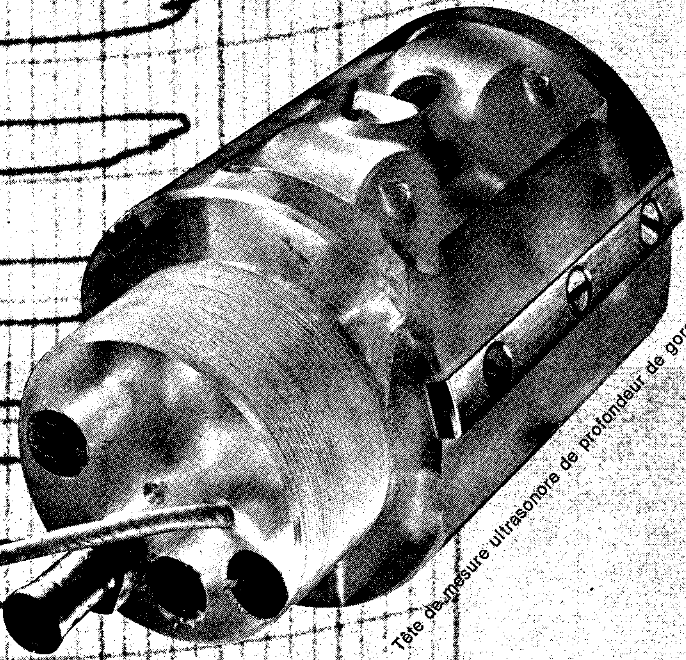

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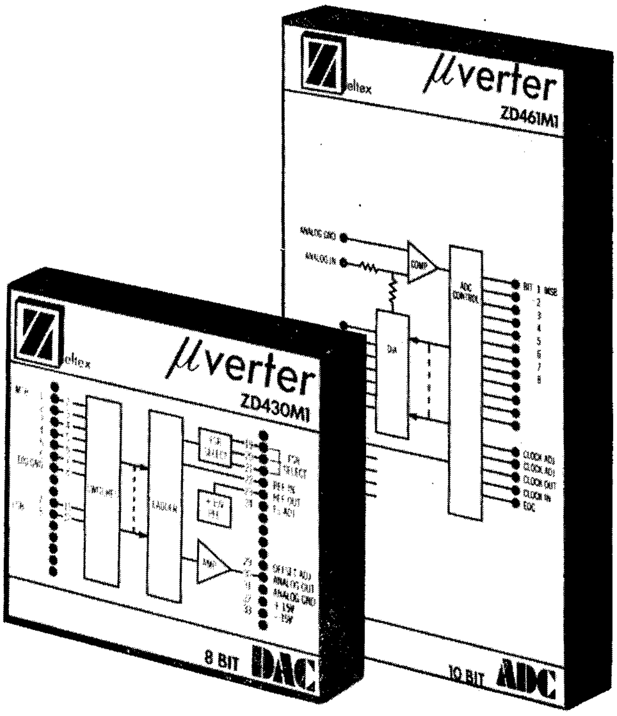

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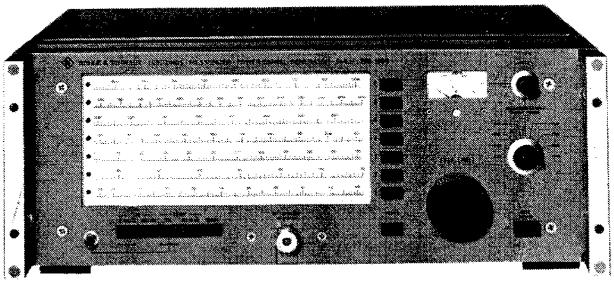

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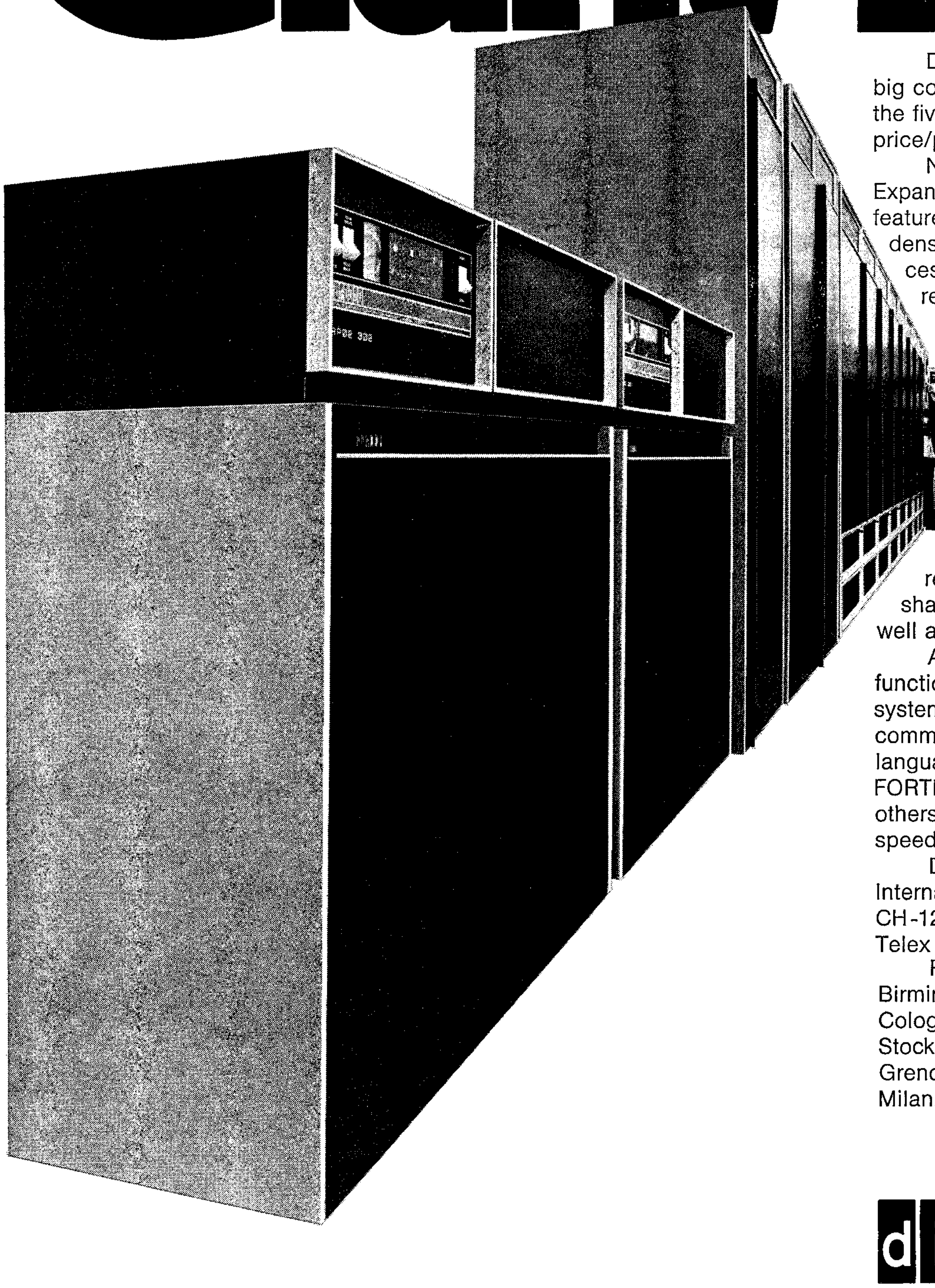

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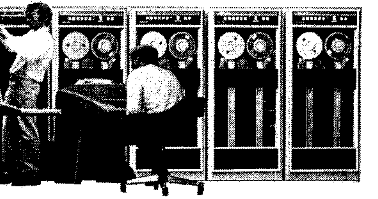

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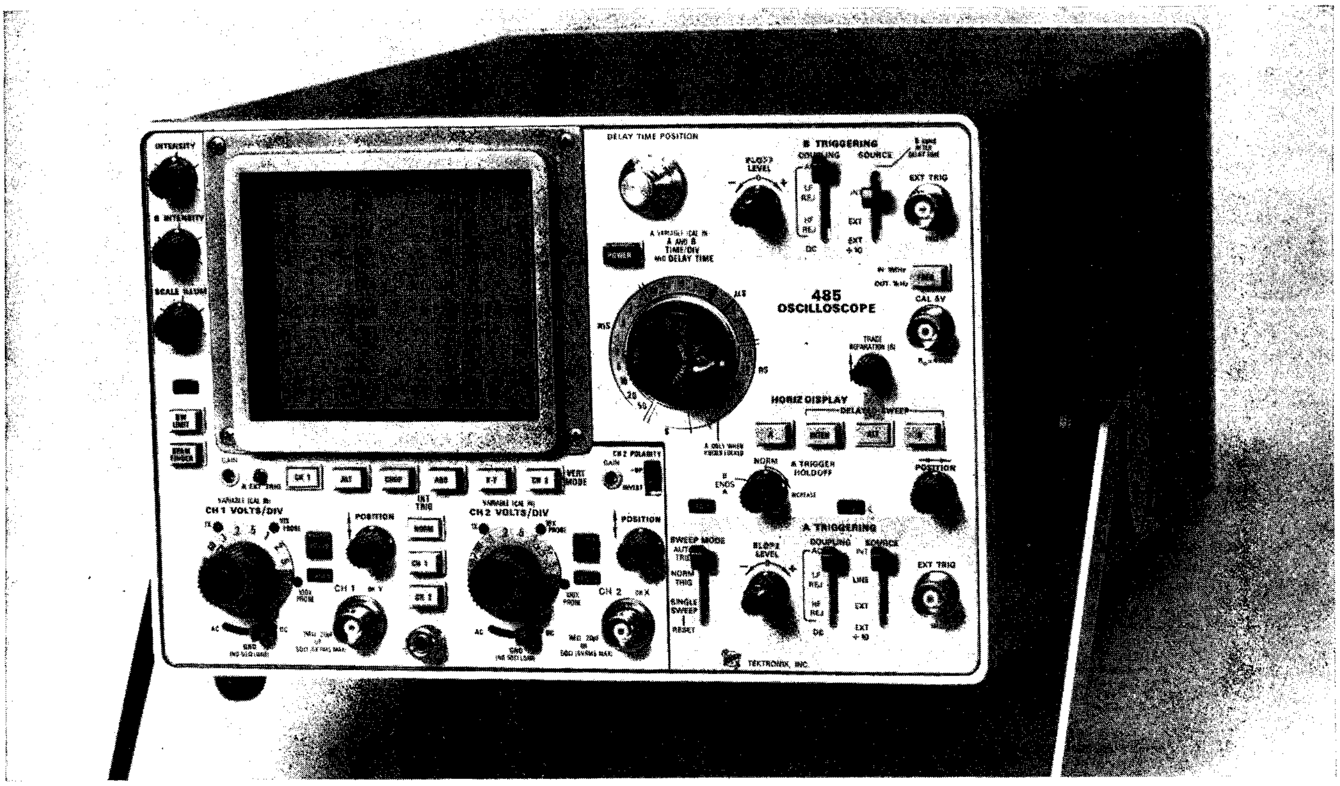
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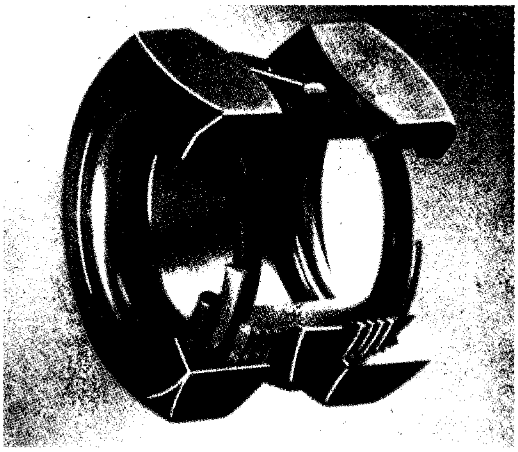

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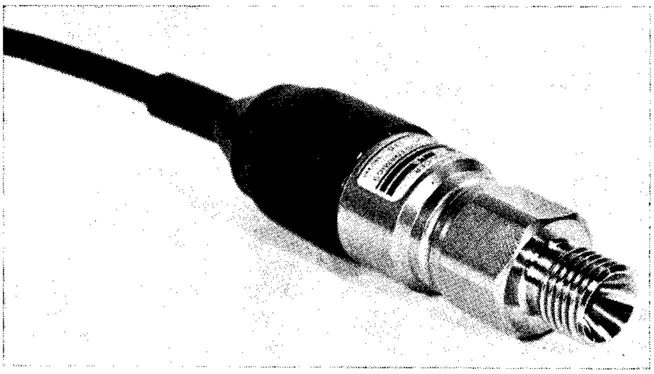

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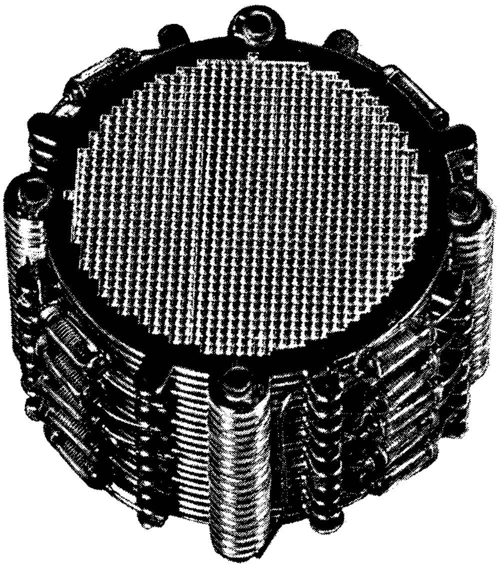

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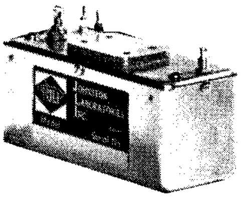

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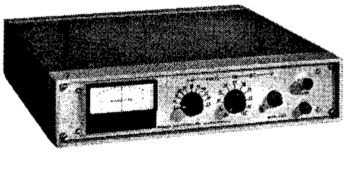

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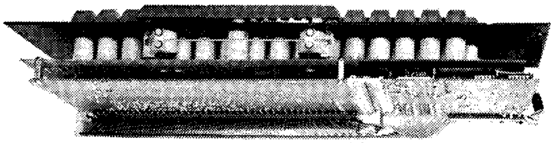
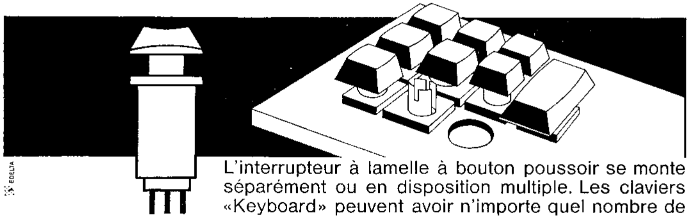
interrupteur à lamelle à bouton poussoir pushbutton reed switch





L'interrupteur à lamelle à bouton poussoir se monte séparément ou en disposition multiple. Les claviers «Keyboard» peuvent avoir n'importe quel nombre de touches. Les montages incorporés ont un système de code «diode-matrix» avec circuit intégré qui donne la suite logique de deux touches, «strobe», etc. Existe en version «CHANGE OVER» réf 2 RB1. Les types 1 RB1 et 2 RB1 sont livrables avec voyant lumineux.

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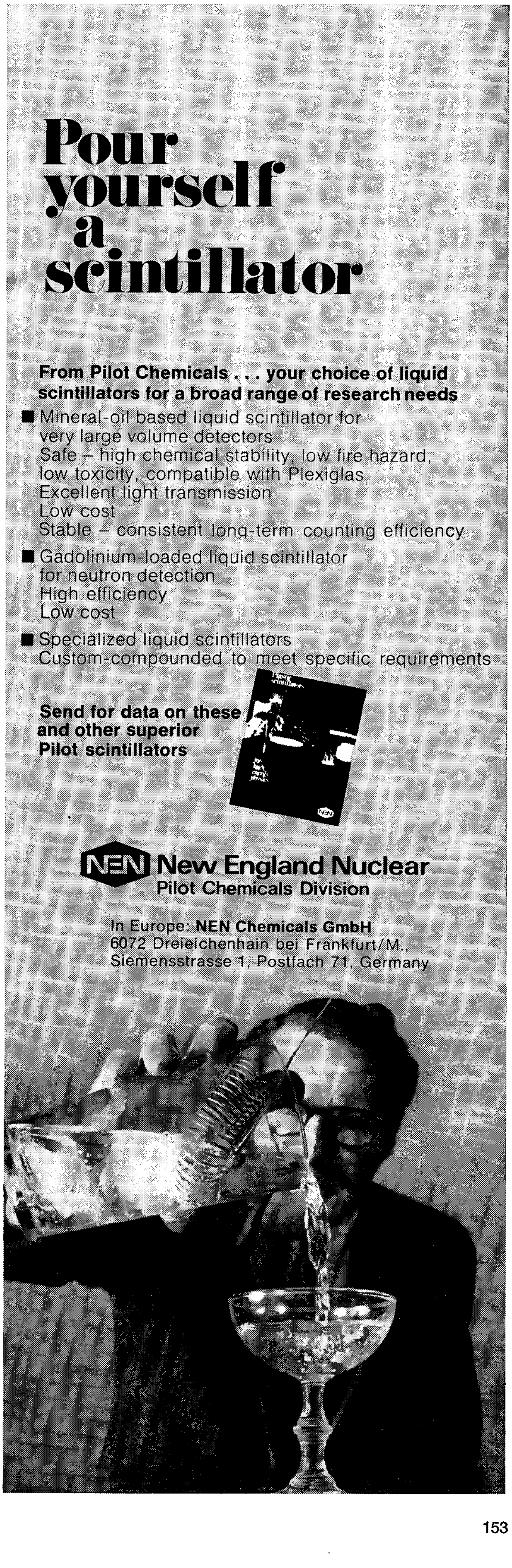

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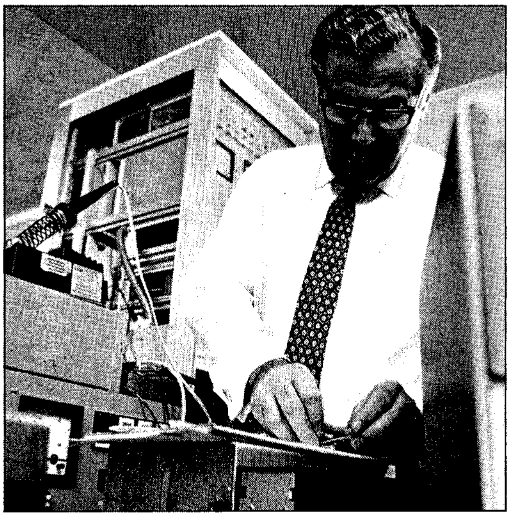

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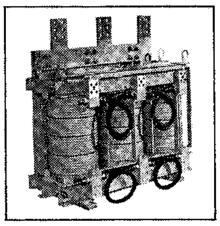

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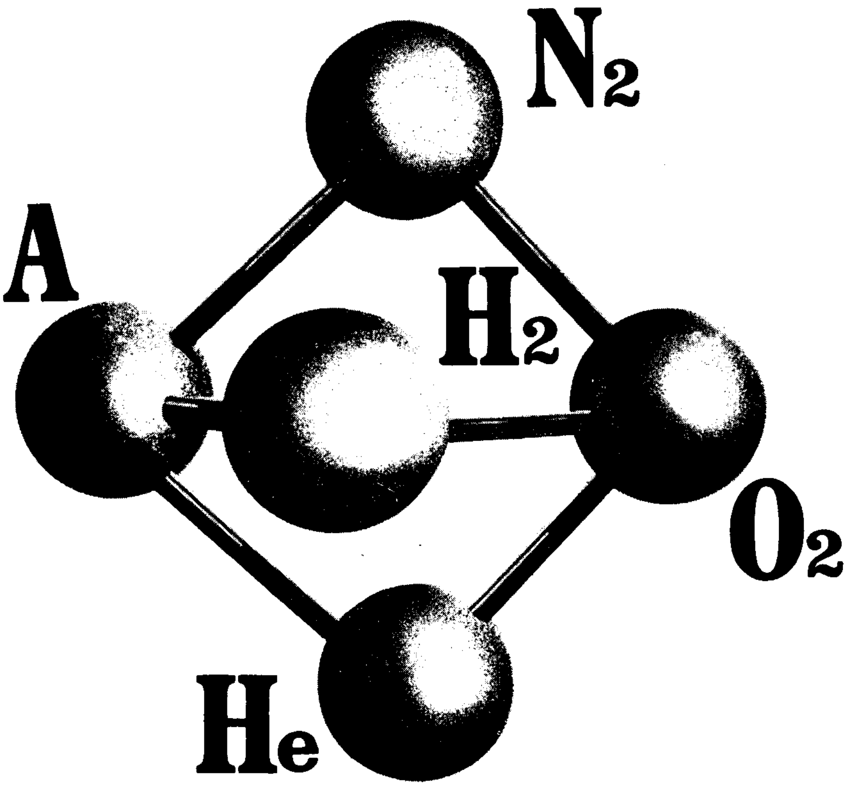
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- Températures de fonctionnement : - 40 °C à + 150 °C.

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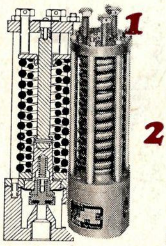
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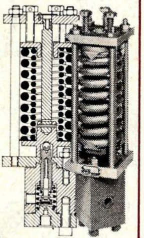
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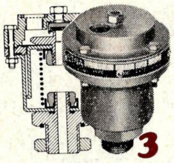
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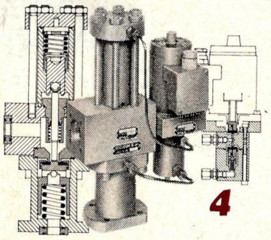
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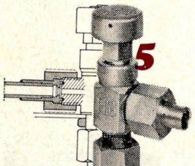
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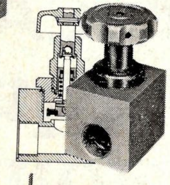
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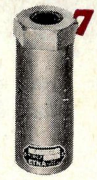
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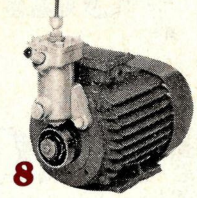
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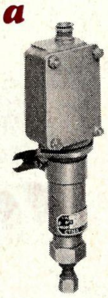
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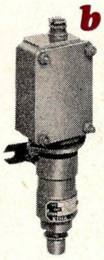
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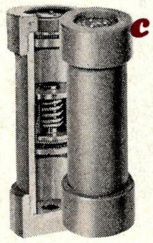
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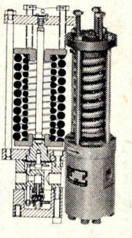
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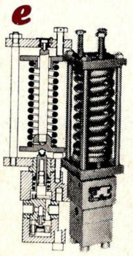
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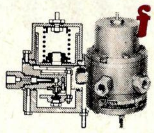
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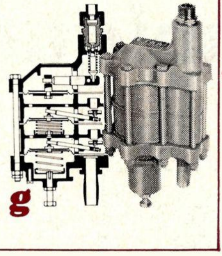
g

PRESSOSTATS

- Boîtier électrique standard type protégé, sur lequel se montent les différents ensembles de contrôle de pression.
- Appareils très robustes, insensibles aux vibrations et sans fuite.
- Fidélité dans le temps de la pression de réglage.
- Réglage précis fait au montage sur demande et qui peut être modifié.
- Ecarts fonctionnels réduits, ce qui est important pour les installations où l'échelonnement des pressions doit être aussi précis que possible.

a PRESSOSTATS A PISTON
- Pression d'utilisation : 100 à 400 bar.
- Températures de fonctionnement : - 40°C à + 110°C.

b PRESSOSTATS A MEMBRANE
- Pression d'utilisation : 0,2 à 100 bar.
- Températures de fonctionnement : - 25°C à + 110°C.

c ACCUMULATEURS OLEO-PNEUMATIQUES
- Pression de service maximale : 336 bar.
- Etanchéité absolue de la charge d'azote.
- Aucun regonflage périodique ni au stockage ni en service.
- Piston séparateur avec ressort compensant automatiquement l'usure des garnitures.
- Possibilité d'utiliser le volume total pour le stockage du liquide sous pression en adjoignant des bouteilles d'azote auxiliaires.
- Températures de fonctionnement : - 40°C à + 110°C.

Garnitures spéciales pour fluides hydrauliques de synthèse résistant au feu (esthers phosphoriques)

DETENDEURS

- Faible écart fonctionnel : 10 à 15 % entre ouverture plein débit et refermeture étanche.
- Etanchéité absolue après refermeture.
- Aucun risque de pompage.
- Dispositif anti-retour évitant toute possibilité de vidange de la canalisation vers l'amont, pour les détendeurs à l étage.
- La partie aval des détendeurs type haute pression est conçue pour résister à la pression amont maximale.
- Dispositif anti-givrage prévu dans certains cas.

d DETENDEURS A MEMBRANE A 1 ETAGE
- Pression amont maximale : 250 bar.
- Pression aval de 1 à 100 bar.
- Températures de fonctionnement : - 25°C à + 110°C.

e DETENDEURS A PISTON A 1 ETAGE
- Pression amont maximale : 320 bar.
- Pression aval de 50 à 300 bar.
- Températures de fonctionnement : - 40°C à + 150°C.

f DETENDEURS A MEMBRANE A 1 ETAGE POUR ENCEINTES PRESSURISEES
- Faible poids.
- Grand rapport de détente.
- Pression amont maximale : 200 bar.
- Pression aval : 0,2 à 4 bar.
- Températures de fonctionnement : - 50°C à + 70°C.

g DETENDEURS A MEMBRANE A 3 ETAGES INCORPORES
- Pression amont maximale : 250 bar.
- Pression aval : - 0,005 à + 2 bar.
- Etanchéité absolue après refermeture.
- Grande précision de la pression détendue même pour une grande variation de la pression amont, grâce aux trois étages de détente.
- Températures de fonctionnement : - 25°C à + 110°C.
- Modèles prévus pour alimentation de carburateur mélangeur.

Notice 24AR

ETNA

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