CERN COURIER

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CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. 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 1500 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 900 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 382.9 million Swiss francs in 1973.

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 1973 is 188 million Swiss francs and the staff will total about 370 people by the end of the year.

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Annual Report

The CERN Annual Report for 1972 has recently been published. Copies are available, on application, from the Public Information Office (CERN, 1211 Geneva 23, Switzerland) stating clearly — name, address, number of copies, language version (English or French).

CERN COURIER next edition

The next edition of CERN COURIER will cover the months of July/August and will appear at the end of August.

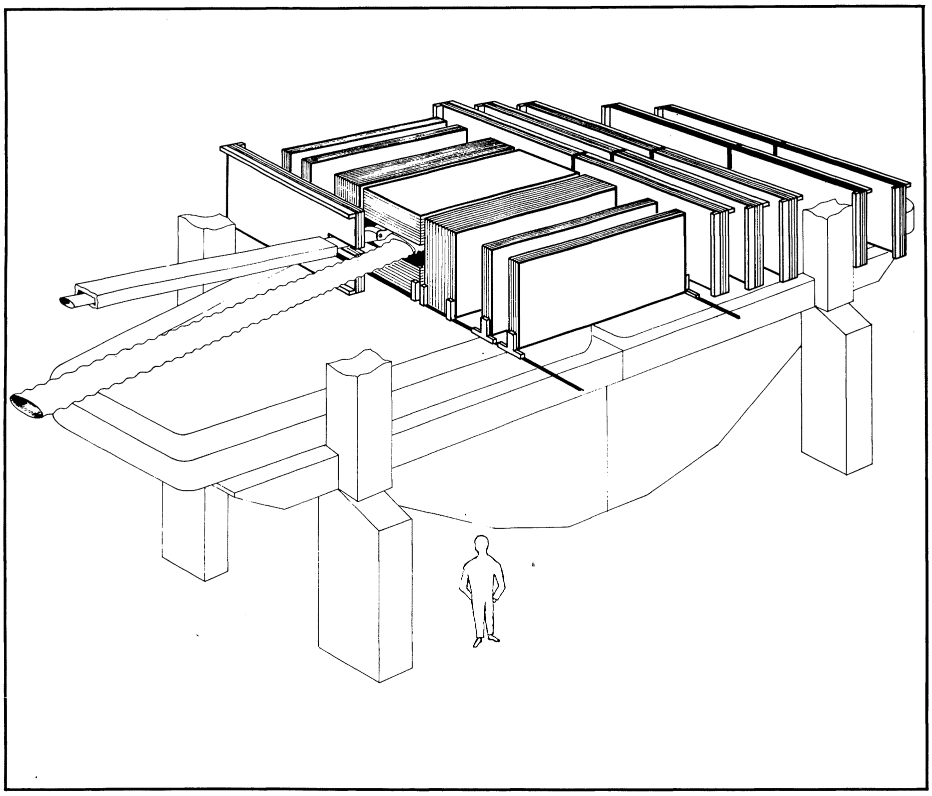
Cover photograph: The large Magellanic Cloud photographed by the 1 m Schmidt telescope of the European Southern Observatory at La Silla in Chile. The photograph was taken in the blue wavelengths (4000 to 5000 A). The large Magellanic Cloud is an irregular galaxy very close to our own galaxy (150 000 light years away) and can be seen only from the southern hemisphere. This photograph is one of 2000 which will be used by the ESO Sky Atlas Laboratory, installed at CERN, for the production of the Atlas of the Southern Sky.

Frascati Instrumentation Conference

From 8-12 May, the 1973 International Conference on Instrumentation for High-Energy Physics was held at Frascati. The Conference, organized by the 'Laboratori Nazionali di Frascati del CNEN', brought together about 250 specialists in particle detectors.

Instrumentation for high-energy physics seems to be a more lively field than it has ever been. The Conference was outstanding both in the quantity of the information which poured out and in the lively polarization of opinions on many aspects of particle detection techniques and data handling. In addition, the participants were able to get a touch of la dolce vita in the beautiful surroundings of Tuscolo. In the freshness of Spring, uncrowded by tourists, the Frascati region was exceptionally attractive and was an ideal setting for a stimulating week.

Schematic layout of the detection system to be installed in the Split Field Magnet at intersection region I-4 of the Intersecting Storage Rings. The drawing shows the bottom half of the magnet with the blocks of multiwire proportional chambers surrounding the collision region. The detection system incorporates about 70 000 wires.



Wires, wires and more wires

The dominant detection techniques discussed at the Conference concerned the use of wire chambers in two related variants — the multiwire proportional chamber (MPCs) and the drift chamber. We will not spend too much time on the first category since they have been described several times before (see, for example, vol. 12, page 362) and have been in vogue for the past five years.

The essential principle of MPCs — setting up planes of wires and detecting the passage of a charged particle by picking up the signal from the wire which receives an avalanche of electrons initiated by the particle — is used in many chambers. They can nevertheless differ considerably in construction, selection of gas and associated electronics depending on the priorities assigned to the different aspects of their performance. As an example we will pick out some features of the biggest system built to date which will be used in the Split Field Magnet recently installed at intersection I-4 of the Intersecting Storage Rings at CERN (see page 182).

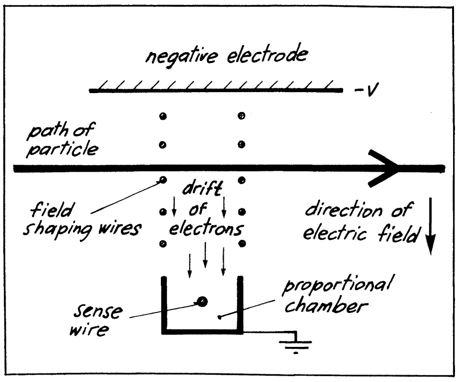
A most important requirement in this case is the reliability of the detector since failures would shut down the experiments for extended periods (as long as a day) because access to the intersection region for repairs is not possible when the stored beams are circulating. This has resulted in a 'conservative' design of the system and in great care in building the detectors. The larger chambers will carry preamplifiers but the pulses will be taken out along 65 m of twisted cable to the rest of the electronics which can thus be kept in order without need for access to the intersection region.

As much as possible of the large aperture of the Split Field Magnet is being filled with detectors. The frame of the larger chambers, 1 × 2 m^2, is only 5 mm thick — they need no further support since they are constructed of plastic foam with the high voltage electrodes sprayed on to the flat surface. The sense wires are 20 μm diameter, spaced 2 mm apart and 8 mm from the high voltage plane.

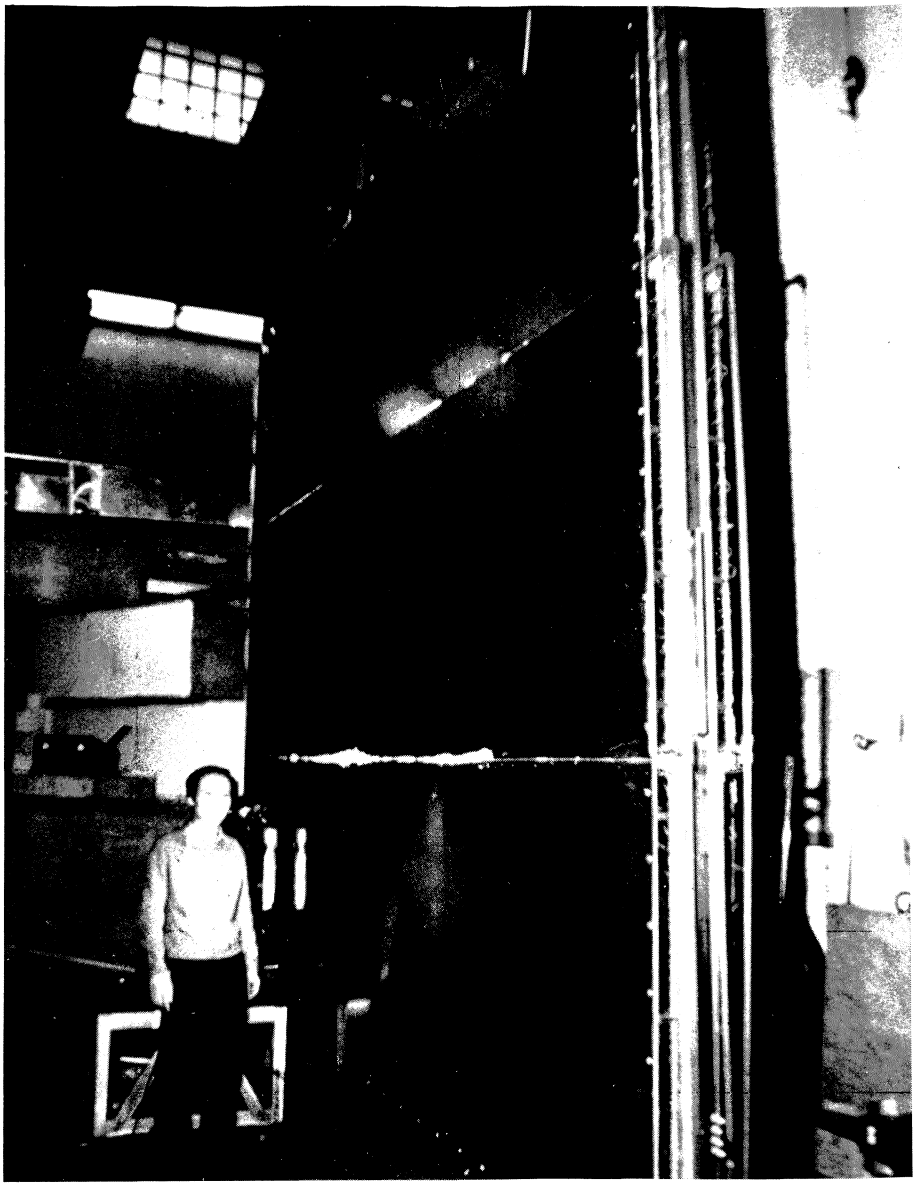
Fourteen of these chambers have been completely tested and others are emerging at the rate of about one per week. Altogether the detector will have 50 000 wires in these large chambers plus another 20 000 in smaller chambers packed closely around the point of intersection.

The newcomer among particle detectors is the drift chamber. The basic idea has been around for some time (it was mentioned in the first paper on multiwire proportional chambers in February 1968) but its abilities have only recently become clear following their use in actual experiments by

The basic idea in the operation of drift chambers is sketched in the diagram. The passage of a charged particle causes ionization in the chamber gas and the liberated electrons 'drift' under the influence of the electric field to 'sense wires' which act as in proportional chambers amplifying the signal. The length of time which the electrons take to reach the wire is a function of the distance of the particle from the wire. The measurements can be so accurate that the particle track can be positioned to better than 100 μm. To achieve very high accuracy it is important that the electrons drift through a homogeneous electric field. If the field is inhomogeneous the electron paths are distorted and the drift time is no longer directly related to the distance between the initiating particle and the wire. Field homogeneity can be achieved by having field shaping wires along the drift distance as indicated in the diagram.



The photograph shows a huge drift chamber constructed at Harvard for use in an experiment at Batavia. The chamber is 4 m by 4 m with a wire spacing of 10 cm.



teams from Saclay and Heidelberg. One participant at the Conference, in a good position to judge, extended his neck so far as to say that, in a few years' time, 80 % of all detectors around accelerators will be drift chambers. With such strong claims being made it is worthwhile devoting a few paragraphs to explaining drift chambers and indicating what has already been achieved.

The idea is to pinpoint the position at which a charged particle traverses a chamber by measuring the length of time it takes for electrons, liberated by the particle in the chamber gas, to reach a wire. This drift time (though 'drift' is really far too leisurely a word) is a function of the distance of the particle from the wire. One possible arrangement is shown in the diagram. The charged particle crosses the space between a negative electrode and an earthed electrode where 'sense wires', acting as in a proportional chamber, pick up signals due to the liberated electrons. Field shaping wires can be used to ensure that the electrons drift in a homogeneous field since inhomogeneous fields can distort the results because the electrons follow tortuous paths.

First results indicated that an accuracy of as low as 100 μm in locating the track is possible and that the accuracy in timing the particle using a series of drift chambers could be down to 5 ns. The results are better than from MPCs and, to crown the achievements, the cost of drift chambers can be even lower than for conventional spark chambers.

Saclay and Heidelberg fastened onto these properties and developed chambers for experiments. The Saclay chambers are used in the SPES spectrometer for nuclear physics at Saturne. They are very simple in construction using long drift distances (up to 50 cm). With a drift field of 800 V per cm in pure methane, the drift velocity is 10 cm per μs and this has been found to be stable to about one part in a thousand over very long runs. Even over such long drift distances the chambers achieve accuracies in track positioning of about 1 mm. The dead time of the chambers (during which they recover from a previous signal) is 5 μs. They have worked without problems for over a year.

The Heidelberg chambers are constructed rather like ordinary multiwire proportional chambers with 1 cm spacing between the wires. They tackled one of the problems in a drift chamber — the so-called right-left ambiguity which means that it is not possible to know on which side of a wire the electron avalanche was initiated. They split the sense wire into two thin wires separated by a shielding wire. This however produces an asymmetric field around the wires which distorts the relationship between drift distance and pulse arrival time.

Nevertheless the distortion inherent in the Heidelberg method is only of the order of 0.35 mm and the method can easily be applied in large chambers. The chambers have been used successfully in a collaborative experiment with CERN at the proton synchrotron studying the leptonic decays of neutral kaons.

Huge drift chambers have been built at Harvard to be used as part of a magnetic spectrometer measuring high energy muons in neutrino experiments at Batavia. They should be able to catch upto six neutrino events from a 200 μs beam spill on a machine pulse. The aim is to have position readings in two dimensions to an accuracy of 0.5 mm. The chambers measure 4 m by 4 m with 10 cm wire spacing. The use of three chamber planes, assembled together with the wires in each chamber off-set with respect to the others by 60°, resolves ambiguity. The chambers have been tested for several months with cosmic rays and at a low energy cyclotron. A spatial resolution of better than 0.35 mm and a time resolution of 14 ns are achieved.

At CERN there has been further work on the basic properties of drift chambers. One of the important tests has been the use of varying potentials along field shaping wires so as to reconstitute a homogeneous field over the drift distance when the chamber is placed in a magnetic field. This seems to work but is a rather awkward method of solving the problem of operation in a magnetic field.

One extraordinary experiment, demonstrating the accuracy which can be achieved with the chambers, was to place a drift chamber between two single-wire chambers. With freon in the two single-wire chambers the sensitive area around each of the two wires was reduced to about 100 μm. When charged particles passed through this array, readings from the drift chamber showed four distinct peaks. It was then realised that the drift chamber was distinguishing between particles going to the right of the top wire and to the right of the bottom wire, to the right and left, to the left and right and to the left and left. This corresponded to a position measurement accuracy of 50 μm.

Work has also concentrated on trying to draw two co-ordinates efficiently from a single-wire plane. One technique is to have an amplifier at each end of the sense wires and to measure how the current reaching a wire divides between the two amplifiers. This distinguishes one co-ordinate, of course, since it is a particular wire in a plane and the other co-ordinate in giving the position along the wire where the avalanche struck. Results for the co-ordinate along the wire are of the order of 1 cm in 1 m.

Other techniques are based on the delay line method developed at Berkeley. One particularly good example is a Los Alamos detector with a helically wound wire parallel to the sense wires. They have achieved 0.25 mm in 50 cm. A new idea is to take the centre of gravity of induced pulses on strips close to the sense wires. It is a complicated and expensive method but tests indicate that it might achieve accuracies in the other co-ordinate close to that from the drift chamber proper.

Just how far the abilities of drift chambers can be taken remains to be seen, for there is still room for a great deal of applied research to determine and develop the properties of these chambers.

Bubble chambers change of life

The bubble chamber has been the work-horse of high-energy physics for the past ten years and has poured out an enormous quantity of physics. Seven large chambers have recently come, or are coming, to life; their designs have essentially evolved from the principles worked out at Brookhaven in 1964. There are five hydrogen chambers — the Argonne 12 foot which has been in action several years; Mirabelle, the French chamber at Serpukhov, which now has 300 000 photographs under its belt; BEBC at CERN which begins its physics programme this summer; the Brookhaven 7 foot which is due for operation soon in its new location; the Batavia 15 foot which is almost ready for its first tests. The two heavy liquid chambers are Gargamelle, which has been in action at CERN for over two years, and SKAT at Serpukhov, which is scheduled for operation next year.

These chambers, as they are at present, are almost certainly the last of their very fruitful generation. They display the great advantages of bubble chambers — detecting with high precision all charged particles emerging from an interaction in all directions — but have limitations which are becoming more troublesome in the new fields of interest in high-energy physics. There is the move towards higher energies; here the poor ability of conventional bubble chambers for detecting neutral particles is a serious limitation because the majority of interactions will produce neutrals. There is the move to higher statistics or, an aspect of the same thing, to studying rare interactions; here the low data-taking rate and lack of selectivity of the conventional bubble chamber are serious drawbacks.

The conventional chamber by itself is an inappropriate detector for much of the physics which confronts us in the years to come. Bubble chamber instrumentalists are therefore concentrating on developing techniques which will either greatly improve the capability to detect neutral particles or be selective and capable of higher data-taking rates. The great advantages of the bubble chamber technique could then be preserved.

The great white hope for neutral detection is the track sensitive target. By now it is more than a hope, for the work at the Rutherford Laboratory in collaboration with CERN has shown that the TST technique is well mastered and gives excellent results. The idea has been described in some detail before (see, for example, vol. 11, page 356). Essentially it involves the use of a small volume of hydrogen, which presents the usual simple target of protons to the incoming beam particles, surrounded by a larger volume of a neon-hydrogen mixture, which shortens the distances that neutrals travel before 'materializing' into electron-positron pairs thus enabling them to be measured. The idea was shown to work when experiments at DESY demonstrated that both volumes could be sensitized simultaneously. With transparent walls around the hydrogen volume, tracks in both volumes can be photographed and the events subsequently reconstructed.

Rutherford now have 1.6 million photographs with a TST in their 1.5 m chamber. They have operated with up to 82 molecular per cent of neon in the mixture which corresponds to a radiation length of 35 cm. The hydrogen target volume is enclosed in an all-perspex chamber. Track quality in both volumes is good and no problems have been found in the geometric reconstruction of the events or their analysis.

Brookhaven are at an advanced stage of development for a TST in the 80 inch chamber. Argonne is collaborating with CERN and Rutherford to build a TST for the 12 foot chamber. Batavia are thinking of a TST for their 15 foot chamber. A TST for BEBC was a recommendation of the ECFA Working Group which considered experiments at the SPS; no formal decision has been taken yet but it is probably not without significance that neon dewars have already been ordered at CERN.

For selection of events and higher data-taking rates, fast cycling bubble chambers are being developed for use in hybrid systems in association with electronic detectors. This subject has also been covered in some detail before (see, for example, vol. 11, page 91) and has also been in the air long enough to be able to spell out its potential with confidence.

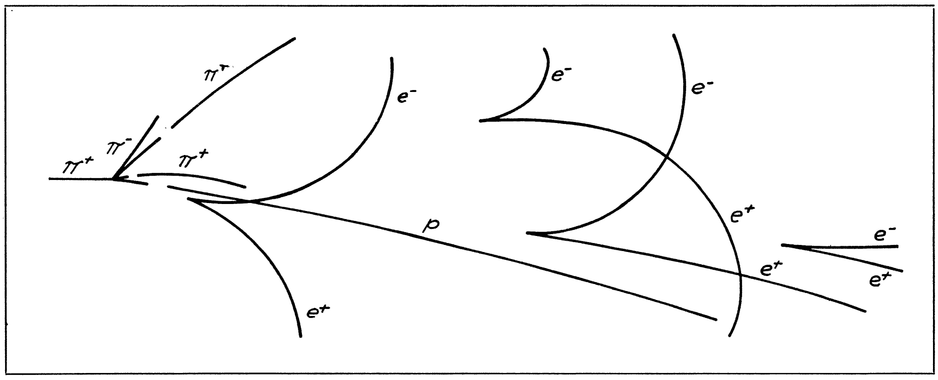
It involves using a fairly small hydrogen bubble chamber, serving as the target volume, with a pressure system which can make the liquid sensitive many times per second. Electronic detectors around the chamber catch emerging particles and when they record that an event of interest seems to have taken place they tell the chamber cameras to take a picture. The fast cycling bubble chambers give precise information on what happens at the vertex of the interaction and they are sometimes therefore referred to as 'vertex detectors'. (Incidentally, they have also every right to be called 'track sensitive targets' but this title has already gone elsewhere.)

Two types of fast cycling bubble chamber were described at the Conference. The one receiving most attention is the rapid cycling chamber where Stanford lead the field. These chambers use electromagnetic systems to operate mechanical pistons at high speeds. They have wide 'opening-angles' where particles can emerge to the electronic detectors without passing through much matter en route. Among their construction problems is the need, even more so than with conventional bubble chambers, for exceptional mechanical reliability of the components. (This becomes obvious when considering a rapid cycling chamber operating at 60 pulses per second — in a single day it will go through over five million pressure cycles.)

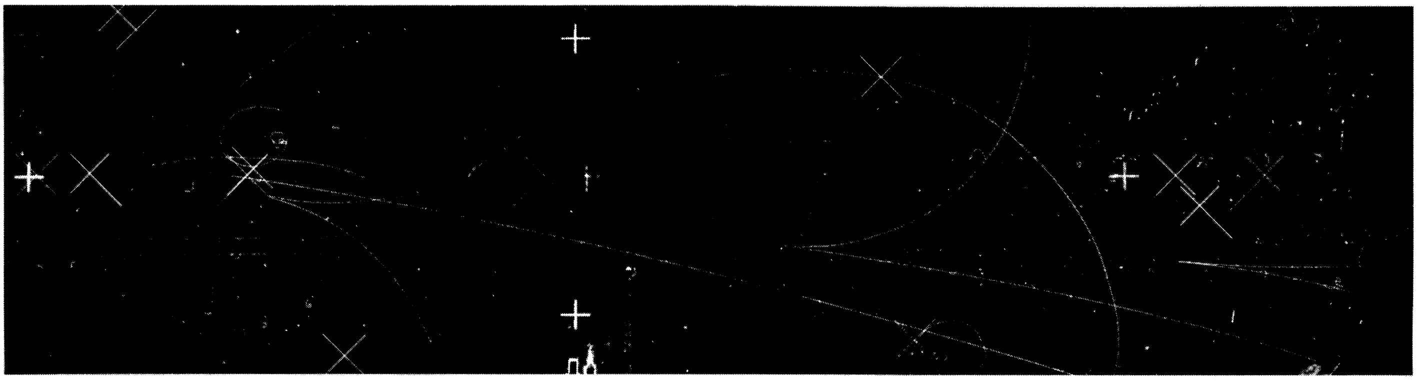
Stanford have a 40 inch chamber, with 100 million pulses behind it, operating at the rate of 10 Hz — from these pulses about 5 million pictures have been taken. Recently (see April issue page 114) a 15 inch rapid cycling chamber began operation in an experiment working at 20 Hz and has taken 60 000 pictures from 20 million pulses. It is hoped to step the pulse rate up to 30 Hz and subsequent development may take it to 60 Hz.

Rutherford have also begun work on a rapid cycling chamber aiming for a maximum rate of 60 Hz. A detailed design has been drawn up. They intend to install a chamber, 30 cm diameter and 20 cm high, inside a 2 T magnet previously used for a helium bubble chamber. Tests with a prototype piston assembly are beginning using the electromagnetic vibrator intended for the final version of the chamber. At CERN the HYBUC bubble chamber has demonstrated rapid cycling capabilities (see vol. 11, page 353). In tests last year it achieved a rate of 50 Hz and a proposal to use HYBUC as a rapid cycling chamber for the study of the magnetic moment of the xi hyperon is being prepared.

The other type of fast cycling chamber discussed at the Conference was the ultrasonic bubble chamber where sound waves generated by piezo-electric crystals apply the pressure swings which sensitize the chamber liquid. Promising results have been obtained at CERN (see vol. 12, page 367) and Dubna but a lot of development would still be needed and may not result in qualities preferable to those which can already be obtained with fast cycling chambers. Fast cycling is the better bet at the moment and, it seems appropriate to say in the bubble chamber context, the



One of the first photographs taken with the track sensitive target which has operated so successfully in the 1.5 m bubble chamber at Rutherford. The tracks are photographed both in the hydrogen of the target volume and in the surrounding hydrogen-neon mixture which has made it possible to record a 'four gamma event' such as is rarely seen in a hydrogen chamber.



pressure has been taken off ultrasonic chambers. The one prospect that might lure attention back to ultrasonic chambers is that of being able to grow bubbles to visible size and to snuff them out again all within a single cycle of the sound wave. This implies a time of about 1 μs which, in hybrid systems, would be extremely attractive.

One topic worth raising in connection with fast cycling chambers is that proton synchrotrons are not an ideal feed. An electron linac emitting a sequence of separate bursts of accelerated particles is well suited for efficient operation with a fast cycling chamber, which is a good reason for Stanford to be prominent in this field. Proton synchrotrons, however, provide a steady stream of accelerated particles over some hundreds of milliseconds. To avoid disrupting the rest of the experimental programme while feeding a fast cycling chamber requires some tricks to chop out bits of the beam or, if only low intensity is needed, to peel off a strip of beam continuously.

Streamers looking good

Another 'visual' device, the streamer chamber, is now firmly established in the catalogue of detectors. Streamer chambers use high voltage pulses to initiate sparks in the wake of a charged particle. The pulses are kept short so that the sparks do not develop but are photographed as a series of tiny 'streamers' along the track. The detector preserves many of the advantages of the bubble chamber — almost isotropic detection, high precision (more so than in bubble chambers since the tracks are in gas and multiple Coulomb scattering is not a limitation) — and it can also be triggered so as to select the required events. The data-taking rate is limited mainly by camera speed but could climb to about 100 Hz with the use of television cameras such as the Plumbicon though at the cost of precision.

Stanford have long experience with streamer chambers. In their most recent experiment on the Ξ^* their chamber took over 2.5 million pictures without any equipment failure whatsoever. Dubna have built an enormous chamber, 8 m long, for use at Serpukhov. (A technical trick with this chamber is to send a burst of X-rays to trigger the spark gap in the high voltage pulse system.) An Orsay/Washington team are developing a helium streamer chamber to study diffraction dissociation at Batavia. A Munich team have recently installed a streamer chamber surrounding intersection I-7 at the CERN intersecting storage rings and two other streamer chambers are in action in the hyperon beam-line at the proton synchrotron.

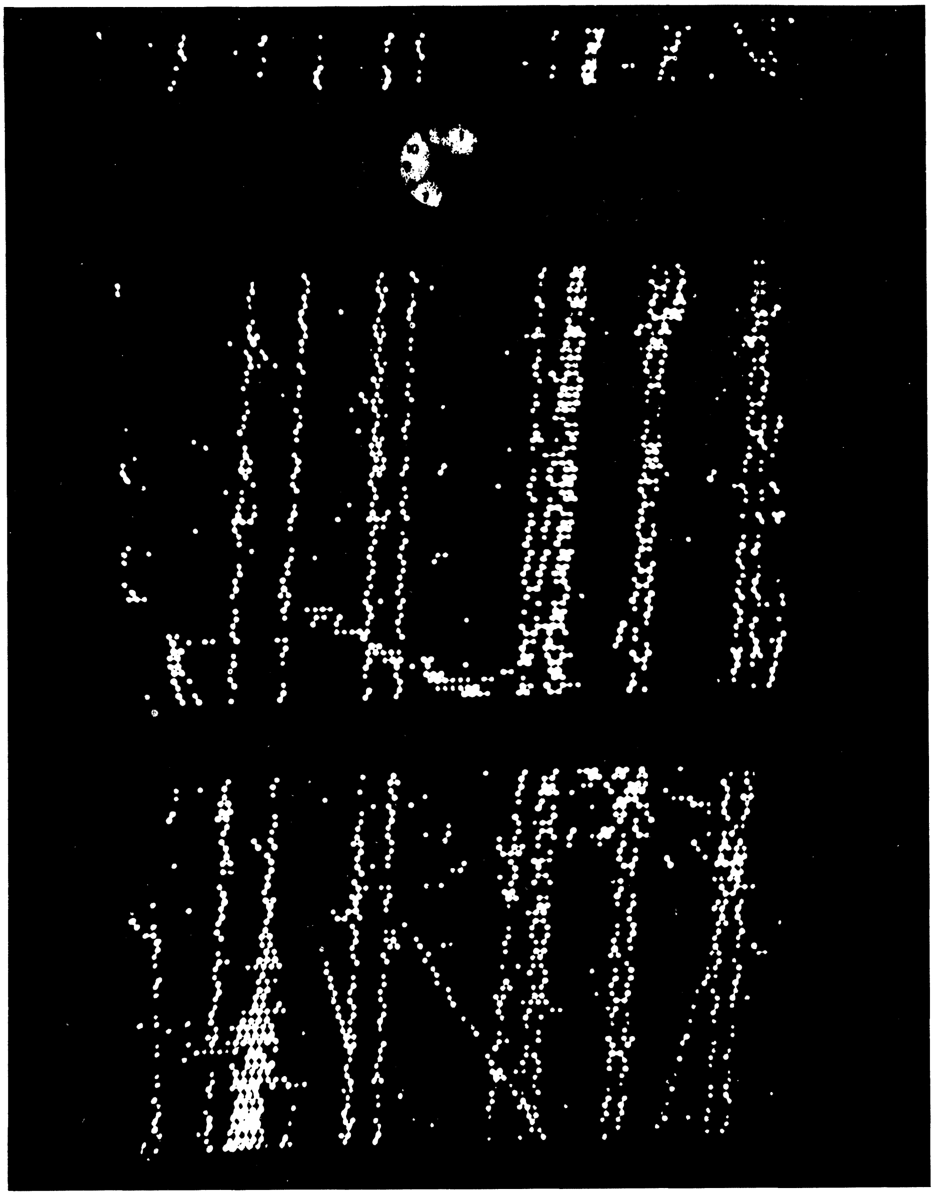
There has been a little work at CERN on another type of visual detector, the projection chamber, which has some of the features of the streamer chamber combined with some of the features of the optical spark chamber. Stacks of projection chambers can be built up of many layers of wires carefully aligned so that the chamber is transparent to cameras looking in particular directions. The light from sparks between the planes is much brighter than in streamer chambers and there is certainly no need for image intensifiers. In addition there are none of the high voltage problems of streamer chambers, though by now this is not much of a gain.

Some specific applications have been considered where projection chambers could be very useful. For example, the wires in a many-layered system could present about 1 gm per cm^3 of matter to incoming particles which would help in 'materializing' neutrals and even neutrinos. A spatial resolution of 100 μm should be possible.

Transition radiation

At the time of the last Instrumentation Conference at Dubna in 1970, the possible use of transition radiation in particle identification came to the fore following some pioneering work at Yerevan (see vol. 10, page 275). Since then further experiments have confirmed many predictions of the theory and construction of transition

A cosmic ray shower passing through a large array of flash tubes. More than 10 000 tubes were set up in this Durham University experiment which looked for quarks. The array was well shielded so that the majority of the particles recorded are penetrating high energy muons. Knock-on electrons and a small cascade can readily be distinguished.



radiation detectors is under way at Yerevan (where big detectors are being built for cosmic ray experiments), at Brookhaven (for experiments at the AGS) and by a Hawaï, Maryland, Oxford team for 100 GeV energies.

Transition radiation is produced when a charged particle travelling at relativistic energies crosses the boundary between two media of different refractive index. The radiation can be detected in the optical and the X-ray region. To achieve adequate intensity a series of boundaries are presented to the particles, for example in the form of a stack of spaced foils. There is still quite a bit of work to be done to optimize such things as foil thickness, spacing, type of gas, etc.

The interest in pursuing this technique is that the intensity of the radiation emitted by a particle is related to the gamma of the particle and not the beta (as in Cherenkov counters for example). In the optical region the intensity is proportional to log gamma and in the X region is directly proportional to gamma. At very high energies the beta (velocity divided by the velocity of light) of all particles becomes very close to one and highly sophisticated instruments (such as the DISC counter described in vol. 12, page 234) are needed to distinguish one particle from another. However, the gamma (which relates the mass increase of a high energy particle to its rest mass) can still differ considerably for the different particles and their identification should be easier.

Much more experience is needed of the use of transition radiation devices in experiments before they really become established.

Flash in the tube

A surprising flurry of interest was generated by the reports of the cosmic ray physicists on the use of neon flash tubes for high energy charged particle detection — surprising because this technique has been around since1955.

Cosmic ray studies have generally not required very good time or spatial resolution. They have more often required large volume, rugged detectors for such intrepid experiments as neutrino searches down mines. Another factor is that they have not been backed by a fortune and cheapness of the detectors has been important. The neon flash tube meets all these requirements.

Recent work has pushed the performance of flash tubes to figures which become interesting for experiments at accelerators. Normal tube sizes are 7.5 mm outside diameter, 5.5 mm internal diameter and they can easily be made 2 m long or more. It is possible to have them with walls as thin as 0.3 mm. They are stacked in many layers and a charged particle passing through produces ionization in the gas of the tube causing a flash which can be photographed. The track position can be determined to an accuracy which is dependent on the number of tube layers — for example 0.3 mm with eight layers.

The tubes normally have a long sensitive time of around 100 μs (and hence can catch more information than is wanted) and a long recovery time of as much as a second (which limits the data taking rate). However the use of special gas mixtures, rather than the usual neon with a few percent helium, plus the application of modest a.c. clearing fields to snuff out the ionization quickly, has brought these figures down to a few μs for the sensitive time and a few ms for the recovery time. Digitized read-out, rather than passing via photographs, is also possible using a simple probe on the front of the flash tubes which detects a voltage pulse when a tube discharges.

Flash tubes continue to be used in very large arrays for cosmic ray experiments such as the MARS spectrograph at Durham. MARS will be sensitive to charge particles with energies from a few GeV to almost 6000 GeV. An example of the new interest in their use at accelerators is a 10 000 tube hodoscope at the Frascati electron-positron storage ring, ADONE, which will be used in an experiment to study proton-antiproton production.

Dealing with the data

The tremendous advances in data-taking abilities, which stem from the development particularly of multiwire proportional chambers and drift chambers, bring in their wake an acute problem of gathering and analyzing enormous quantities of data. It is not much use being able to collect information a hundred times faster than a year ago if the data handling system cannot be upgraded by a similar factor.

The first question concerning storing data is one of philosophy — one attitude is to throw away as much as possible using a very selective trigger, the opposite is to store nearly everything with multi-event triggering giving data which can incorporate several experiments and can be worked on comparatively at leisure. This would be canned physics on tape rather like canned physics on film in bubble chamber experiments. Even in the first case, the new detectors provide so much information so quickly that the conventional magnetic tapes are becoming inadequate. They are each able to store about 10^8 bits of information and, with this capacity, a thousand tapes from a single experiment is no rarity.

A venture into the use of TV video recording techniques for storing data is well advanced at CERN. It has the potential of recording 10^6 bits per square inch of tape and a single video tape, 7000 foot long and 1 inch wide, could then hold as much data as about 700 conventional tapes. The video tape unit has a rotating head moving at high speed across the tape which itself moves past at slow speed. The information is written across the tape at an angle of 5°. A longitudinal address makes it possible to recover specific data quickly. The error rate is 1 in 10^7 to 10^8. The system is scheduled to be in operation in a few months' time.

With techniques such as video recording the storage problem should be reduced again to manageable proportions. Next comes the problem of analysis. If we consider one of the modern data collection systems, such as the array of multiwire proportional chambers in the Split Field Magnet mentioned above, it can record say 10^5 events per second of which perhaps 10^3 could be accepted by the on-line computers and stored. Even with the large central CDC 7600 computing system at CERN, a time of about a second can be absorbed in analysing a single event. Thus the analysis of data from a few seconds of operation of the SFM detectors could drown the central computer system for an hour.

The problem could be solved by sheer weight of computers — say a CDC 6600 to each experiment — but, as one of the more voluble participants put it, what is needed is either money or imagination. The absence of the former tends to be a considerable stimulus to the latter and there have been several important developments in the past year which help to cut corners in data analysis by computer.

A very successful approach has been to build special digital hardware processors to take over the repetitive tasks which occur in analysing particle interactions. A great deal of the computer's work in pattern recognition is repetitive and well suited to attack by the new special purpose processors. The processors are based on computational methods rather than using analogue procedures. They score heavily, compared with large multipurpose computer systems, because their task is specific and many manoeuvres necessary when using conventional computer architecture are eliminated. Given a limited, well defined task the sequential nature of calculations within a computer need not be followed and parallel calculation gives another big contribution to speed.

Processors have been developed at CERN, for example, which provide for point finding and track tracing through magnetic fields with data coming from wire chamber detection systems. Compared with the normal computer programs used on the CDC 7600 they achieve speeds which are two orders of magnitude better. Pattern recognition using such hardware processors thus goes a lot faster and the burden on the main computer is eased. Special purpose processors are likely to find widespread application wherever repetitive calculations can be well defined.

In addition to the hardware processors, there is also a software attack on the data analysis problem. New computing methods are being tried to help in pattern recognition and momentum analysis. Thus, though the flood of data which can be extracted from the new detection systems is still a problem, data storage and analysis techniques are rising to meet it.

CERN News

SFM glides into position

At the gingerly pace of 5 mm per second the Split Field Magnet (see vol. 12, page 236) moved from an adjoining annex, where it had been assembled and tested, to its position in intersection region I-4 of the ISR. The move began on 24 May after a day spent carefully loading the 1000 ton magnet onto sixteen bogies. A day and a half later it was lowered into its position.

It was essential to achieve good distribution of the load and to maintain it. The bogies had hydraulic and pneumatic systems to adjust the load during the transportation and to ensure adequate stability. Large concrete blocks were attached below the magnet and shimmed every half metre so that they travelled only a couple of millimetres from the floor. Thus any failure en route could only have dropped the magnet a maximum of 3 mm.

The magnet now rests on three large jacks, each capable of supporting 500 tons, which make adjustments possible in three dimensions. With these jacks the alignment of the magnet was carried out to a precision of better than 0.1 mm. The associated compensator magnets, which will ensure that the Split Field Magnet, does not disturb the orbits of the protons around the rest of the storage rings, are also in place and aligned.

The vacuum vessel has been installed and baked out and some of the multiwire proportional chamber detectors have been introduced into the magnet aperture.

On 21 June the ISR is scheduled to begin operation again but the SFM will not be powered during the first run. This is to check, independently, that the new vacuum chamber does not introduce any problems, since the ISR performance is so dependent on ultra-high vacuum, and that the heavy magnet and complex installation procedure have not disturbed the alignment of the nearby ring magnets or otherwise altered the working conditions of the machine. In July the magnet will probably be powered for the first time in its destined place.

Synchro-cyclotron face-lift begins

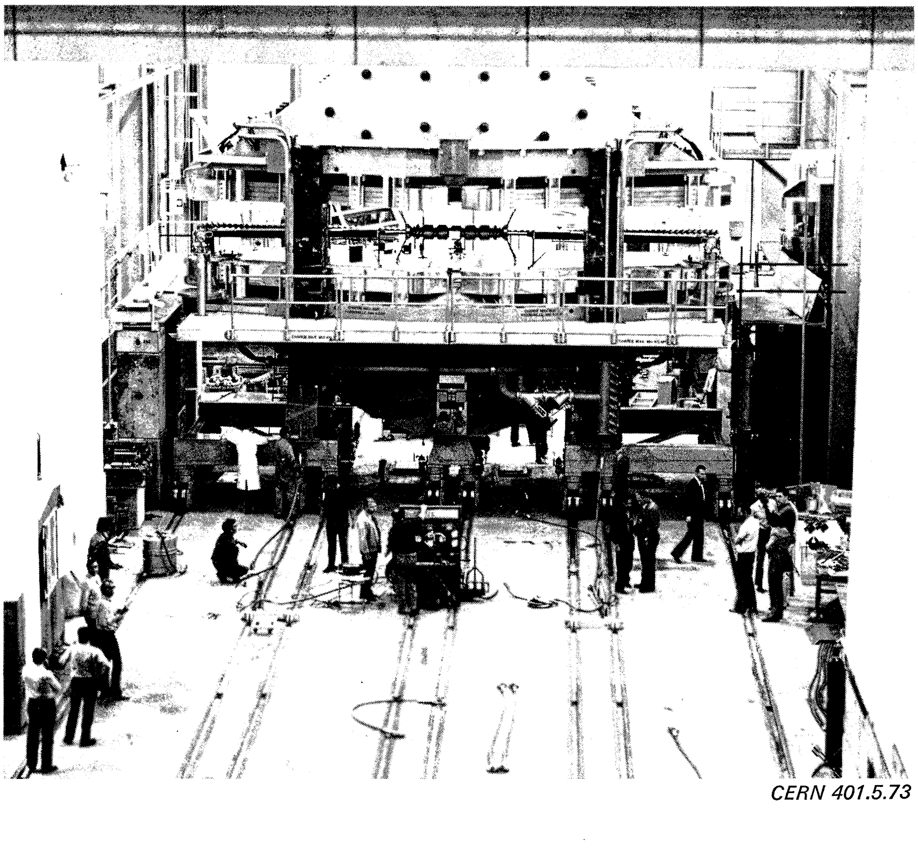
On 7 June, the experimental programme at the 600 MeV synchro-cyclotron came to a halt and the machine is shut down for about a year for a series of major modifications. The SC was the first accelerator to operate at CERN and has been in service for almost sixteen years. For several years, work has been under way on an improvement programme to update the machine properties so that the SC becomes again a 'front line' accelerator in its energy range.

The improvement programme was first mooted in 1967 and was given official blessing in November 1968. The main aims are to increase the beam intensity (from 1 to 10 μA) and to improve the efficiency of beam extraction (from 5 to 50 %).

The increase in intensity will be obtained by raising the acceleration voltage and the repetition frequency of the acceleration cycle by means of a new r.f. system. A rotary capacitor is the heart of the new system and will replace the old tuning fork. It is designed to give an acceleration voltage of 30 kV and a repetition rate of 466 Hz. The technological problems encountered during its construction have delayed the implementation of the improvements by more than eighteen months but the r.f. equipment has now been satisfactorily tested at the manufacturers and is on its way to CERN.

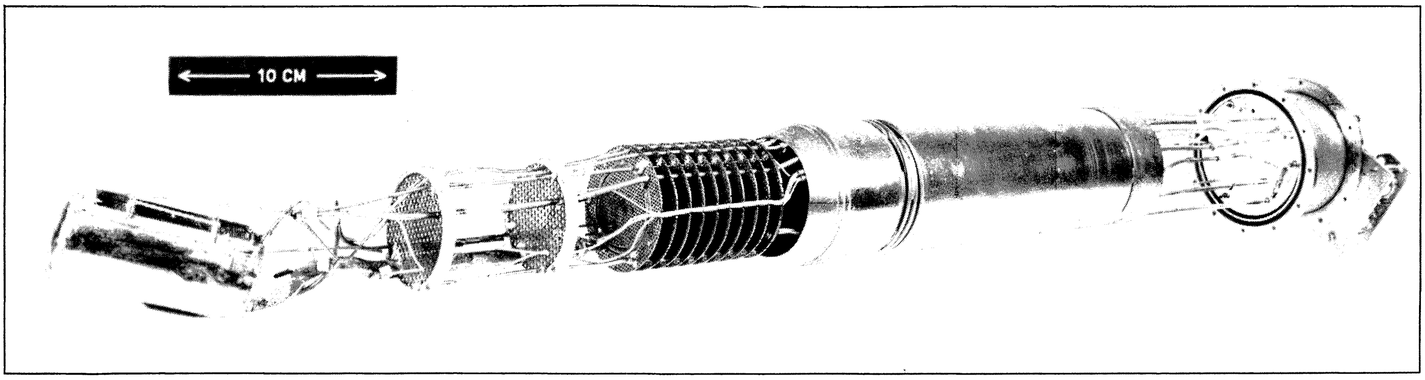
The low extraction rate obtained at

The 1000 ton Split Field Magnet being pulled into position in the ISR at the end of May. It passed with just a few centimetres to spare through the door, which is normally filled with a shielding wall, connecting its assembly annex to the storage rings.



CERN 401.5.73

Polarized proton target 100 cm³. Gaseous helium 3 enters from the right and is cooled in a series of three heat exchangers before passing through an expansion valve into the target volume. The target, 10 cm long, is on the extreme left in the photograph and is filled with beads of propanediol. A waveguide feeds 80 mW to the target volume at 70 GHz. The liquid helium cryostat itself sits in a helium 4 cryostat which is not shown.



CERN 99.1.73

the SC, and at other accelerators of the same type, is mainly due to radial betatron oscillations whose amplitude can reach about 10 cm. In the renewed SC this amplitude will be reduced by installing a new type of ion source (hooded arc). The central region of the machine will also be modified to provide axial focusing of the beam close to the source where magnetic focusing is not effective. It will thus be possible to obtain a narrow beam.

Extraction in the existing machine is also reduced by the interference with the main magnetic field caused by the extraction channel. An electromagnetic channel fitted in the renewed SC will reduce this interference and increase the effectiveness of the extraction system.

The internal target system will not be abandoned and will continue to provide beams of mesons and neutrons in the neutron hall. It has been necessary to re-think the design of the targets completely in order to take account of the energy which will be dissipated in the targets under the new machine operating conditions. Few modifications are intended for the secondary beams in the neutron hall. New high intensity pion beams with varied characteristics will be provided for the proton hall.

Two devices will increase the duty cycle of the beams to the experiments: a peripheral secondary acceleration electrode (the C) will produce long-lived bunches onto the internal targets and a pulsed magnetic field will allow the stored internal beam orbits to be displaced and thus make slow extraction possible.

Dismantling and reassembly of the accelerator will take place in several stages. The existing r.f. system and the polepieces will first be removed giving access to the vacuum chamber which will then be withdrawn. Any damaged coils will be replaced by new ones with coils insulated with glass-fibre and potted in resin. While the coils are being fitted, the polepieces and then the magnet yoke will be drilled so that the new ion source can be introduced vertically into the machine from below. It will then be possible to fit a new vacuum chamber, the polepieces and the new central region. Finally, the r.f. system will be installed.

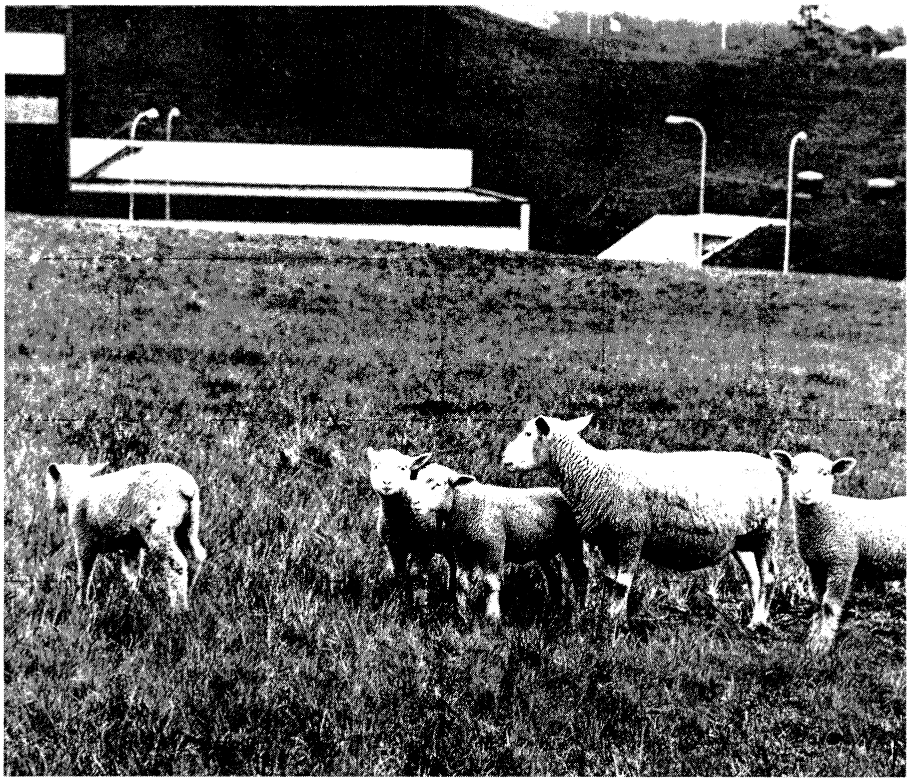
Thorough tests are scheduled during the various reassembly phases and it is estimated that it should be possible to re-commission the SC in May of next year.

New advances in polarized targets

Further steps forward in the development of polarized targets have been taken using a new target material — 1.2 propanediol. The target was subjected to a magnetic field of 2.5 T and cooled with the help of a helium 3 cryostat, which made it possible to reach cryostat temperatures as low as 0.5 K, and reached a polarization of 90 %. The use of the same substance has made it possible to polarize a large volume target, 100 cm³, to the extent of 70 %. Its size makes this target a 'first' in the construction of targets for use in experiments.

A general description of the techniques in polarized targets can be found in vol. 7, page 28. They involve high magnetic fields, very low temperatures and microwave power to line up particle spins in a known direction. A group at CERN has done much pioneering work on such targets and particularly on new materials which are more readily polarized. Propanediol was first polarized at Berkeley (to 50% at 1 K) and has since been improved at CERN.

It has been found that propanediol is a good substance for the construction of frozen spin targets such as are being developed for use in the Omega spectrometer. In frozen spin targets, polarization is achieved in good conditions and the target is then transferred to the position where it can be better used for particle physics experiments. Such a system is also being developed at the Rutherford Laboratory. Propanediol has two advantages. The 'relaxation' time is very long — one month to revert to its initial state in planned experimental conditions (i.e. with a field of 2.5 T and a temperature



All large organizations have their sheep and CERN is no exception. A herd was brought to work on the grass covered mounds of the ISR in May and provided a very pleasant Springtime diversion.

CERN 4.5.73

of 0.06 K). The necessary time to achieve polarization is very short — two to three minutes with a microwave power of 6 mW per cm^3 (this is about four times faster than butanol which in addition only reaches a polarization of 70 % as against 90 % for propanediol).

After these fine results had been achieved, research with this substance continued at lower temperatures. It has proved possible with the helium 3/helium 4 dilution cryostat (see vol. 11, page 353) to obtain a positive polarization of about 98 % and a negative polarization near 100 % at a cryostat temperature of 0.16 K and a magnetic field of 2.5 T. The temperature of the propanediol remained at 0.37 K as a result of the heating effect of the microwave power.

The research then extended to deuterized materials which make it possible to obtain polarized deuterons. It is more difficult to polarize deuterons than protons because of their lower magnetic moment (six times smaller than that of the proton). With the same magnetic field, thermal agitation more readily disorientates the spins of deuterons than of protons.

During the first tests, partially deuterized 1.2 ethanediol, which has similar properties to 1.2 propanediol, gave a polarization of 37 % for deuterons while the residual protons in the target were polarized to 97 %. The significance of these results becomes more obvious when it is realized that these values correspond to the same spin temperature (0.0012 K) for both protons and deuterons.

The advantage of dynamic polarization using microwave power, as opposed to the static (or 'brute force') method using only high field and low temperature, is very obvious. By the static method, even if it were easy to reach a temperature of 0.0012 K, months or possibly years would be needed before thermal equilibrium was reached between the cryostat and the nuclei of the target and thus before these polarization rates could be attained.

It was intriguing that the different nuclei of the ethanediol target assumed the same spin temperature and the CERN group has been studying the way in which this coupling took place. It seems that the phenomenon is brought about via the free electrons of the substance which, by their interactions, generate a reservoir of energy called a spin-spin interaction reservoir. The different kinds of nuclei couple thermally to the reservoir and this is thought to be the mechanism whereby such high polarization rates are obtained. The microwave power cools the reservoir and, via the thermal coupling, the nuclei are cooled to the same temperature and are highly polarized since there is a direct relationship between temperature and polarization.

The big chambers

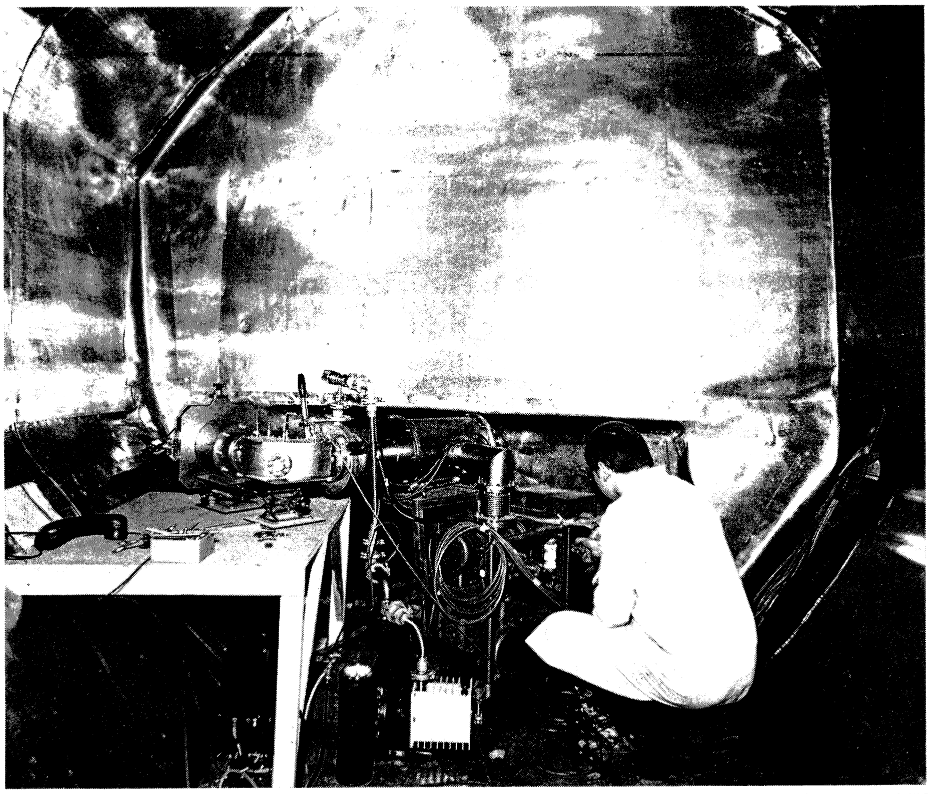
By the time this issue appears, if all goes to plan, the European bubble chamber, BEBC, will have started its first physics run.

Only two cameras were in action when the first pictures were taken in the chamber at the beginning of March and it was not possible during the test programme to determine all the optical parameters required for the geometrical reconstitution of the photographed tracks. This will therefore be the first task of the run. For the first experiment (being carried out by a Birmingham-CERN-Glasgow-Heidelberg-LPHE Paris collaboration) the chamber will be fed with a separated 9 GeV/c negative kaon beam to study kaon-proton interactions. At least half a million pictures will be taken.

Apart from the quickly repaired hydrogen leak that we mentioned in the March issue, no serious problems arose during the previous tests which is a very encouraging sign for the physics programme. The chamber now has to show its paces in the relentless running of normal experiments. It will operate with a metal piston until the Autumn when the permanent plastic piston will be installed.

While BEBC is entering the commissioning phase, the heavy-liquid bubble chamber, Gargamelle, has just resumed operation for a series of neutrino experiments using a freon filling.

The experiments scheduled for last December had to be postponed for safety reasons. Vibrations, caused by the enormous forces of the pressure cycles, had fractured some of the pipework and thorough surgery was necessary during the long shutdown of the proton synchrotron at the beginning of this year. The pressure system was completely dismantled. The trolley which carries the nitrogen



View inside the heavily shielded room where measurements on rare isotopes of lithium and sodium were carried out. 3.4 m of concrete and iron hide the detectors from the target region and, in addition, the room is lined with cadmium to cut down the background of neutrons.

CERN 17.1.72

reservoirs (having a capacity of over 50 m^3) was rebuilt. The framework was reconstructed using tougher girders in a close triangular pattern and, to improve rigidity, the wheels were replaced by piles set firmly in the ground. Struts bearing on the sides of the pit were also added in order to absorb static and dynamic reactions.

The repair of the pressure system went without incident and the chamber was tested again in mid-May. The desired results were achieved — the vibrations which had caused trouble with the previous structure are now damped out and experiments can safely continue.

New measurements on rare isotopes

A team from the Laboratoire René Bernas at Orsay completed a series of experiments at the proton synchrotron in May which has given new information on rare isotopes of lithium and sodium. They have measured the mass of lithium 11 to an accuracy of one part in 10^5 (i.e. to 150 keV) and have more precise date (masses to within 100 to 800 keV) on sodium isotopes from sodium 27 to 32. Measurements with this precision are not exceptional for stable masses but are a considerable achievement for isotopes so far from stability.

The Orsay work supplements the research at the isotope separator ISOLDE at the synchro-cyclotron (see for example vol. 10, page 4) where refined measurements on heavier elements of the periodic table are carried out. Orsay have concentrated on the light exotic nuclei which need GeV energy protons to be produced and live milliseconds (rather than seconds or minutes for the nuclei studied at ISOLDE). Very little is known about these nuclei and there are a number of interesting questions to be answered.

The stability of lithium II for example has posed an interesting puzzle ever since it was discovered by a group at Berkeley in 1966. Most theoretical calculations predict it to be unbound and to give off two neutrons instantaneously. The precise mass measurement by the Orsay group shows that it is marginally bound (by some 200 keV only) and this can probably be reconciled with current theories.

The measurements performed on a sequence of sodium isotopes are interesting because there are terms in the mass formulas that diverge rapidly when the number of neutrons is increased, giving predictions that can differ by tens of MeV. The few hundred keV precision of the PS experiment can thus select clearly between the models.

The experiment sat along the neutrino beam-line from the PS where it could receive protons ejected at an energy of 25 GeV. The protons were directed onto a special target consisting of thin foils of uranium and graphite interleaved. Collisions with the uranium nuclei ejected nuclear fragments into the graphite which was heated. Alkalies diffuse rapidly through graphite and emerge as ions from the surface. Electric fields then pull them through a mass spectrometer which sorts out the different isotopes. They are detected in an electron multiplier which counts ion impacts. The masses are measured by a modification of the well-known isotopic doublet method.

A significant feature about the latest measurements, which has yielded the greater precision, has been much better shielding between the target region and the detector region. The isotope signals can be lost in the flood of neutrons from the target region and, to reduce this dramatically, the detector is placed in a shielded box lined with cadmium (which has a very high cross-section for catching neutrons). On the target side there is a wall of concrete and iron 3.4 m thick. With this arrangement the isotope signals soar out of the neutron background. Typical counting rates were 30 counts per PS pulse for lithium 11 and 1 count per 20 PS pulses for sodium 32 (which is a very exotic isotope).

In addition to the mass measurements the isotopes could be studied using a neutron detector and a beta detector. The phenomenon of delayed neutron decay is well documented for heavy elements but much less so for light nuclei. The measurements on lithium and sodium more than doubled the number of known light delayed neutron emitters. Sodium iodide detectors were used to obtain new spectroscopic information on the excited states of the isotopes by observing the gammas emitted as they decayed to more stable states.

The Orsay group enjoyed the collaboration of physicists from Berkeley and Darmstadt.

Scanning tables at CERN

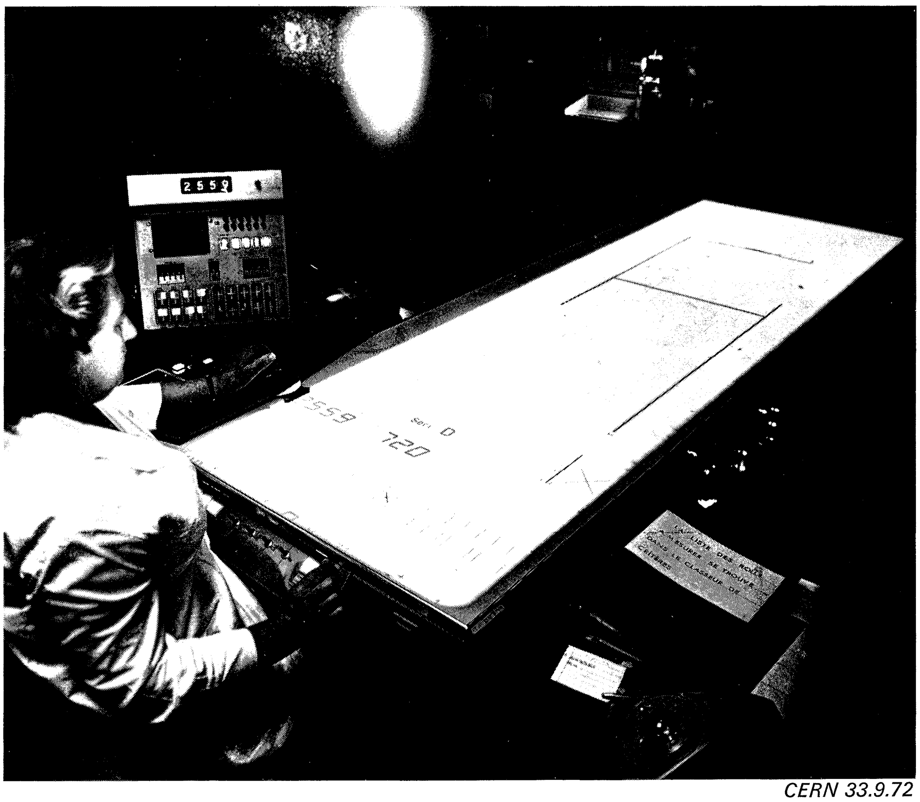
The photographs of the tracks made in a bubble chamber by the passage of high-energy charged particles constitute one of our most direct means of access to the sub-nuclear world. In no other detection technique do we get such a satisfying portrayal of a sequence of particle interactions. The track images are recorded on stereoscopic photographs and are used to make a quantitative analysis of the phenomena which took place in the bubble chamber liquid.

The full measurement of an 'event' consists of a geometrical and kinematic analysis, determining the number, type, momentum and energy of the particles involved in the interaction. This measurement is made by reconstructing the spatial geometry of the tracks left in the bubble chamber by the charged particles then applying the laws of conservation of energy and momentum to the initial and final particles. But to arrive at this point several stages are involved. The film needs to be examined to see whether any events of interest occurred. Such events have to be measured and the computer can then get to work on the measurement data. This article is a brief review of the types of device used at CERN to implement particularly the first stage (scanning) of this process.

Scanning tables consist essentially of an optical projection system. They allow an operator to select interesting events, according to criteria which can vary from experiment to experiment, and to assemble sufficient data for subsequent measurement. These data are recorded in some way (on magnetic tape, for example) so that they can be fed to the measuring device when the film is measured. The scanning can be difficult, on the one hand because what is seen of a track on the film does not often, by itself, identify the particle which caused it and, on the other hand, because uncharged particles leave no track by themselves

Studying bubble chamber film on one of the MILADY scanning tables where sufficient information is collected to be able to tell the HPD measuring machines where to look. The operator picks out events of interest on the film and records details such as vertex position and a few track co-ordinates on magnetic tape.

An HPD (Hough Powell Device) which carries out precise measurement, automatically without human intervention, on the film previously scanned on a MILADY table. An optical-mechanical spot sweeps over the film and full track co-ordinates are transmitted to a computer.



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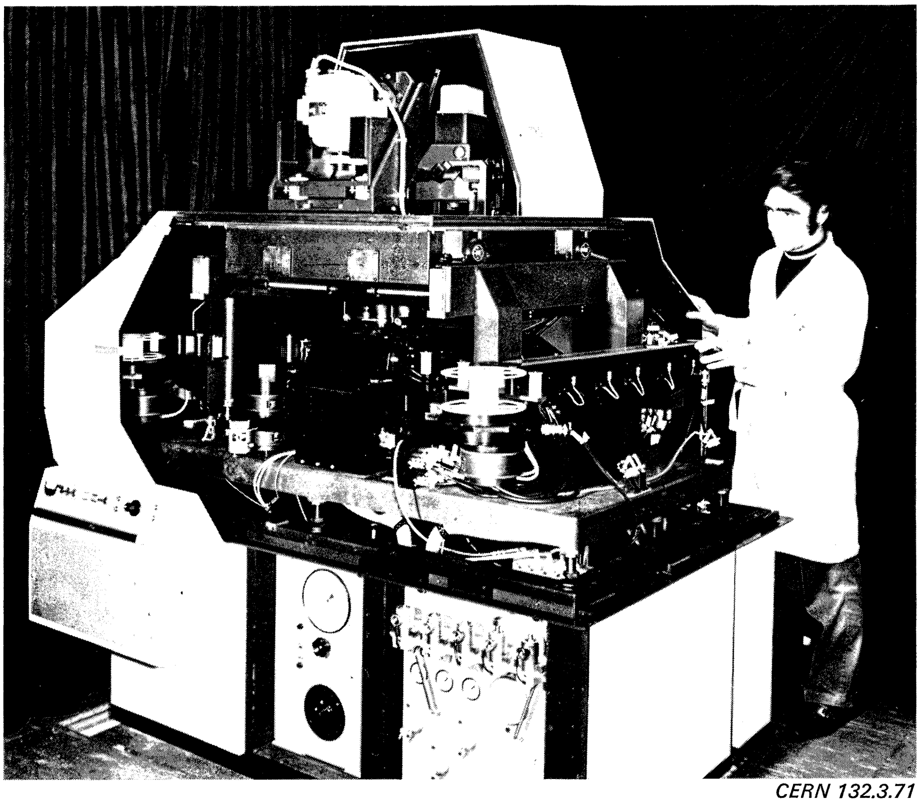

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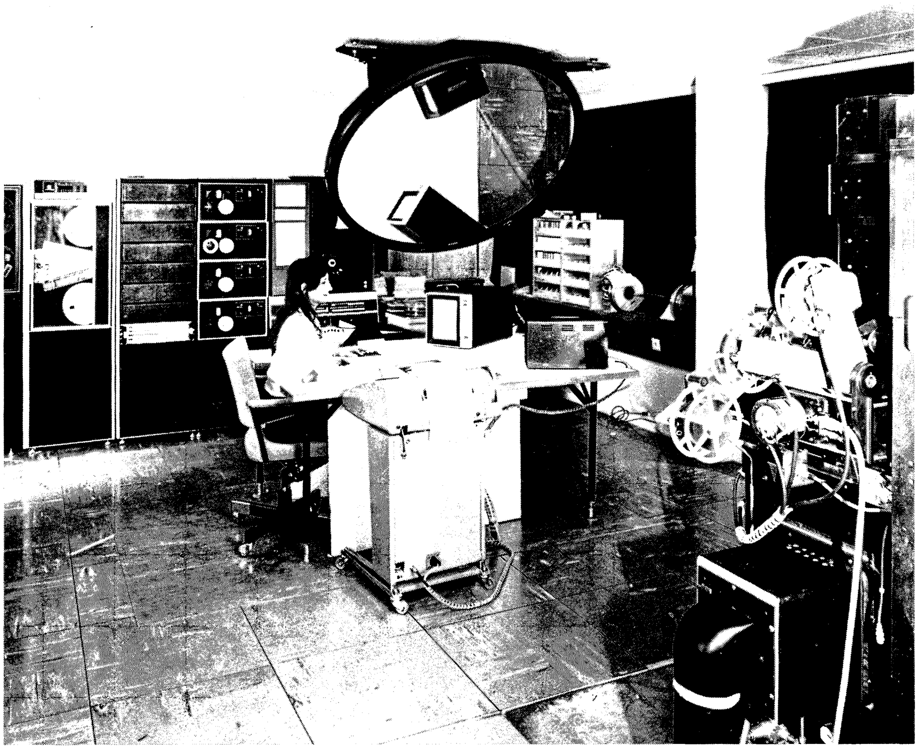
A LSD (or Spiral Reader) measuring machine which receives film previously scanned on Shivamatic scanning tables. An operator is involved in the measurement process to set the machine on the vertex of the event to be measured. A slit, moving in a spiral, then searches the film and sends track information to a computer.



CERN 202.5.72

in the bubble chamber and yet can be an essential part of the information which is required.

The increase in the number of photographs associated with bubble chamber experiments led to a search for new solutions, particularly aiming for the automation of scanning and measurement. Scanning is a relatively straightforward operation for a human being. However, it has proved very difficult to implement efficiently by an exclusively automated process. One of the first attempts was the HPD (or Hough Powell Device) which in its initial design, was intended to be an entirely automatic system for the selection and complete measurement of events of interest without human intervention. The bubble chamber film is scanned by a television-type sweep with an optical-mechanical spot recording the tracks of the charged particles.

Difficulties connected with operating conditions and with the available computer capacity showed, however, that a completely automated machine was not the best answer from the economy point of view. In the HPDs currently in service, the bubble chamber films undergo preliminary scanning on projection tables known as MILADIES. Ten MILADY tables are used at CERN connected to a computer which records the scanning data on magnetic tape.

The MILADY operator assembles data such as the serial number of the photograph, the event type and the approximate co-ordinates of the point of interaction (vertex) and of just two points on the tracks made by the particles. These data are then used by a program in the computer, which is designed to reduce the incoming mass of data as far as possible by collecting information from the film only as picked out by the scanning data. The lack of communication between operator and machine leads to a failure rate often as high as 20 % and hence there is a need for a recovery cycle using a separate system where there is a dialogue with an operator as the measurement proceeds.

Two HPDs have been used extensively at CERN for film from the 2 metre hydrogen bubble chamber. A number of other Laboratories also use HPDs and new scanning tables for use with HPDs adapted to film from the large European bubble chamber, BEBC, have been made by industry with assistance from CERN. These tables, named BESSY (BEBC European Scanning System), have been designed with economy very much in mind and fifty have been ordered by other research centres.

Another type of scanning and measurement system is the LSD (or Spiral Reader). It differs in several ways from the HPD. Although scanning on separate tables is still necessary, this operation is made as simple as possible. The scanning is carried out on Shivamatic scanning tables, of which there are six at CERN, connected to a computer which records information such as the serial number of the photograph, the event type and the vertex region.

This information is enough for the LSD because the assembly of data and the measurement stage are supervised by an operator, so that human intervention is possible and the need for a large on-line computer is avoided. The measurement data are kept to a reasonable volume by using, as a filter, a vertex-centred slit which describes a spiral. This rejects information on the film which is not related to the vertex of interest. When there are failures, there has to be re-measurement or a special recovery cycle.

Two LSDs are in service at CERN and are used to measure events on the films from the 2 metre bubble chamber.

The problems posed by the scanning of film from the large heavy liquid bubble chamber, Gargamelle, are very different. This is because of the special optics in Gargamelle, which has two rows of four wide-angle lenses. The SAAB scanning table has an optical system capable of projecting the four images from the same exposure simultaneously. These high precision tables make it possible to move the group of four images in such a way that they are either presented separately to the operator or superimposed partially or totally. The measuring operations are carried out on-line with a computer which is provided with the necessary data by the operator. Four of these scanning tables are in use at CERN.

Other tables, called MINNIES, are used for scanning and measuring the film from Gargamelle. Like the BESSY tables, they were designed for economy and they are suitable for scanning and preliminary measuring which does not call for the complexity which

A SAAB scanning table designed to cope with the special film from the heavy liquid bubble chamber, Gargamelle. The chamber volume is covered by separate cameras and separate images can be projected. Measurement is carried out on-line with a computer.

ERASME, the latest scanning and measuring system at CERN. It combines both stages and allows operator intervention in the measurement process to an extent which has not been possible before. ERASME is designed to handle film from the European bubble chamber, BEBC.

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CERN 237.12.72

the SAAB tables can handle. Three are in use at CERN. The projection system is placed above the table, thus dispensing with the ceiling mirror, and the eight projection lenses are mounted on a single stage.

The latest major development in the scanning and measurement of bubble chamber film at CERN is the ERASME system (Electron Ray Scanning and Measuring Engine). It is specially designed for scanning and measuring film from BEBC and its distinguishing feature is that it facilitates operator intervention in both scanning and measuring stages. The operator can identify interesting events by optical projection of the film and proceed to measure them by means of a precision cathode ray tube incorporated in the apparatus. TV displays allow the operator to assist in the process of measurement and data analysis, at any time.

The innovation of the ERASME system is this ability of the operator to follow the course of the complete measurement. If the reconstruction of the tracks of an event should fail, the operator can intervene immediately to provide additional information, correct certain results, or decide to remeasure all or part of the event.

Around the Laboratories

CAMBRIDGE Accelerator closes down

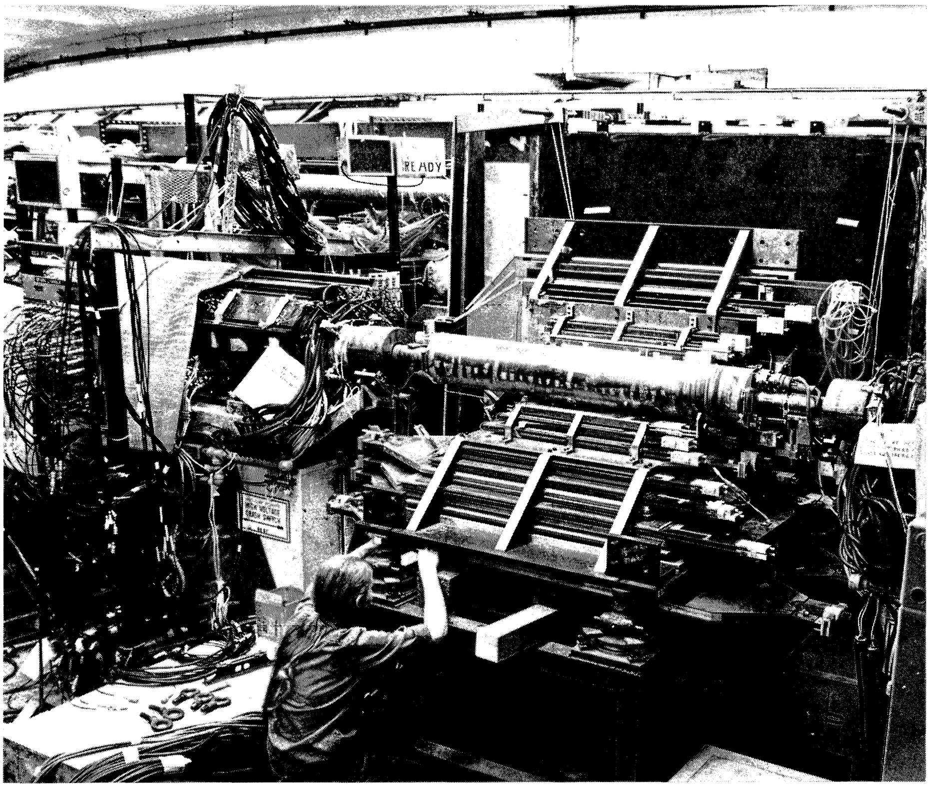
On 19 May high-energy beam was accelerated for the last time in the Cambridge Electron Accelerator. Operation at low energy, to complete three synchrotron radiation experiments, continued for two weeks more before the synchrotron was finally closed down.

The Laboratory was funded by the U.S. Atomic Energy Commission and run by M.I.T. and Harvard. Construction of the accelerator began in 1957 and it came into action in March 1962 as the highest energy electron synchrotron in the world. It was designed as a 6 GeV machine to give 6 × 10^{12} electrons per second — both these figures were slightly exceeded (6.28 GeV, 9 × 10^{12} electrons). The machine design contributed a great deal to the subsequent design of electron synchrotrons at Daresbury, DESY and Yerevan.

High-energy physics, particularly studying aspects of electromagnetism, was carried out at the Laboratory from 1962 until 1970 when budget cuts restricted the research programme to colliding beam physics. This was done in a special loop, known as the bypass, added to the synchrotron ring. In the bypass, electron and positron beams of energies up to 2.5 GeV could be specially treated and brought into collision. The last of these experiments, which finished on 19 May, are now being analysed.

An attempt was made to keep the accelerator alive as a synchrotron radiation facility but this was not supported by the National Science Foundation.

The abilities of the Cambridge Electron Accelerator have been overtaken by other machines and it has now passed down the road already taken by the Brookhaven Cosmotron and the Princeton Pennsylvania Accelerator. As we record its closing down we pay tribute to the high quality of the machine physics and the high-energy physics which has come from the CEA Laboratory.



One of the last scenes of action at the Cambridge Electron Accelerator. The photograph was taken during the installation of the 'BOLD' detector around the collision region in the machine bypass. BOLD was used in the final high-energy experiments at the accelerator to study electron-positron interactions.

(Photo CEA)

BATAVIA Beam intensity climbing up

In the first week of June the accelerated beam intensity at the National Accelerator Laboratory did a quantum jump to well over 2 × 10^{12} protons per pulse and then continued to climb steadily as the machine was tuned.

The quantum jump followed some work with the sextupoles in the main ring — work carried out mainly by V. Ohnuma, R. Steining and E.J.N. Wilson (temporarily at NAL from CERN). It was suspected that the sextupoles, which are in the ring to control the chromatic properties of the machine, were in fact introducing stop bands and causing protons to be lost. After some theoretical calculations the sextupoles were physically shuffled around the ring and when operation began again the 300 GeV beam intensity per pulse jumped to 2.7 × 10^{12} compared with the previous 1.1 × 10^{12}. This was with only ten booster pulses being fed to the main ring. About 70% of the injected beam was accelerated to peak energy which is a much higher figure than had been previously achieved.

Further tuning during the following week took the intensity higher still and the latest information we have is that 3.99 × 10^{12} protons per pulse at 300 GeV was reached on 8 June. It is believed that 5 × 10^{12} is within grasp without any further major changes.

From Brookhaven comes the news that their intensity record has also been exceeded. On 25 May the AGS accelerated over 9×10^{12} protons per pulse. We hope to have more information for the next issue.

DARMSTADT UNILAC project

At the end of 1969 a new Laboratory was set up near Darmstadt for research particularly with beams of heavy nuclei. It will house a versatile heavy ion accelerator known as UNILAC, which is scheduled for first operation at the end of 1974.

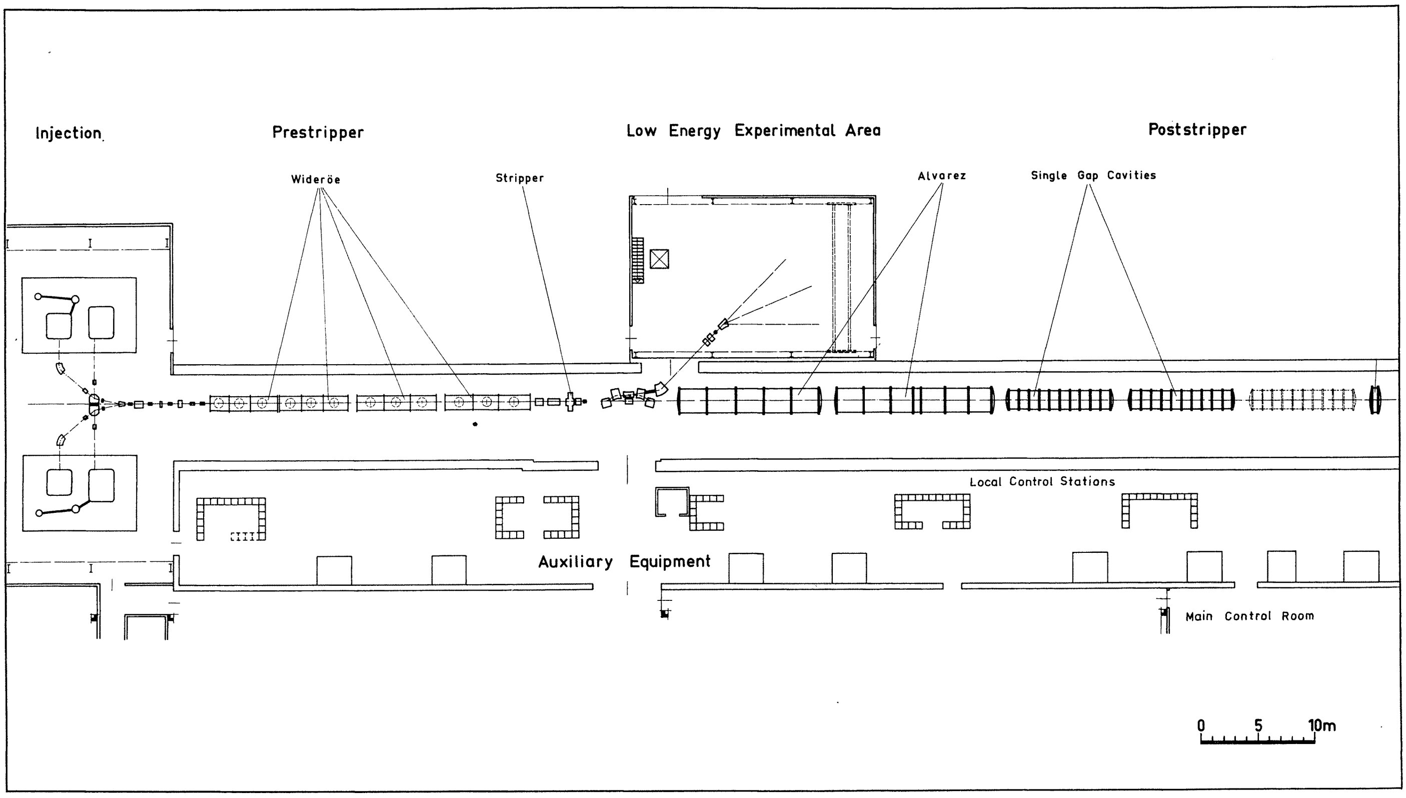
The accelerator design is almost a compendium of the different types of linear accelerator. The pre-injector stage will give two separate inputs so that the ion species to be accelerated can be changed smoothly. The first acceleration stage is a 'Wideroe structure' where the slow moving ions are accelerated each half cycle in the gaps between drift tubes, the tanks being fed with low frequency power. Such a structure was first used for the acceleration of heavy ions (mercury ions to 1.25 MeV) as long ago as 1931 at Berkeley.

There are then two short accelerating units of the helix type. One will serve to even out energies after the ions have passed through a gas or foil stripper increasing their charge; the other will serve as a rebuncher to form the beam prior to it being fed into a further acceleration stage using an Alvarez structure (as is familiar from most proton linacs). At this position, before the Alvarez tanks, beam can be bent off into a low energy experimental area for atomic and solid state physics experiments.

Finally, the Alvarez stage is succeeded by single-gap cavities which will take energies up to 8.5 MeV per atomic mass unit (using the gas stripper) or 10.2 MeV per a.m.u. (using the foil stripper). It is hoped to achieve high intensities, for example about 10^{14} ions per second at mass number 70, 3×10^{13} at mass number 184 and 2×10^{12} at mass number 238.

Initially however the machine will operate with lower capabilities — 3.6 and 5.9 MeV per a.m.u. and intensities such as 10^{13} for neon and 10^{11} for xenon. Xenon will be the heaviest ion to be accelerated until more r.f. power is installed at the Alvarez stage.

With these initial aims, the machine is scheduled to be brought into action at the end of 1974. Almost all the components are being manufactured. The accelerator tunnel is nearly complete and preparations are being made for the installation of the first units.



Layout of UNILAC, the versatile heavy ion machine being built at Darmstadt. The different types of linear accelerator stages are indicated. The ultimate design aims are to achieve energies as high as 10.2 MeV per atomic mass unit, to accelerate ions through to uranium and to have high beam intensities.

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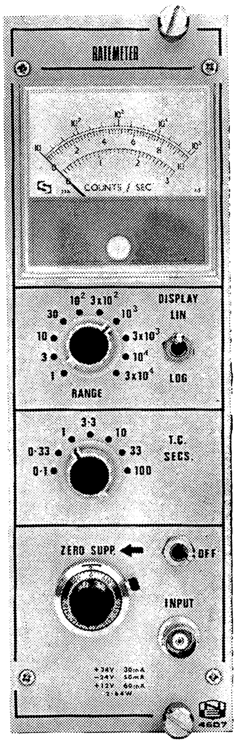

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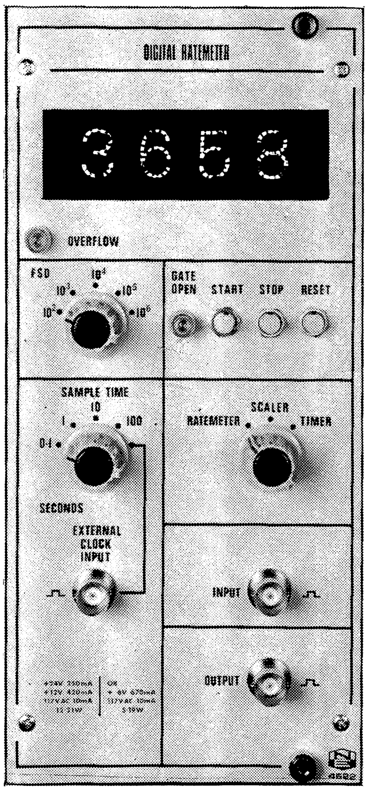

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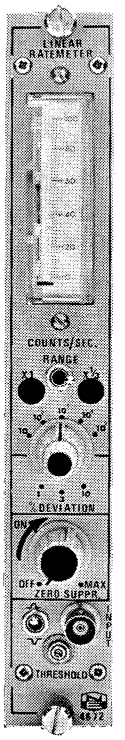

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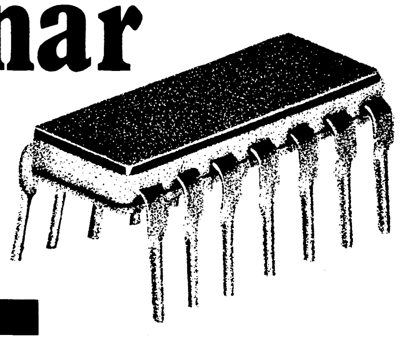

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93410

256-words × 1-bit

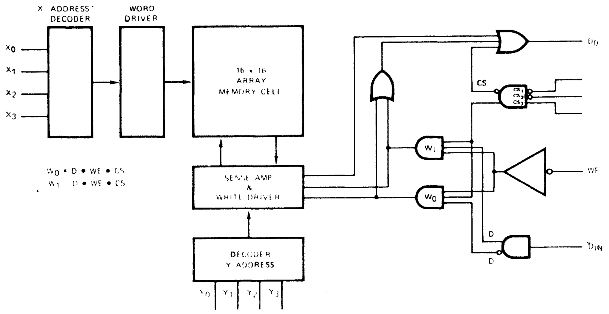
- 3 chip select Eingänge t ACS = 30 n sec
- Read access time t AA = 50 n sec
- Leistungsverbrauch 2mW/bit
- Nicht invertierter Data-Ausgang
- Data-Ausgang mit offenem Kollektor
- TTL-kompatibel
- Ebenfalls in ECL erhältlich
- 16-Pin Keramik DIL-Gehäuse

93415

1024-words × 1-bit

- 1 chip select Eingang t ACS = 30 n sec
- Read access time t AA = 60 n sec
- Leistungsverbrauch 0,5mW/bit
- Nicht invertierter Data-Ausgang
- Data-Ausgang mit offenem Kollektor
- TTL-kompatibel
- Ebenfalls in ECL erhältlich
- 16-Pin Keramik DIL-Gehäuse

Logische Schaltung 93410



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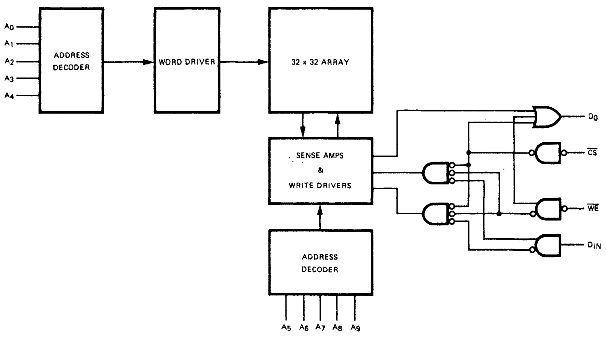

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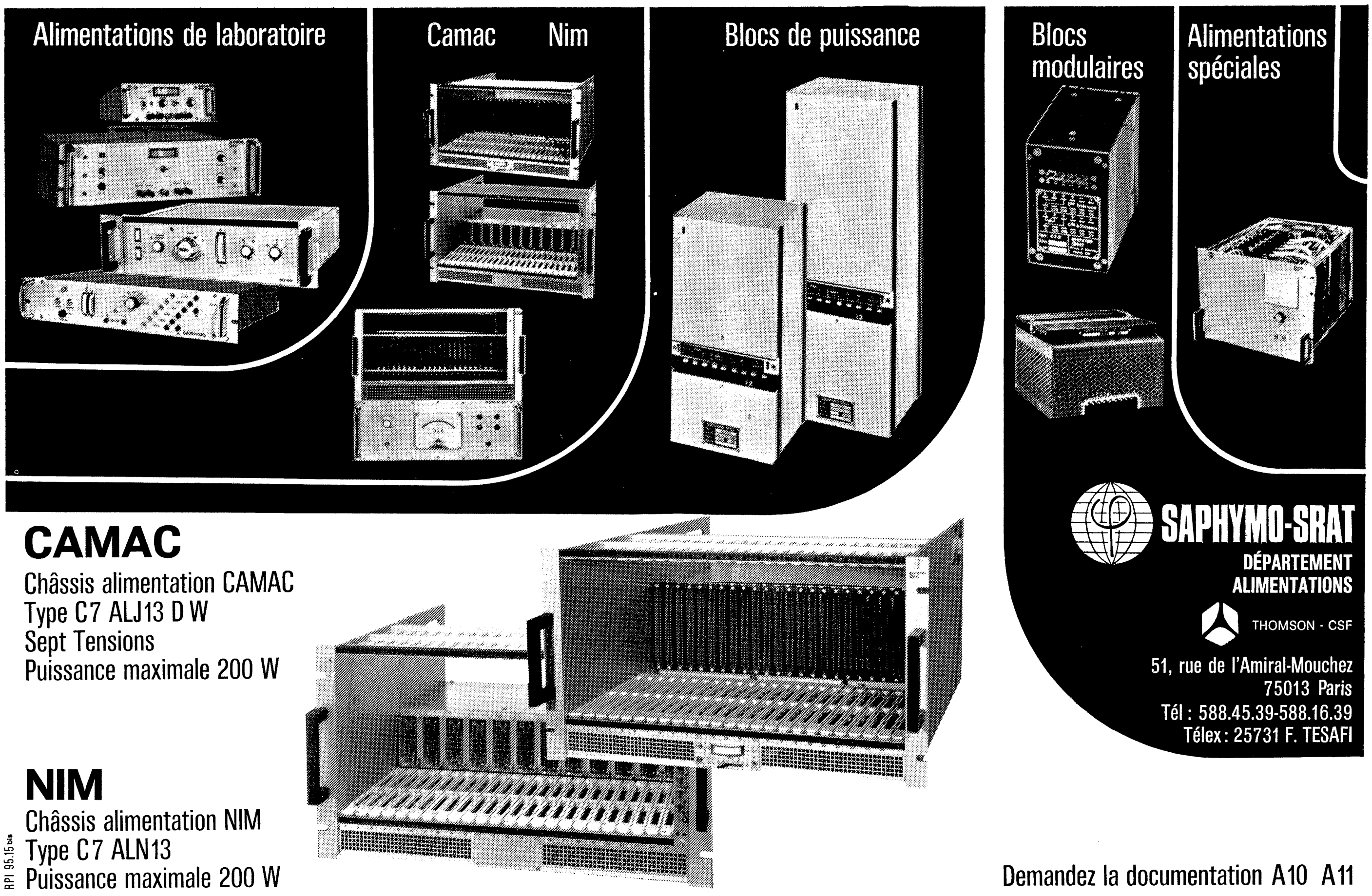

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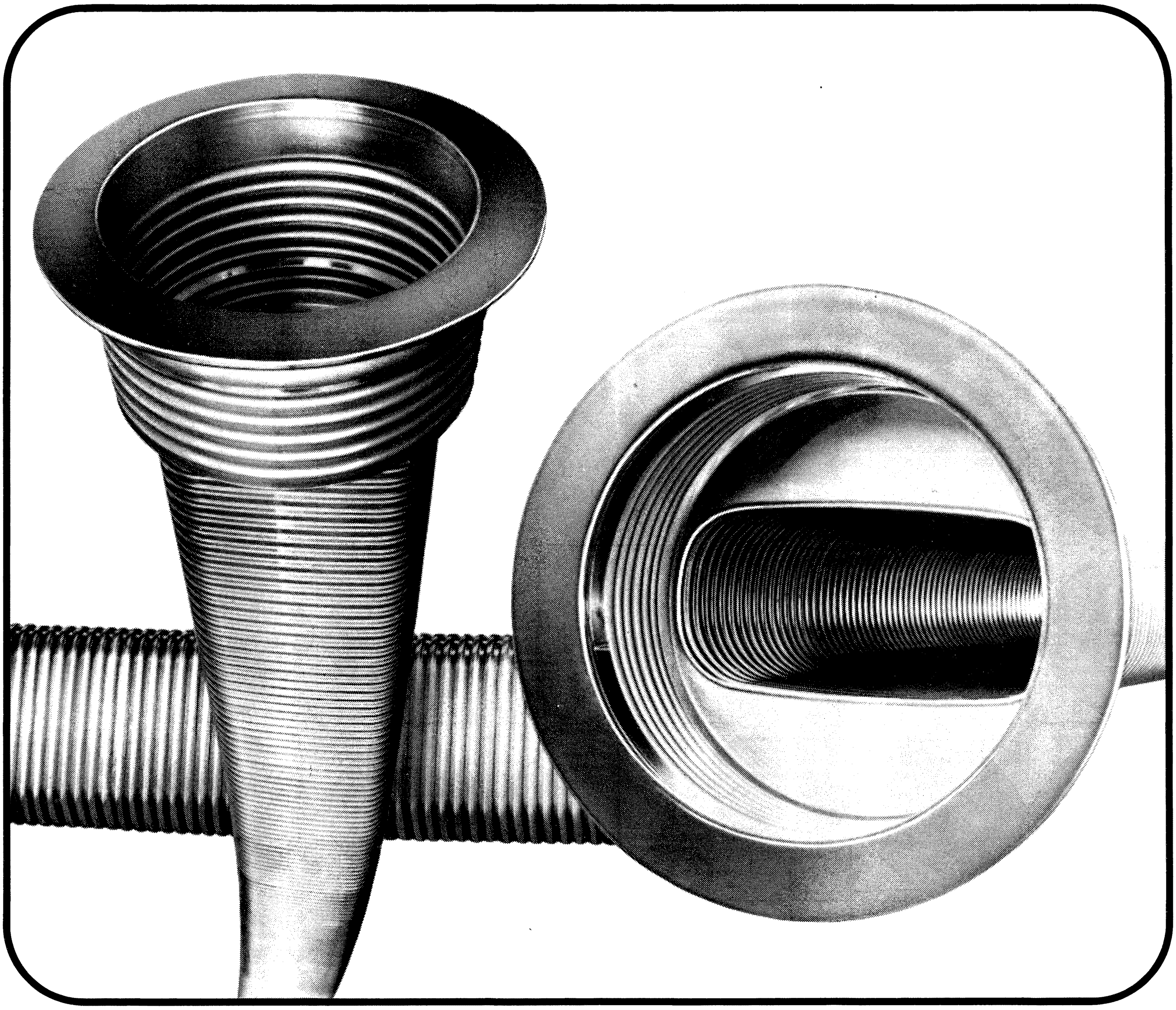

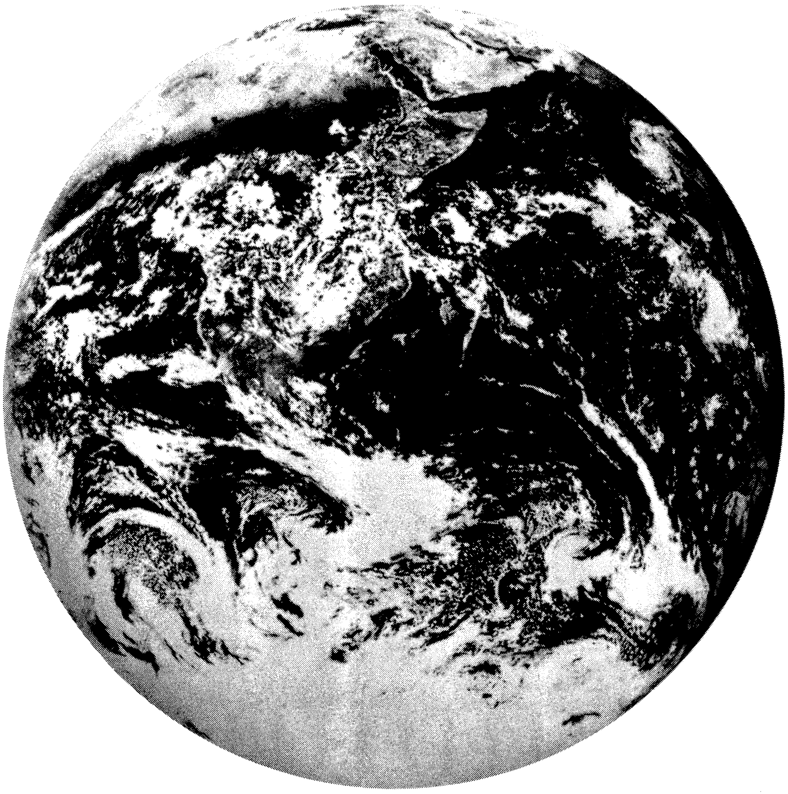

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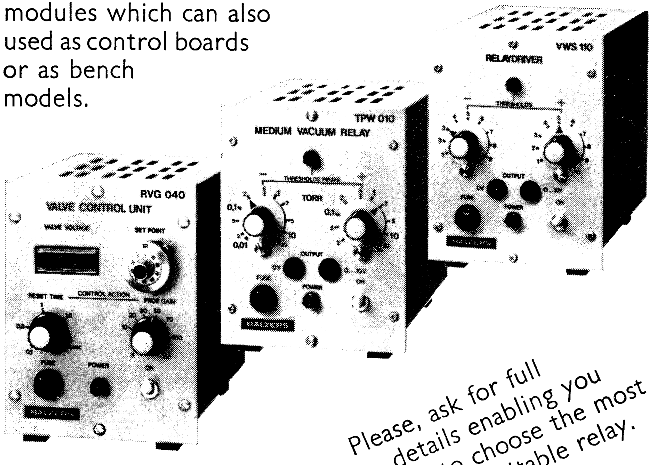

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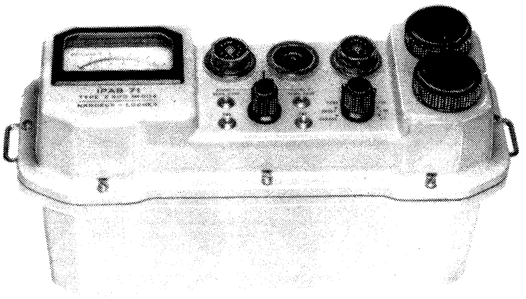

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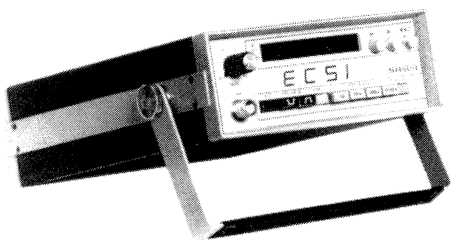

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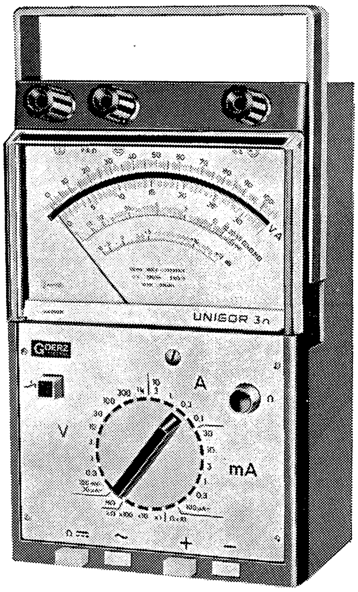
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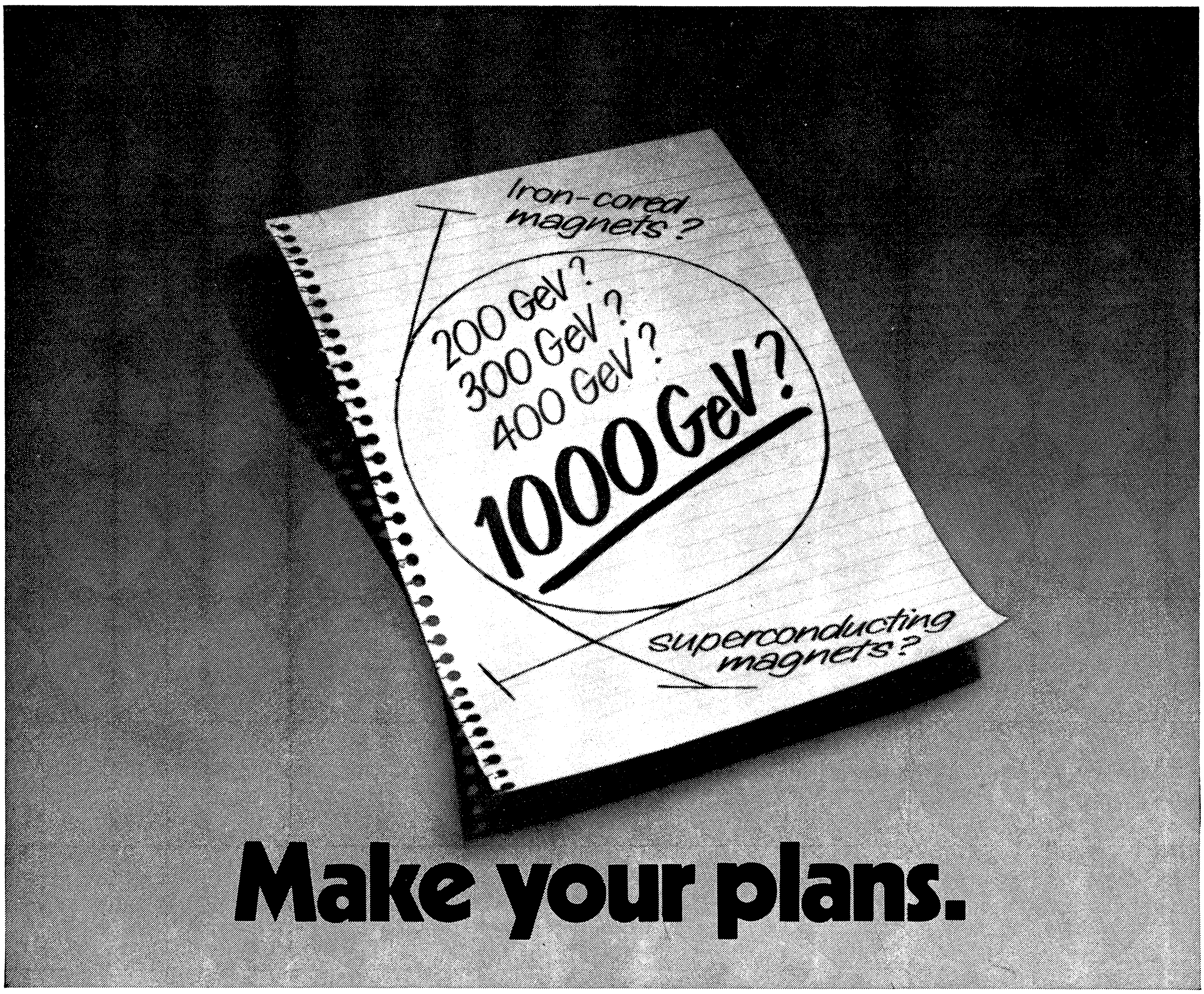

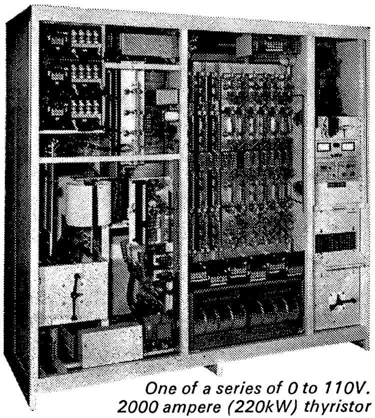

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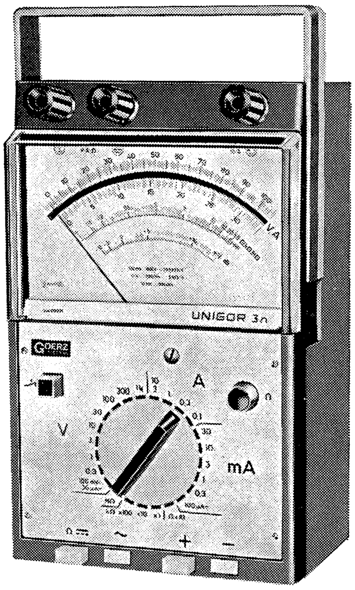

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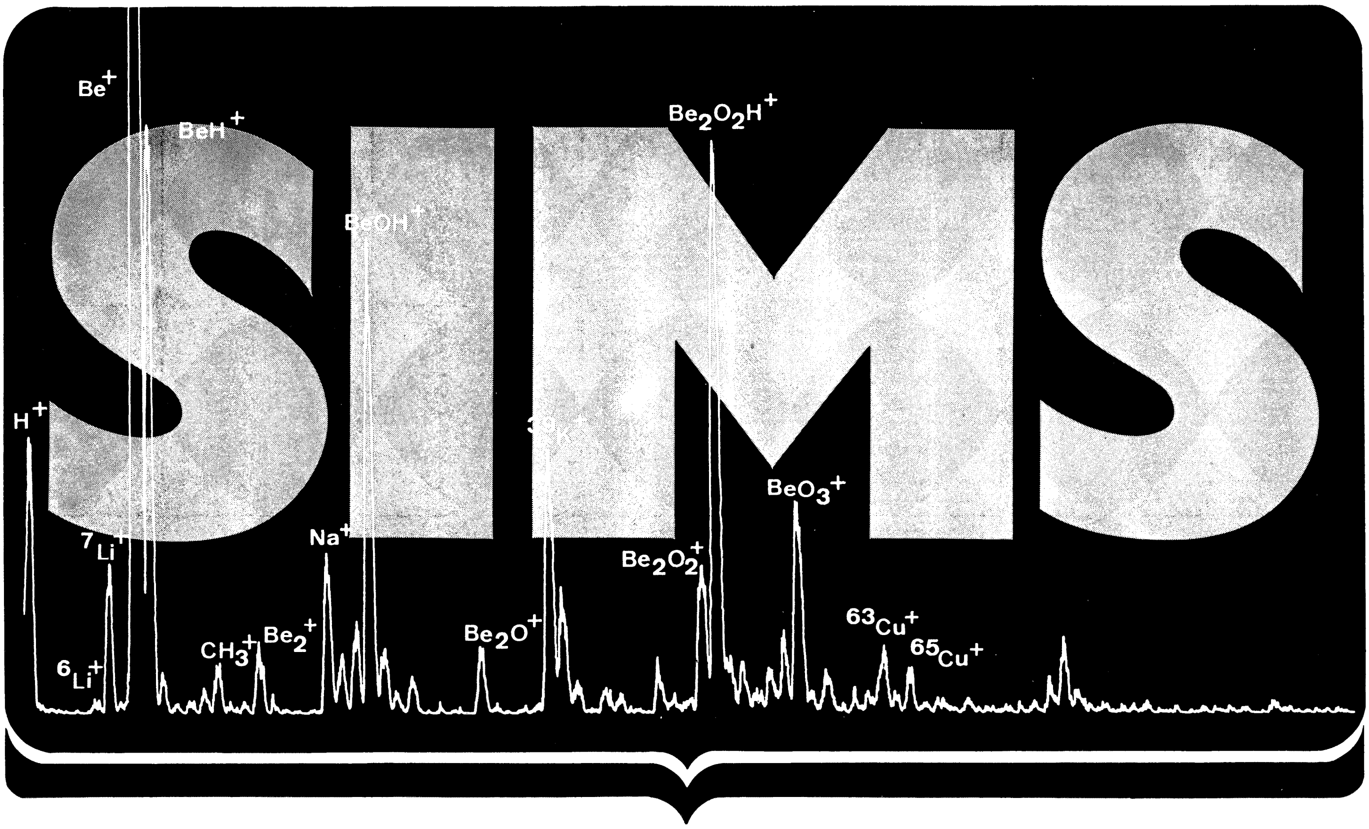

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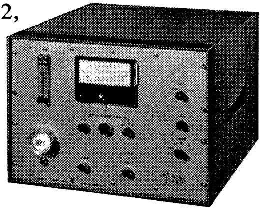

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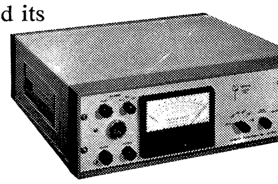

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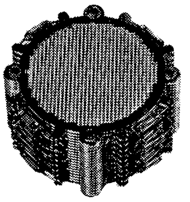

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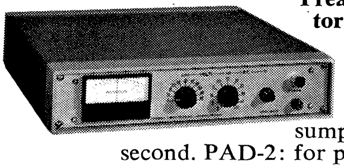

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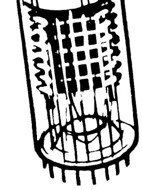

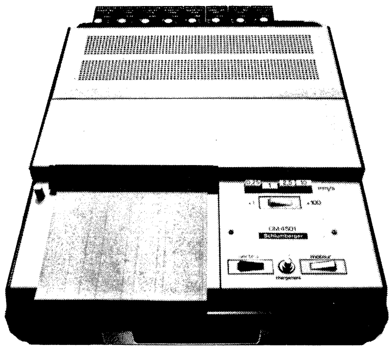

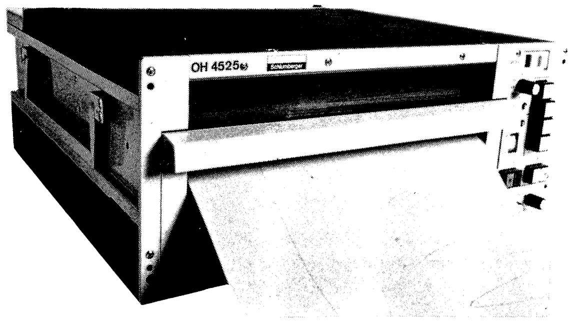
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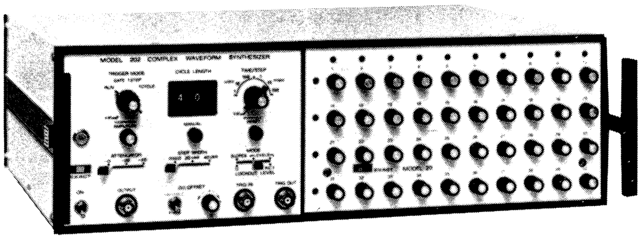

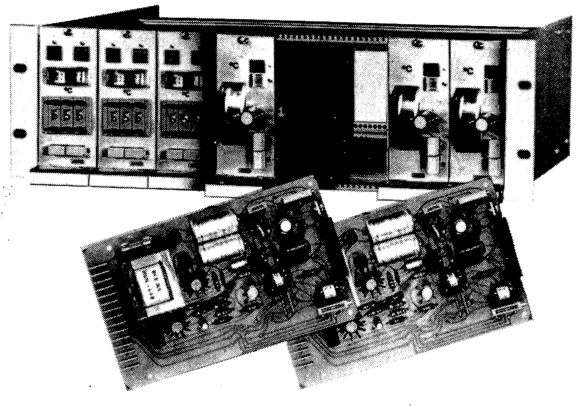

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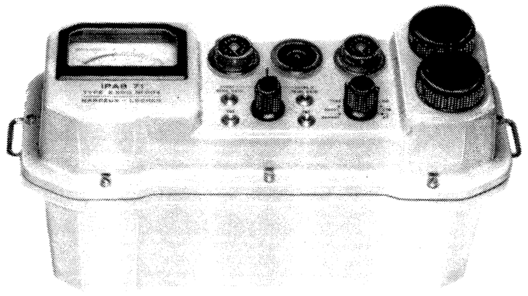

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Autonome, étanche, alarme

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- Seuil du discriminateur : 1 volt
- Capacités équivalentes : GM - PM : 0,6 pF
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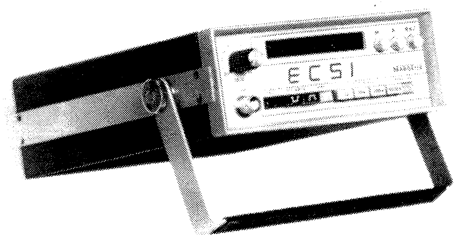

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E.C.S. 1 Réf. E. 521

Portative, autonome, 6 décades

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- Impulsions à l'entrée : polarité positive ou négative durée ≫ 100 ns
- Réglage du seuil : 0,1 à 10 V
- Impédance d'entrée : 1000Ω
- Température de fonctionnement : - 10° C + 50° C

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Usine : 37600 Loches - FRANCE

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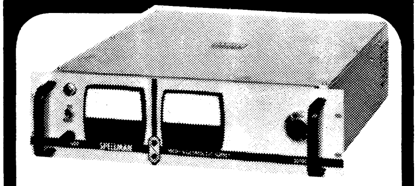

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Current	0-3 mA
Regulation and Ripple:	10 PPM
Polarity:	Reversible

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Output:	2 to 5 kV — 1mA
Input:	28 Vdc
Dynamic Focus Capability:	Programmable 200 volts peak to peak output with 4 µsec response
Frequency Response:	DC to 60 kHz

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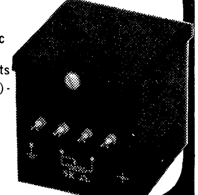

Input:	28 Vdc
Output Voltages:	from 400 Vdc to 4000 Vdc
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Ripple:	0.01%

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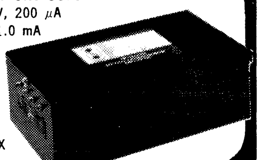

Anode:	10-15 kV, 200 µA
G-2:	400 V, 1.0 mA
G-1:	—100 V, 1.0 mA
Regulation:	0.1%
Ripple:	0.1%

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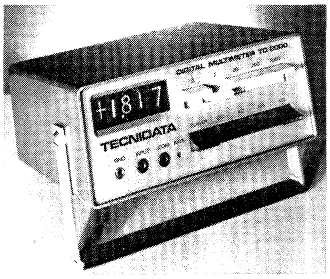

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