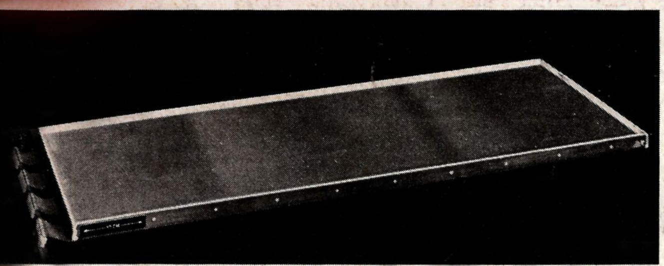
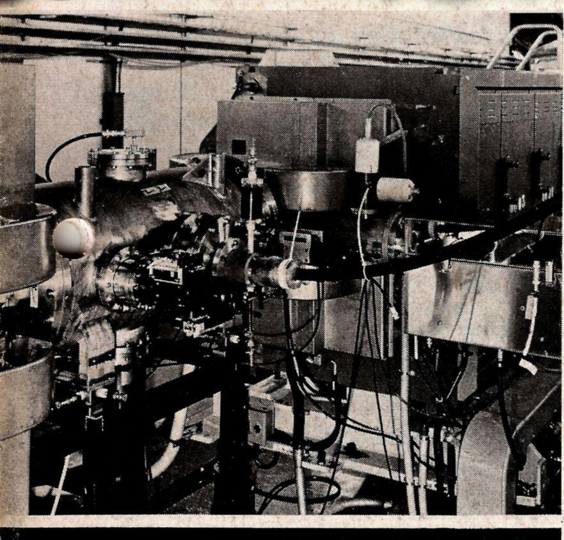
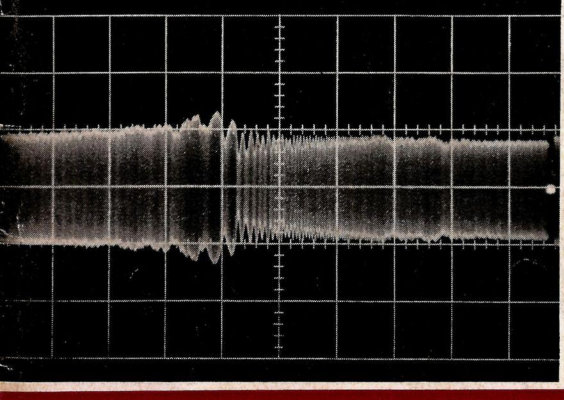
CERN COURIER

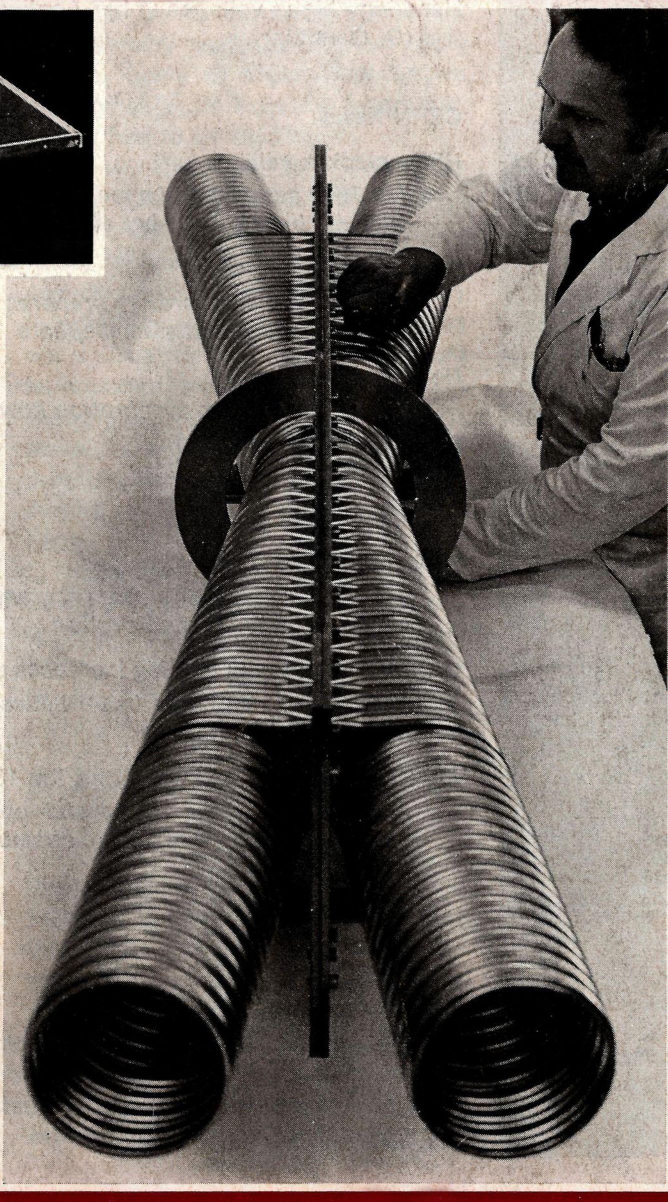
No. 11 Vol. 12
November 1972

European Organization for Nuclear Research









applied research at CERN

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.

CERN COURIER is published monthly in English and French editions. It is distributed free to CERN employees and others interested in sub-nuclear physics.

The text of any article may be reprinted if credit is given to CERN COURIER. Copies of most illustrations are available to editors without charge.

Advertisements are published on the sole responsibility of the advertisers.

Editor: Brian Southworth
Advertisements: Micheline Falciola
Photographs: PIO photographic section

Public Information Office
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 41 98 11 Telex 2 36 98

Printed by: Ed. Cherix et Filanosa S.A.
1260 Nyon, Switzerland

Contents

Cover photograph : Ultrahigh vacuum chamber, tracks in an ultrasonic bubble chamber, measurements on the behaviour of ferrites, multiwire proportional chamber, electrostatic septum... products of applied research at CERN which are described in this issue.

Applied research at CERN

In the words of its Convention, CERN exists 'for nuclear research of a pure scientific and fundamental character and in research essentially related thereto'. The applied research undertaken at CERN has thus been directed to the solution of problems, or the opening up of greater possibilities, in relation to its physics programme.

These problems and possibilities are often extremely demanding in both scientific and technical skills. It is often cited as a subsidiary reason for supporting activities such as high energy physics, that 'frontier' research, by virtue of its extreme needs, tends to promote advances in a variety of surrounding disciplines.

We concentrate this month on a few applied research stories from the work of recent years at CERN. They are not intended to be a comprehensive coverage. For example, we have left aside computing work (since this was covered extensively in the March issue) and other topics recently given a lot of attention.

Nevertheless, we hope that the few stories give an idea of the range of applied research at CERN and of its challenging nature. Some of the work has had very successful application, some would need much further development to bear fruit, some has been superceded by other advances. It cannot all be of immediate use — that is part of what the word 'research' means.

The research, as emphasized above, is linked to CERN's physics programme and it is there that applications are sought. But applications can obviously be found outside, both from direct use of the device or technique evolved, or from other uses of the knowledge which is unearthed, or from the increased expertise of industry working together with CERN. All knowledge emerging from the work of CERN is freely available for application elsewhere if application can be seen. Perhaps we do not do enough to make known our applied research activities and this issue may help a little in this direction.

Much ado about nothing

The vacuum system of the ISR

R. Calder

The vacuum system of the CERN Intersecting Storage Rings differs from those of typical particle accelerators in one vital respect : the pressure has to be four to five orders of magnitude lower. This requirement can be readily understood in terms of the time ratio the particles spend circulating (of the order of one second in an accelerator and, typically, one day in the ISR). It would be an exaggeration to say that the problem of attaining this vacuum was more difficult in the same ratio but it was considerably more difficult and involved many basically different techniques. Some of these were known on a small scale from the laboratory, others had to be developed.

A major triumph of the ISR vacuum system has been the successful marrying of many hitherto specialised laboratory techniques into one very large and very complex system without loss in reliability or performance. It is still not unusual to find ultra-high vacuum laboratories which have difficulty in working at 10^{-11} torr — in the ISR there are hundreds of metres at this pressure and soon it is expected to extend to the full 2 kilometres of the rings.

This article will try to sketch some of the problems encountered in meeting the requirements of the vacuum system and how the applied research in this field led to their solution.

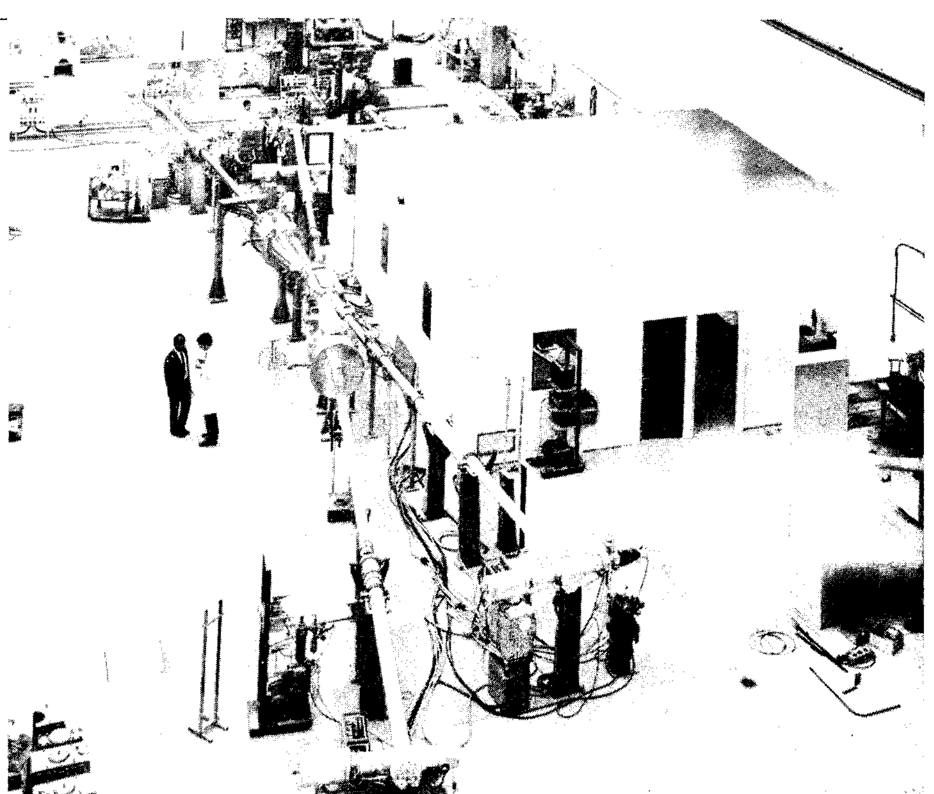
Sources of gas

The pressure in a vacuum system, in the simplest analysis, is given by the balance between the residual gas inflow rate and the exhaust rate. The latter, determined by the size and speed of the vacuum pumps, is limited by available space and cost. The former is the sum of several sources including leaks from the surrounding atmosphere, desorption of gas which has been adsorbed on the interior surface of the vacuum chamber and the permeation of gas through the chamber material itself.

Assuming that all leaks have been eliminated — in itself not a trivial problem since these may range from leaky joints to microscopic pores via slag inclusions in the chamber material — and that surface desorption has been reduced to a negligible value by in situ bakeout of the vacuum system at 300 °C, there is left what perhaps appears the negligible possibility of gas permeating through the metal chambers. In fact, this constitutes the major limitation in a vacuum system such as the ISR where the available pumping speed is severely restricted by the low conductance of the chamber.

The chamber material is a nitrogen enriched austenitic stainless steel chosen on the basis of mechanical strength, low permeability, good vacuum properties, etc. Careful measurements showed that this material, even after an in situ bakeout at 300 °C, was releasing hydrogen gas at the rate of about 3.10^{-12} torr litre per second per cm^2 (equivalent to about 10^8 hydrogen molecules per second per cm^2). The measurements also showed that this hydrogen appeared to be diffusing out of the bulk of the material (rather than desorbing from the surface) and the constancy of the rate over long times suggested a virtually infinite reservoir of hydrogen. This was confirmed by chemical analysis which showed the hydrogen impurity to be about 0.001 % or 10^{19} molecules per cm^3 of steel.

This outgassing rate would have caused unacceptably large pressures in the beam pipe between pumping stations — pressures which could not be reduced by larger pumps but only by reducing the outgassing rate by one to two orders of magnitude. Laboratory measurements showed that the



The special vacuum chamber prepared for intersection region I-6 undergoing tests in the West Experimental Hall. Note the conical form of the two downstream sections of the chamber. Thin walls at the ends of the cones enable particles produced in the interactions to escape to the detectors almost without hindrance.

CERN 371.10.71

diffusion rate, and hence the outgassing rate, was very temperature dependent. This suggested a way of removing the source of hydrogen — the steel was subjected to a heat treatment of about 1000 °C in a vacuum furnace before being used. At this temperature the hydrogen release is so fast that the concentration of dissolved hydrogen falls rapidly to a value determined by the partial pressure in the vacuum furnace. In this way it was possible to obtain the tons of stainless steel with special low outgassing rates which were needed for the ultra-high vacuum system of the ISR.

Cryopumping for even lower pressure

In addition to the ultra-high vacuum requirement of 10^{-10} to 10^{-11} torr all around the ISR rings, dictated essentially by beam life-time considerations, the experimenters would like the intersection regions with pressures in the 10^{-12} torr range or better. Such low pressures reduce the ratio of the background signals due to proton-gas molecule collisions compared to the true proton-proton collisions. Pressures even into the 10^{-13} torr range have been obtained, notably in intersection region I-6, using cryopumping techniques.

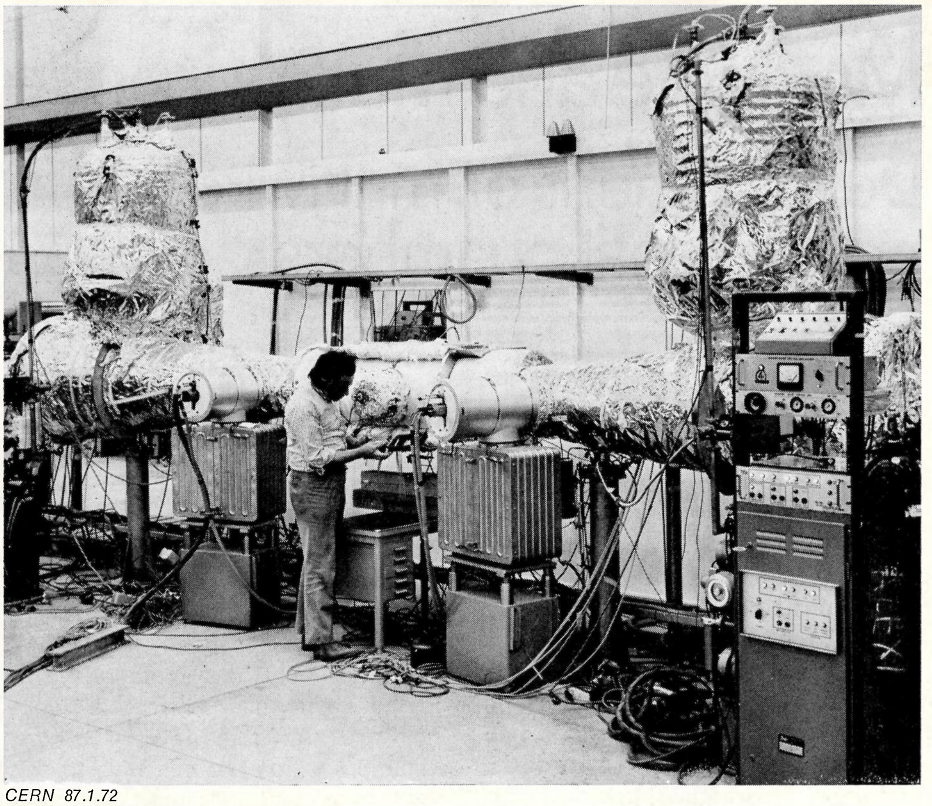
In a cryopumped intersection region a surface is cooled to a low temperature and acts as a trap to 'solidify' any gas molecule which strikes it. The speed of the pump depends on the area of the cooled surface (12 l/s and 45 l/s per cm² of surface are possible pumping rates for nitrogen and hydrogen respectively) and the pressure limit depends on the temperature of the surface and the gas (lower temperatures are needed the lower the boiling point of the gas).

Hydrogen, as described above, is the major gas load in the ISR ; unfortunately it is the most difficult gas to condense apart from helium. The theoretical low pressure limit of a cryopump is given by the saturated vapour pressure of the gas being condensed at the temperature of the pumping surface. For hydrogen this is still about 10^{-6} torr at 4.2 K (a convenient refrigeration temperature using liquid helium as coolant) but it should fall to an extrapolated value of 10^{-13} torr at 2.5 K. In practice, however, it proved impossible to condense hydrogen to pressures below about 10^{-10} torr, independently of what temperature was used. This anomaly was traced to an interaction between the (black body) thermal radiation coming from the vacuum chambers at room temperature and the condensed hydrogen layer — the latter being continually desorbed by this thermal bombardment. The interaction is not one of simple heating but depends in a complex way on the thickness and purity of the condensed layer and on the characteristics of the cold substrate carrying the condensed layer.

Although it was possible to operate a liquid helium cooled cryopump down to 10^{-13} torr in the laboratory even when exposed to thermal radiation by modifying the substrate (e.g. by the precondensation of an inert gas layer of argon or neon) a more practical solution has been developed and used in the ISR. This involves using optically and almost thermally opaque chevron baffles at 77 K which are optimised for molecular transmission. This is a compromise involving a considerable loss of conductance, and hence pumping speed, to the vacuum chamber. The pump and baffles are thus designed to achieve a given pressure and then dimensioned to give the required pumping speed. Two liquid helium cooled cryopumps have been installed in I-6. Each has a speed of about 15 000 l/s and a limit pressure of about 2.10^{-13} torr. They have operated for several months in the upper 10^{-13} torr range.

Measuring very low pressures

An advance in one technique often exposes a weakness in another. It was noticed that laboratory systems, designed to extend knowledge of very low pressures, frequently appeared to be limited at about 1 to 2.10^{-12} torr. Nearly all very low pressure gauges use a tungsten filament heated to about 2300 °C to provide a source of ionising electrons. The apparent limit pressures were traced to an artefact introduced by the gauge itself — the vapour pressure of tungsten evaporated from the heated tungsten filament. Operating the filament at a carefully chosen and reduced temperature can extend the useful range of the gauge by almost an order of magnitude.



CERN 87.1.72

The same chamber installed in the storage rings with two cryopumps (the vertical, foil-covered cylinders). With the cryopumps it has been possible to take the pressure in the intersection region down to the 10^{-13} torr range.

The hot tungsten filament is at the root of another problem. It produces heating in the surrounding vacuum chamber causing an increase of hydrogen desorption and a real increase of the system pressure. Recent development work has shown that it will be possible to construct an extremely sensitive gauge using the high gain of an integral channel electron multiplier. The gauge should be useful down to 10^{-15} torr and, since it uses an extremely low ionising current of a few nanoamperes, it will produce practically no heating or disturbance to the vacuum system.

Beam induced vacuum problems

'Pressure bumps' in the ISR have been in the news before (see vol. 11, page 245). They are the major obstacle to achieving the design stored beams of 20 A and the design luminosity. They are localised regions of about 10 m in which the pressure, normally stable at about 10^{-10} torr in the absence of the beam, begins to rise when the stacked proton beam current exceeds a certain value. Pressure bumps may occur anywhere around either ring at one or several points simultaneously. The mechanism is one of gas release from the wall of the vacuum chamber under ion bombardment. The ions, formed by the ionising effect of the proton beam on the 10^{-10} torr of residual gas, are ejected out of the space charge potential of the beam onto the wall with an energy of about 1 keV. The released gas increases the local pressure and thus gives, in turn, more ions. Hence we have the makings of an avalanche effect and the pressure may stabilise at some higher value or increase without limit until it destroys the stacked beam.

The danger is obviously greatest where the residual pressure is greatest, where the pumping speed is lowest or where the vacuum chamber wall is contaminated and there is a large gas yield per incident ion. It is now clear that, even after the elaborate cleaning and degassing procedures, the vacuum chamber is not as clean as was thought. On the basis of thermally induced desorption, it had been concluded that hydrogen dissolved in the metal is the only source of gas. But now it is apparent that the surface is covered with a layer of strongly adsorbed contaminants (H_2, H_2O, CO, CO_2, CH_4, hydrocarbons etc.) which are only released under energetic ion bombardment.

During the initial operation of the ISR the critical current for run-away pressure bumps was about 4 A. At that time the 10^{-10} torr operating pressure was achieved after an in situ bakeout of about 4 hours at 200 °C. Since then the temperature has been raised to 300 °C and the bakeout time lengthened to about 24 hours — the critical currents have climbed to 10 to 12 A. The normal operating pressure is still about 10^{-10} torr but clearly the surfaces now appear much cleaner under ion bombardment.

Why stop there ? Because many components of the ISR were designed for a maximum bakeout temperature of 300 °C, and further increase of the bakeout times at constant temperature seems to give practically no advantage. Other parameters have to be attacked — those of residual pressure and pumping speed. All the intersection regions were initially equipped with titanium sublimation pumps in addition to the normal sputter-ion pumps, which are the standard pumping element around the ISR. Pressures at the intersections were typically around 2.10^{-11} torr and the 'pressure bump' phenomenon rarely occurred in these regions.

A vacuum improvement programme is therefore under way to equip the whole of the ISR with additional sublimation pumps. They are installed in eleven of the 24 sectors which operate regularly at 2.10^{-11} torr. Pressure bumps in the unimproved sectors still limit the performance but there are high hopes of reaching the design current early next year when the whole vacuum system is improved and running at 2.10^{-11} torr.

In the meantime extensive laboratory investigations are under way to find ways of eliminating surface contamination. The most promising approach at the moment seems to be to simulate and accelerate the ion-induced desorption by running a high pressure (10^{-2} torr) inert gas discharge in the vacuum chamber. Subsequent gas release rates on test samples have been reduced by two or even three orders of magnitude by this technique. But there is a technical problem — how to propagate and control a gas discharge around 2 kilometres of ISR vacuum chamber. At the same time, more sophisticated cleaning and bakeout techniques, new surface treatments or even the possibility of a new chamber of an altogether different material is under study.

The results of applied research in the fields of materials science, low temperature physics, ultra-high vacuum technology and engineering have helped to create in the ISR the largest ultra-high vacuum system ever built. Exciting specialised techniques, such as cryopumping at 2.5 K have been integrated with everyday nuts and bolts in their thousands. Possibly the most important achievement of the ISR vacuum system is the extremely high reliability of many apparently commonplace components — there are over 10 000 demountable flanges, for example, which must all be leak-tight simultaneously. This reliability is the result of careful and thorough applied research. There are still problems — such as the pressure bumps but, to (mis-) quote from the Shakespeare play which gave us our title, 'Think not on it till tomorrow : we'll devise thee brave punishments for it'.

Multiwire and multipurpose

Development of multiwire proportional chambers

G. Charpak

The multiwire proportional chamber, in its present form, was born in 1968. It could have come into the world twenty years earlier, and been extremely useful, for it is based on ideas and techniques long known to us. The proportional counter after all was around in the 1930s and the physics of its operation in the 'proportional mode' had been studied. Moreover, various types of wire chambers had been tried before but their construction reflected a certain lack of understanding of what mechanisms were at play and their properties limited them to particular applications.

Many physicists working with wire spark chambers had been tempted to put a direct voltage onto the wires and had tried to observe the pulses produced on a wire by the passing of a charged particle. These attempts were doomed to failure because the structure of a wire spark chamber is not appropriate. In particular, if the cathode and the anode are made of wires of the same diameter, operation in the proportional counting mode is almost impossible.

In 1967 we were intrigued by the failure of these attempts and constructed a small wire chamber using the knowledge we thought we had from proportional counters. There were thick cathode wires, very fine anode wires, shielding rings around every wire input through the insulators. We also made the mistake which frustrated the majority of the previous attempts to produce multiwire proportional chambers — being certain that the capacitive coupling between the neighbouring wires would prevent the localisation of the pulse on one single wire, we connected one wire out of two to the cathode potential or to an intermediate potential. This intermediate wire was meant to play the part of an electrostatic screen between the sensitive wires. This reduces the precision of localisation by a factor equal to two and complicates the construction.

The chamber operated satisfactorily nevertheless and we noted the following properties :

The electron avalanche reaching a wire creates a negative pulse on the wire and a positive pulse on the neighbouring wires. There is therefore no point in having an intermediate shielding wire. All that is needed are amplifiers which are sensitive to only one sign of pulse. The induced positive pulses are therefore a blessing. They make it possible to have the wires as close to one another as we want, without capacitive coupling becoming a problem.

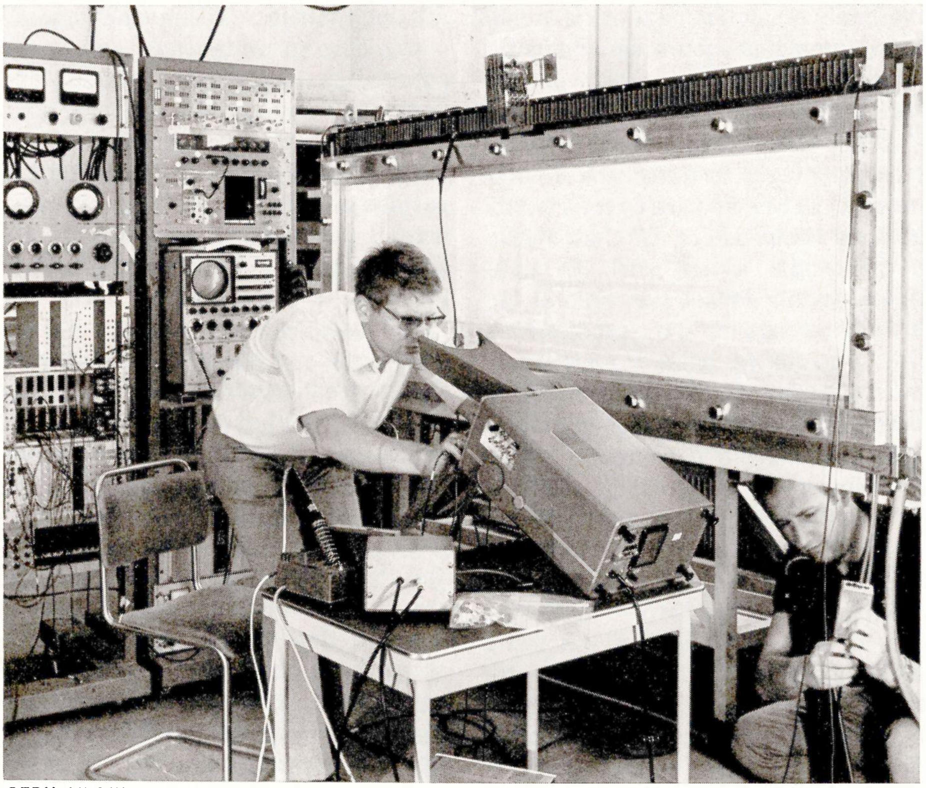
The moment at which the pulse appears on the wire depends strictly on the distance from the track to the wire. When the wire planes are brought to a 2 mm spacing the resolution times obtained are very exiting — 25 nanoseconds to reach full efficiency. This is at least one order of magnitude better than spark chambers. In addition, each wire accepted a counting rate of nearly a megacycle, which meant an advance of at least four orders of magnitude on spark chambers.

We then modified the construction of the chambers. The sensitive wires were put on to the same potential, and the inputs were shielded, not by individual rings, but by guard plates. We got down to a more thorough study of the properties of the chambers.

Among the properties which were highlighted and which have had the most consequences we can mention the following :

1. It was soon clear that, as usual, one cannot get something for nothing. To make use of all the extremely interesting advantages of multiwire proportional chambers necessitates considerable expenditure on the electronics needed to collect a

Large multiwire proportional chambers for use in high energy physics experiments. On the left, a large chamber, such as is used in the CERN/ Heidelberg experiments on neutral kaons, is being tested. On the right is a prototype chamber of the type to be installed in the aperture of the Split Field Magnet at the Intersecting Storage Rings. Special construction techniques have achieved the evident lightness but more importantly have increased the useful detection volume.



CERN 149.2.70

CERN 90.2.71

signal from each wire and to amplify it for use in the subsequent decision-making circuits. Initially, the cost was around 60 Swiss francs per wire. A lot of work has gone into this problem and important advances have been made with regard to the chamber filling and the electronic circuitry.

A variety of gases and gas mixtures were studied and it has proved possible to use a mixture, colloquially known as the 'magic gas', which gives a gain a hundred times higher than the 'classical' gases used in the proportional counters.

Initially the magic gas suffered from exposure to radiation, its performance deteriorating with time. With further research this was eliminated by the addition of isopropyl alcohol, or better still methylal, to the gas.

The magic gas eases the burden on the subsequent electronics since the signals arriving on the wires are a hundred times greater. Work on the electronic circuits has resulted in techniques for grouping the circuits of several wires on the same wafer. More importantly, the specification for an integrated circuit has been evolved and their production on a large scale should considerably reduce the costs associated with the electronics of multiwire proportional chambers.

2. Large multiwire proportional chambers can be confronted with greater equanamity when the associated costs for electronics are lower. However, there were considerable constructional difficulties in building large chambers appropriate for particular uses. We can take as one example the large chambers destined to be used in the Split Field Magnet of the ISR. These chambers could not sensibly use a strong metal frame to withstand the tensions introduced by hundreds of stretched wires since the frames would fill a significant proportion of the valuable magnet aperture. Special honeycomb sandwiches of plastic foam are to be used. They have great strength and yet introduce much less matter in the magnet aperture.

Large multiwire proportional chambers are now being used in several experiments. At CERN, they have been in action in the CERN/Heidelberg neutral kaon experiments for over a year and an indication of the advance in particle detection, which the new technique has brought about, is that data is collected at the rate of several thousand events per PS pulse.

3. Another type of detector, related to the development of multiwire proportional chambers, has been receiving a lot of attention recently. It is known as the drift chamber and was in fact proposed at the same time as proportional chambers. It makes use of the correlation between the time of arrival of a pulse at the wires and the

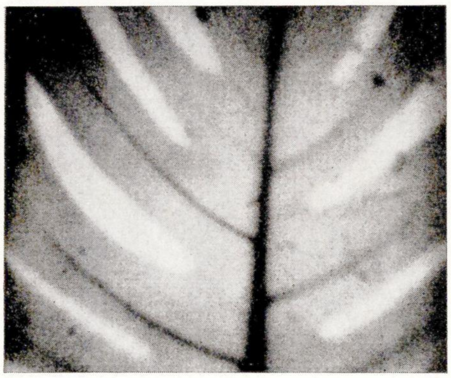
1. An X-ray photograph of a leaf taken using multiwire proportional chambers to detect the X-rays. A spacing of 1 mm between the chamber wires achieved good definition.

2. Gammas emitted by radio-isotopes in a thyroid gland are detected by multiwire proportional chambers after a grid collimator.

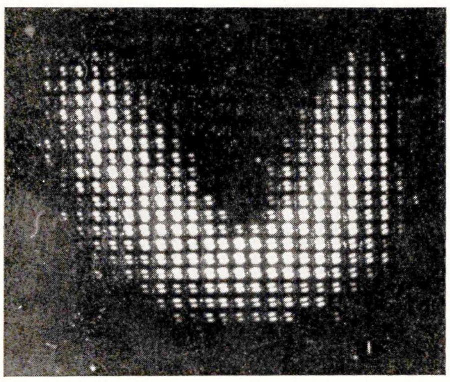
3. The same observation technique applied to a 'phantom' thyroid in which radio-isotopes have been fixed.

position of the track which originated the pulse. This correlation is so good that track coordinate measurements can be taken with a precision of the order of 0.1 mm.

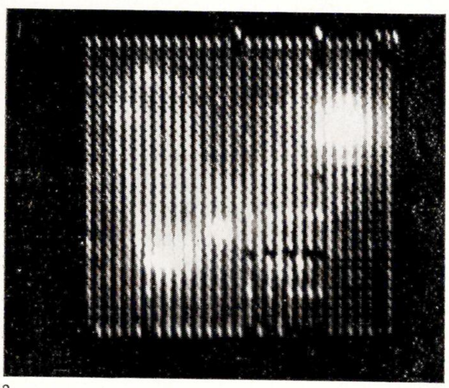
Groups at Saclay and Heidelberg have put a lot of applied research into drift chambers and have achieved spectrometers with remarkable properties using them. It may prove that this technique has a great role to play in the future. The drift chamber is also



1.



2.



3.

the cheapest solution to track localization problems even when compared to spark chambers.

4. The use of the induced positive pulse allows us to detect the coordinate parallel to the wire by means of a cathode composed of wires which are perpendicular to the sensitive wire. Although this is not very interesting for high energy physics experiments, it is essential for what has proved to be one of the main uses of multiwire proportional chambers : gamma radiography for medical purposes.

If we wish to measure the distribution of radiation, X rays or gamma rays, emitted by isotopes which have been fed into a human being, it is essential that the two coordinates should be determined in the same detector. This is because we are trying to measure neutral radiation and the secondary electrons which it creates in a detector cannot, as a rule, go through to a second detector. For years various groups had tried to construct self-triggering spark chambers but such chambers are extremely "touchy". The proportional chamber has certain of the properties which the medical people consider to be essential and active research on further uses is now being carried out in several hospitals.

Thus, in addition to the field of high energy physics, where we are now engaged in the construction of giant detectors based on proportional chambers, important applications have been found elsewhere. Serious difficulties have had to be overcome and perhaps are yet to be overcome. But with the understanding which we have acquired of the phenomena which underlie the behaviour of multiwire proportional chambers we should be able to surmount them.

Finding out about ferrites

This article is a collaborative effort with contributions from C. Arnaud, H. Bargmann, H.P. Kindermann, H. Kuhn, W. Middelkoop, G. Nassibian, W. Pirkl, K.H. Reich, C. Rufer, and D. Zanaschi.

Although ferrites (ferri-magnetic ceramics) have a wide range of applications in the communications industry, the way in which their peculiar properties are used around accelerators (mainly in r.f. accelerating cavities and as yokes of 'kicker' magnets) is unusual and required detailed study in order to achieve satisfactory results.

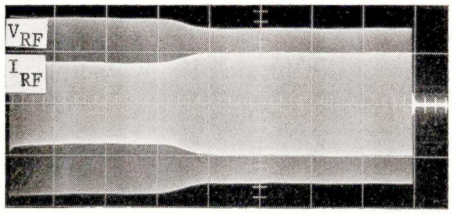
The basic principle of their use in an r.f. cavity is simple — the change of incremental permeability of a ferrimagnetic material is used to vary the inductance of a resonant circuit which must be tuned, fairly rapidly, over a frequency range (of the order of four to one in the case of the CERN PS). The need for research on ferrites arose because accelerator people seem to be the only users of large rings (up to about 60 cm diameter) of this material. Taking into account the comparatively small quantity required and the comparatively low financial return (on an industrial scale), industry could not be expected to put in either the extended specialised research or the sophisticated apparatus for continuous production quality control. Research therefore was done at CERN, in active collaboration with the ferrite manufacturer, who finally managed to satisfy nearly all the challenging requirements.

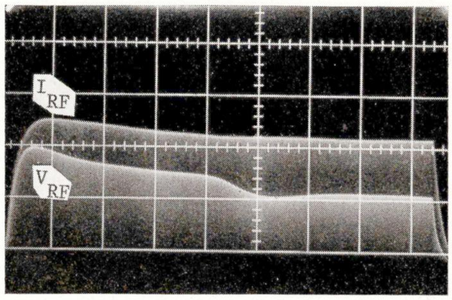
The problems in using ferrites in kicker magnets are different. Here the electrical and mechanical properties of commercially available ferrite blocks are entirely adequate but research was needed because the ferrites are installed in a high vacuum — a condition not encountered elsewhere.

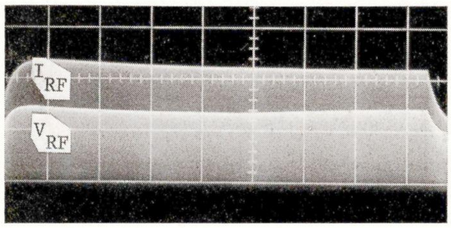
Electrical problems

When a ferrite is taken through a magnetisation cycle its incremental permeability and loss at any instant will depend on the r.f. frequency, the

The top traces show the time dependent effect on r.f. voltage and power loss in ferrites discovered in the course of the studies. (The time-scale is 10 ms/square). The two lower sets of traces show how temperature affects the drop in voltage. The centre traces were taken with the ferrite temperature at 20 °C (the r.f. current is here held constant). The bottom traces were taken at 24°C and the drop has disappeared.







amplitude of r.f. excitation, the temperature and the bias sweep speed.

The frequency dependence is straightforward in principle, although the data are not always available.

The amplitude dependence is more complicated. Over most of the usable range of operating conditions the incremental permeability increases with the amplitude of the r.f., so that the resonant frequency of a ferrite-loaded resonator drops when the voltage is raised. For a fixed bias current, this results in an asymmetric frequency response curve. Moreover, there is a fairly well defined limit above which increasing the excitation produces no corresponding increase of flux. As a result of work at CERN and at NAL, it was discovered that this limit is time dependent for many ferrites, dropping by perhaps 30 % after times extending up to tens of milliseconds. To complicate matters still further, the limit is strongly temperature dependent. These new findings were fed to the manufacturer who succeeded in producing ferrites which exhibited these awkward characteristics to a lesser degree.

The temperature coefficient of the incremental permeability is quite large, and can be positive or negative depending on the state of d.c. magnetisation. A positive coefficient can have disastrous effects on the thermal stability of a large ferrite assembly since it causes the warmer parts to pass more r.f. flux and thus get hotter still, until mechanical failure occurs. The fact that the loss coefficient also increases rapidly with temperature adds to problems of this type. Theoretical analysis established safe operating temperatures which were confirmed by experiment.

Further complications arise when the working point is moved rapidly. The r.f. losses depend on the sweep speed and can increase very substantially with high sweep speed, a fact that has to be allowed for in the design of the r.f. power supply and cooling system. Another difficulty is that, in some circumstances, for an increase in d.c. bias the incremental permeability after decreasing for the first millisecond, may increase again before decreasing to its steady state value — not a helpful feature when trying to design a servo-loop to keep the resonant circuit tuned to a varying frequency.

Also ferrites are strongly magnetostrictive, and precautions have to be taken against electromechanical oscillations. Their effect can be controlled to some extent by staggering the ferrite rings according to their individually measured frequencies and by suitable clamping.

From this brief discussion it will be appreciated that assessing the qualities of a ferrite is no mean task. The acceptance testing of hundreds of rings was done at CERN on a special test device. By measuring a number of properties for each ring, it was possible to stack the acceptable ones in such a way that all the r.f. cavities were similar in their behaviour and, within each cavity, each ring could be positioned to make the best use of its electrical characteristics.

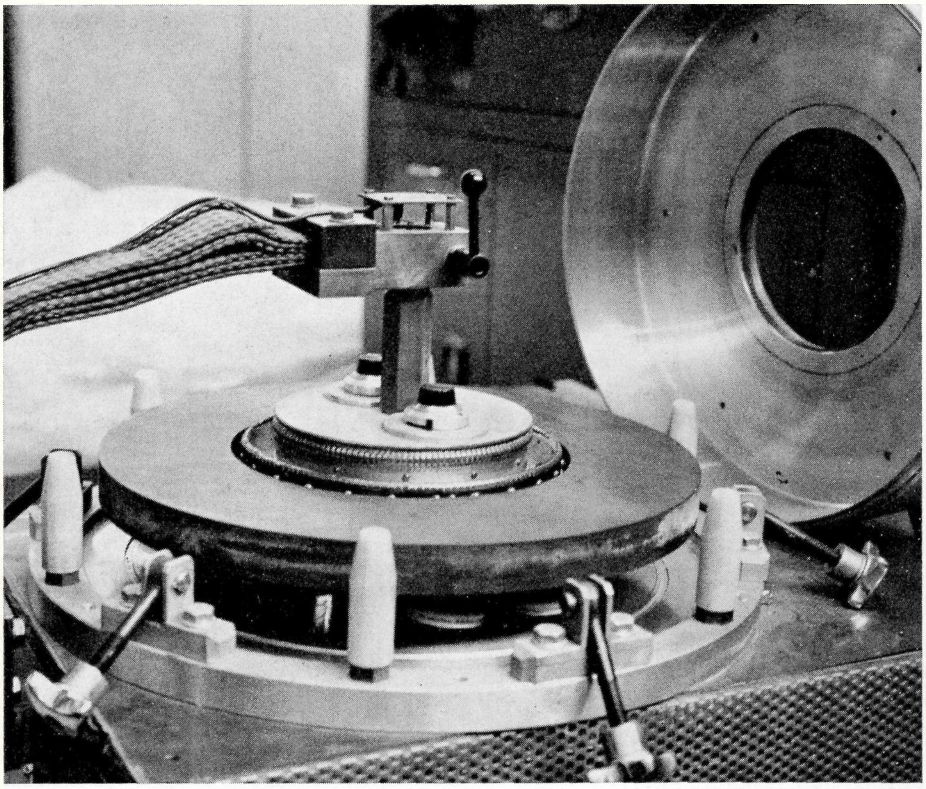
Mechanical problems

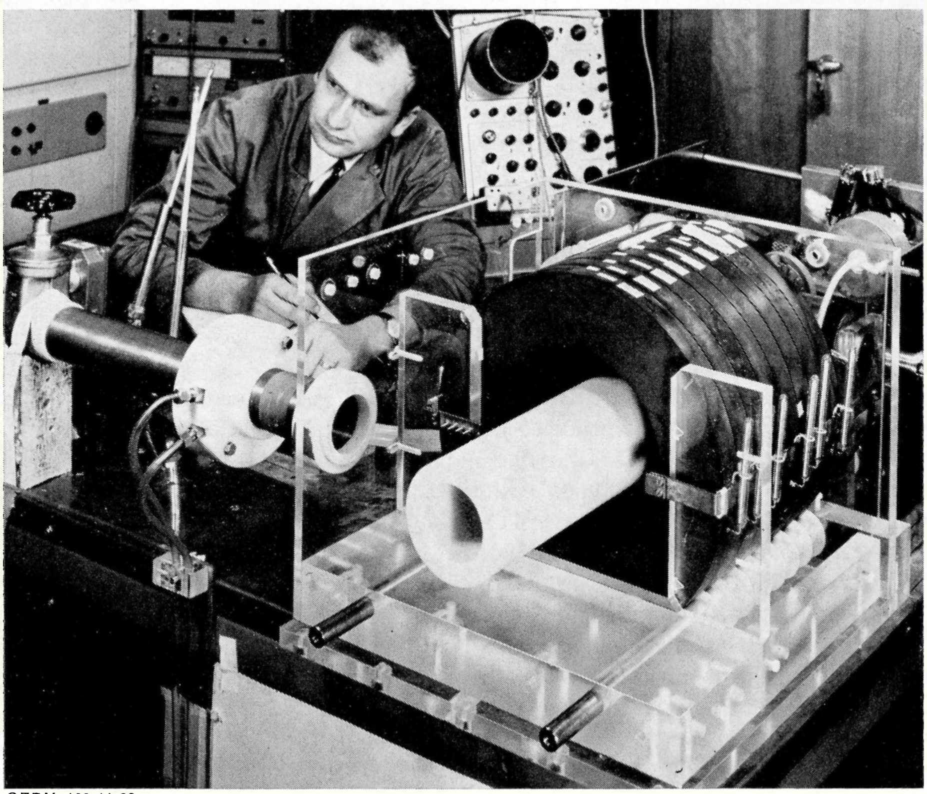
Since an increased r.f. voltage was required for the new PS and Booster cavities, the total power dissipated in the ferrites (mainly due to the hysteresis losses which roughly go with the cube of the voltage) was also increased. The temperature must be kept below 30 to 40 °C so as to avoid thermal run-away effects and subsequent mechanical failure. The most straightforward way to keep temperatures low is to increase the surface for heat exchange but there are technological and financial considerations which lead to an optimum ring thickness of the order of 20 to 35 mm. Also, too effective cooling could be dangerous when switching on because the ferrites, initially at room temperature, could experience a thermal shock.

A great deal of effort has gone into determining the necessary heat exchange surfaces and rates of exchange for a given ferrite. The mathematical model for the ferrite behaviour was chosen first with constant parameters and later with temperature dependent parameters requiring a double iteration computation. The computations were checked in a laboratory test setup. As a result, the Booster ferrite rings (350 mm outside diameter, 200 mm inside diameter, 30 mm thick) are spaced by 1 mm and are air cooled, the air temperature rising from 21 to 27 °C. For the water-cooled 30 kW PS cavities, a version was initially developed with lateral direct

The test cavity, shown open in the photograph, where the properties of individual ferrite rings were measured prior to incorporating them (if they met the required standards) in the accelerator cavities. A ring of 440 mm outside diameter, 250 mm inside diameter and 33.3 mm thick is under test. Below the test cavity is an r.f. power amplifier, capable of delivering more than 1 kW to the ring, and bias supply, capable of delivering a sine half wave of 3 kA peak.

Since the temperature has such an important influence on ferrite behaviour, the cooling of r.f. cavities where large ferrite rings are used has to be studied very carefully. An air-cooling method was selected for the cavities of the PS Booster and the photograph shows tests being carried on a laboratory model. The large rings are on the right.





CERN 160.11.68

cooling (involving impregnation of the ferrites to avoid dielectric losses). However it was not possible in the time available to find a radiation-resistant impregnation which would be satisfactory electrically and the final design has water-cooled copper rings interleaved with the ferrites (440 mm outside diameter, 250 mm inside diameter, 33.3 mm thick).

Vacuum problems

Due to the powder pressing and sintering process used in the manufacture of ferrites, their surface structure is porous and the true surface area is much larger than is apparent. The small pores tend to fill with water when in a humid atmosphere. If the ferrite is then placed in a vacuum at room temperature, it releases the water in the form of vapour at a low rate and this limits the obtainable vacuum of a system for a long time at a level too high for accelerator operation (one gram of water at a pressure of 1×10^{-6} torr gives about 10^9 litres of vapour and the vapour volume is inversely proportional to the pressure).

Something has to be done if these ferrites are to be used in very high vacuum. Three of the possible sources of improvement are :

(i) The ferrite manufacturing process could be altered so as to obtain a much denser product (reducing or even eliminating the number of pores). From the user's point of view this would be the most useful and economic but the technological problem is in the hands of the manufacturer ;

(ii) The magnet could be installed in a vacuum tank equipped with a surrounding oven so that it is possible to bake out the whole assembly in situ. This was the solution chosen by the ISR where the vacuum requirements of less than 10^{-9} torr are exceptional. It involves many complications in the selection of materials, seals, etc. Taking the ISR inflector, where there is a kicker magnet with a ferrite yoke, as a typical example — repeated bakeout cycles to 300 °C lasting about ten days each were initially needed to obtain a vacuum of about 10^{-10} torr with a reasonable pumping speed ;

(iii) A bakeout treatment could be given to the ferrites prior to their assembly in the vacuum system. Because of its relative simplicity, this was the method adopted for the PS and Booster kicker magnets, where the vacuum is 1×10^{-7} torr. To determine the pumping capacity needed on the kickers, approximate measurements were made of the degassing rate of the ferrites. The measurements showed that a ten-fold reduction in the rate can be achieved by a relatively simple treatment. However, the time for which a ferrite is exposed to the atmosphere after a vacuum bakeout or after a pump-down is an important parameter and the rate of outgassing is still very high (compared with values of 5×10^{-11} torr l/s cm^2 for cleaned unbaked stainless steel after 40 hours of pumping). Pumpdown difficulties with these magnets after exposure to the atmosphere are frequent and much more has to be learned about their vacuum behaviour. Systematic measurements are therefore continuing.

As a result of this research with ferrites they can be used in accelerator environments more efficiently and with more confidence that the desired performance can be achieved. In general, the research has provided much more knowledge of the behaviour of ferrites under a variety of operating conditions.

Detecting differently

a) Ultrasonic bubble chambers

H. Hilke

Conventional bubble chambers operate by applying pressure changes to a liquid by means of a mechanically driven piston. The possibility of achieving the pressure changes by subjecting the liquid to sound waves has been studied at CERN during the past four years.

One reason for the interest in ultrasonic bubble chambers is that they would avoid many of the restrictions in chamber construction which come from the mechanical stresses involved in the operation of cumbersome mechanical expansion systems. But, more importantly, the interest is in finding a simpler way of achieving high repetition rates for bubble chamber operation. The possibility of taking many pictures during an accelerator cycle is attractive and opens up the prospect of using a small chamber as a 'vertex detector' integrated with an electronic counter detection system. A high repetition rate for the chamber would bring it more in line with the data-taking capabilities of counters.

In the experiments at CERN a plane standing wave field is set up in the chamber liquid. The sound wave is produced between two piezo-electric transducers or one transducer and a reflector plate. Bubble nucleation as a result of local overheating takes place in those regions where the pressure has fallen below a certain value at the instant when a charged particle passes. (The 'memory' of a bubble chamber is extremely short — about 10^{-9} s — due to fast heat diffusion). There is thus a separation between bubbles or bubble groups of about one wavelength. To achieve an acceptable bubble density in the chamber, so that the particle paths can be accurately traced, high frequencies are required. For a separation of 2 mm between bubble groups a frequency of about 100 kHz is required in helium and 400 kHz in hydrogen. The strongest transducer materials in this frequency range are lead-zirconate-titanate ceramics and these were used in the CERN experiments.

Initially, negative or non-conclusive results were obtained using heavy liquids in the chamber partly due to strong optical distortions caused by the modulation of the index of refraction by the pressure waves. At the end of 1968, liquid helium was tried and the first particle tracks ever to be photographed in an ultrasonic bubble chamber were achieved. Two PZT4 transducers 7 cm in diameter were used separated by 5 to 8 cm and a sound wave frequency of 100 kHz (later 360 kHz) was applied. It was found that the bubbles did not collapse under the first positive pressure swing but continued to grow, reaching visible size in less than 60 sound periods. If Nature had not allowed this to happen the research could have stopped there.

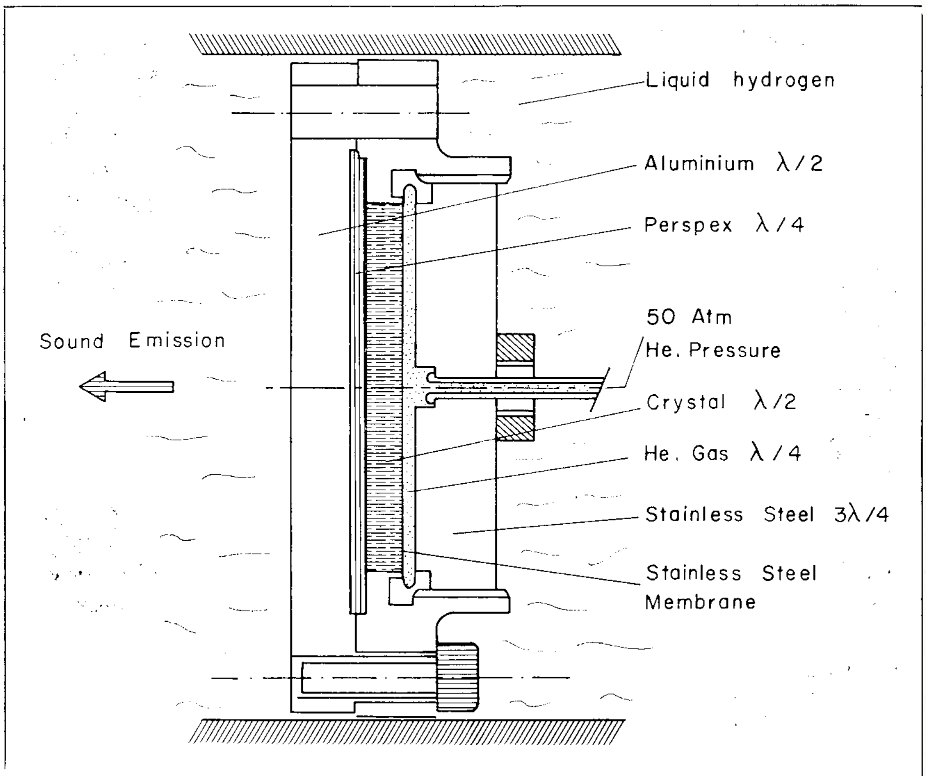
Liquid hydrogen is of much greater interest as a bubble chamber filling because of the simplicity of the hydrogen nucleus. The next step was therefore to try to form bubbles on particle tracks in liquid hydrogen. Unfortunately, the pressure amplitude needed in hydrogen is about 3 atmospheres, which is ten times that needed for helium (where the pressure requirements are the lowest of all liquids because of its low surface tension). The power requirements are even more disturbing being fifty times those needed for helium.

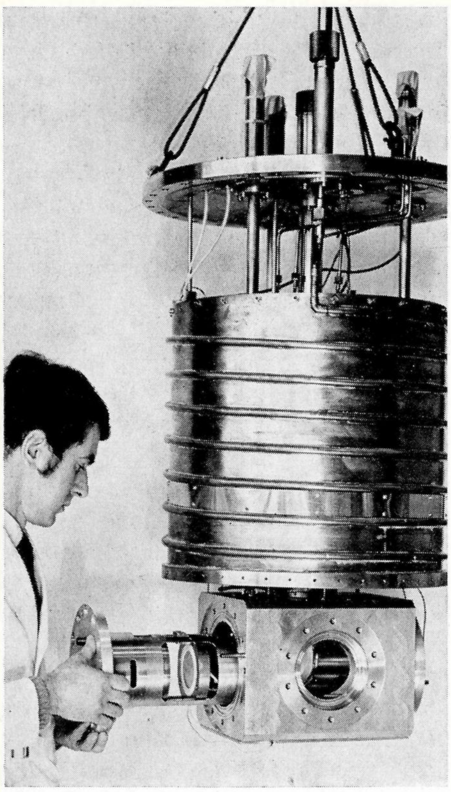
Due to the extreme acoustic mismatch between the ceramic material of the piezo-electric transducer and the liquid hydrogen, there are excessive internal stresses in the transducer (about 2000 atm in the transducer when producing a 3 atm travelling wave in the hydrogen — unfortunately the breaking stress for the ceramic material is 250 atm !) A solution to this problem was sought by

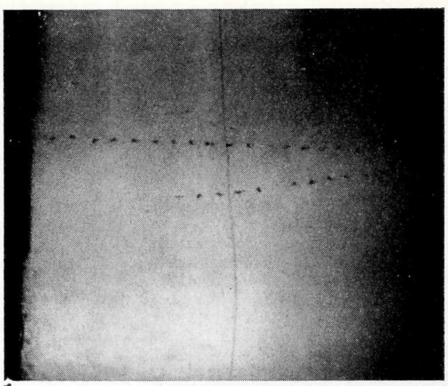
A diagram of the pressurized transducer system. Here a perspex plate serves to match the acoustic properties of the PZT4 disc to those of the liquid hydrogen in the chamber. Good acoustic contact between the plate and disc is achieved by pushing them together with helium gas at 50 atmospheres pressure.

The unit, known as the transducer cradle, holding the piezoelectric crystals being slid into place in the test rig. Visible in the cradle is the disc shape of the reflector and receiver crystal. The first ever tracks in an ultrasonic bubble chamber containing liquid hydrogen were taken in this test rig.

Ultrasonic bubble chamber photographs.
1. This was taken in liquid helium between PZT crystals 5 cm apart using minimum ionizing pions and protons. The bubble regions are separated by a distance corresponding to one wavelength of the ultrasound (2 mm at 100 kHz).
2. This was taken in liquid hydrogen and records Compton electrons initiated by gammas from a cobalt 60 source. The ultrasound was applied, via a glued crystal-perspex sandwich, at about 300 kHz equivalent to a wavelength of 3 mm).







1.

2.

trying to achieve a high standing wave ratio and by introducing acoustic matching. In a preliminary experiment at the end of 1969, carried out in a 1 m chamber (the model chamber for BEBC), two non-matched transducers produced up to 1 atm in liquid hydrogen, which led to track sensitivity only by adding a piston expansion to build up the necessary pressure swing. Later set-ups, which allowed much more accurate tuning resulted in higher wave amplitudes. But at high power levels the pressure gains (or quality factors) were poor due to non-linear effects, whereas at low power the gains were better than expected.

The efforts to produce a good acoustic matching system resulted in a lot of frustration. Plexiglass has almost ideal properties to achieve an efficient match between the ceramic transducer and the liquid hydrogen. But attaching plexiglass plates to ceramic discs appropriately is not at all easy. Pressurization or gluing is needed to ensure good acoustic contact. It was found that pressing the plates together (using high pressure helium gas) could result in still further loss because of rigidity requirements not being met. A series of glues were tried but only one could stand the 1 % difference in contraction between ceramic and plexiglass on cooling to liquid hydrogen temperatures. (This glue was a 1 : 5 mixture of 3 methyl butane and 2 methyl butane, which solidifies only at liquid nitrogen temperatures.)

Both types of matching system, pressurized and glued, were tried. Both proved capable of giving the required 3 atm pressure swing in hydrogen at 300 kHz (the glued variety performing rather better). Without the help of conventional expansion techniques track sensitivity in hydrogen was obtained for the first time about the end of 1971. With the pressure amplitudes which were achieved,

b) Hydrogen streamer chambers

F. Rohrbach

repetition rates of up to about 100 Hz seem feasible.

Similar work has been going on at Dubna and they are reported to have achieved recently a 1.75 atm pressure swing in a plane ultrasound field with a pressurized system at 30 kHz. This is a continuation of a project which, in 1969, used a cylindrical transducer producing about 1 atm along its axis. In both their experiments, piston expansion was used in addition to obtain particle tracks.

The research at CERN has, for the moment, been halted. It has already answered, positively, many of the questions concerning the ultrasonic bubble chamber technique but further development is needed before the technique could be used. An interesting speculation is the possibility of achieving 2×10^5 separate sensitive cycles per second by operation of an ultrasonic bubble chamber with helium as the chamber liquid using the high power transducers developed in the course of the work with hydrogen. This implies the formation of visible bubbles and their complete recompression in one sound period. Theoretically it looks possible but, in practice, problems such as spurious boiling at the transducer surface could intervene.

Finally, there have been two interesting side results of the experimental work. Numerical integration methods were applied to the problem of bubble oscillation and growth and gave new insight into cavitation phenomena including strong mass transfer. Also, theoretical investigations on the behaviour of piezoelectric transducers have revealed that the currently accepted theory omits a major term. The term is, in fact, predominant in the case of transmission of sound waves into liquid hydrogen and helium and plays a significant role in a wide range of present applications of ultrasound.

A streamer chamber is a particle detector in which the passage of a charged particle is seen in the form of small streamers of plasma (0.5 to 1 mm in diameter and 1 to 10 mm long depending on the parameters of the chamber). Their density along the trajectory is typically 4 to 5 streamers per centimetre for a particle at minimum ionization and a gas under normal conditions. The streamers are produced by applying a short high voltage pulse (about 15 ns and 20 kV/cm for a helium-neon mixture) a few microseconds after particles have traversed the chamber's sensitive volume. The chamber's memory time may be adjusted by mixing impurities with the gas (for example 0.1 to 0.2 ppm of sulphur hexafluoride) which promote the fast recombination of the primary electrons.

The streamers develop for each primary electron, produced by the ionizing effect of a charged particle passing through, as soon as the electron avalanche, which is induced by applying the electric field, reaches a sufficient threshold (of the order of 10^8 electrons). These streamers are characterized by a sudden increase in the luminosity around the head of the electron avalanche. The luminosity is diffused at an apparent velocity ten times greater than the avalanche (10^7 to 10^8 cm/s) and simultaneously towards the anode and the cathode. The light is sufficient for the tracks to be photographed directly by using wide camera apertures and sensitive film.

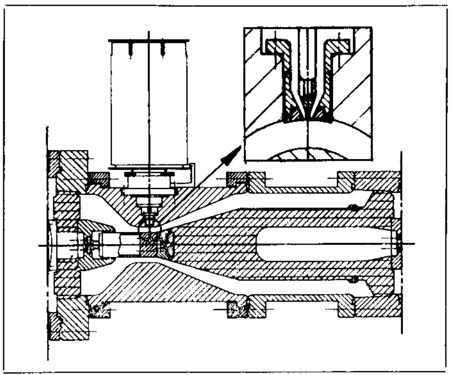
This type of detector has many advantages. It is possible to trigger the chamber for a given type of event. The detector can accept up to 10^6 particles per second and the picture taking rate could, theoretically, be 100 per second or more by avoiding the use of cameras and by introducing direct recording (Plumbicon or photosensitive matrices). At present the rate is usually about five per second but the chamber itself has a very low dead time since there is no discharge as in a spark chamber.

Also, the measurement accuracy is not limited by multiple Coulomb scattering because the density is very low. Almost 4π detection is achieved. Only tracks which are parallel to the field and strongly ionizing may cause breakdown. The latter sets up a light background which is often a nuisance but this can be eliminated if the pictures are taken before the streamer is formed provided an image intensifier is used. The detector may be of any length (a 5 m chamber is being built in the USSR). There is no limit on width, and the depth is directly related to the available voltage.

If such a detector could also have the virtues of a hydrogen target, the result would be a visible and triggerable hydrogen target. Moreover, as the density of the target is very low (about 800 times less than in a liquid hydrogen bubble chamber), the view would in effect be magnified around the vertex and recoil protons with low momentum would become visible and easy to measure.

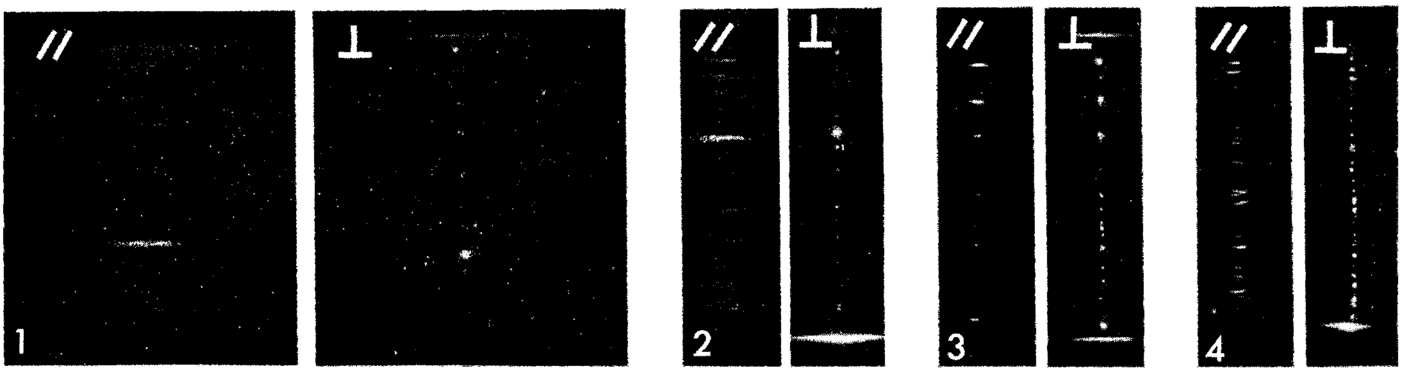
To try to fasten onto these advantages a programme of research to produce a hydrogen streamer chamber was initiated at CERN in 1968. The first tests were performed with conventional high voltage techniques (Marx generator) and soon showed that it would be technically difficult to obtain tracks in hydrogen similar in quality to those obtained in helium-neon mixture.

The main difficulties are : a) to obtain short streamers, the voltage pulse must be very fast (about 6 ns) probably due to the short life-time of the main excited states of the hydrogen molecule (less than 1 ns) ; b) the electric field must be much higher (from 1.5 to 2.6 times higher depending on the impurities added to the gas



1.

1. Drawing of the specially designed Blümlein line which has enabled extremely short high voltage pulses to be achieved. The detail of its spark gap, with the tungsten pin 0.1 mm in diameter to which is applied a trigger pulse from a Marx generator, is picked out.



2.

2. A series of photographs (taken both parallel and perpendicular to the magnetic field) showing streamers as they have been recorded in different gases. 1. In hydrogen where very short high voltage pulses are required — the actual conditions were voltage gradient 33 kV/cm, pressure 200 torr and pulse length 6 ns (1.6 ns rise time). 2. In helium with a 27 kV/cm gradient, 350 torr pressure and the same pulse length as for hydrogen. 3. In methane with a 35 kV/cm gradient, 190 torr pressure and a 9 ns pulse length (2.5 ns rise time). 4. In a helium-neon mixture with a 20 kV/cm gradient, 660 torr pressure and 16 ns pulse length (4.1 ns rise time).

— the purer the gas, the higher the field must be). The overvoltage has to be about 450 % ; c) the reproducibility of the voltage pulse height must be very good (about 2 % maximum fluctuation permissible which is twice as stringent as in helium-neon) if the picture quality is to be kept constant.

A systematic attack on these problems was mounted in 1970. The biggest difficulty was to generate a 500 kV, 6 ns pulse with less than 2 % fluctuation. No known system had a sufficiently short rise time to achieve this performance. The use of a Blümlein coaxial line to shape the pulse seemed most promising. Systematic studies revealed that the pulse rise time was not limited by the specific inductance of the arc but by the dimensions of the short-circuit plane at the spark gap.

For a maximum pulse length of 6 ns, the rise time must not exceed 2 ns. This means that the radius of the line must be less than 5 to 6 cm. This is incompatible with the fact that the line must be able to carry a very high voltage before switching. To reconcile these competing requirements, a conical Blümlein line was designed and constructed. The spark gap is, of course, located where the field is at a maximum and the self-inductance at a minimum, namely at the top of the cone, and the output may be as high as required by the dielectric strength of the insulation being used. Furthermore, the cone itself is an impedance transmission line. The length of the two channels of the conical Blümlein line may be compensated by applying the difference between the dielectric constant values of the gas in the outside line and of the insulator (araldite) in the inside line. This is important since the difference between the propagation times for the two lines lengthens the pulse's decay time and causes undesirable stray oscillations.

Blümlein lines have been constructed according to these principles and the desired performance has been achieved. The intrinsic rise time has been reduced to 1 ns. To obtain good reproducibility, a d.c. voltage (0.1 % stability) was used to charge the conical line. To trigger the pulse, a new type of spark gap was developed where triggering was achieved with 100 % reliability. It involved the use of an extremely fine tungsten pin (0.1 mm in diameter) to which a trigger voltage of up to 300 kV was applied by a very small Marx generator. All the systems which are used at lower voltages (up to 100-200 kV) proved inefficient as their delay time is too long.

With this generator, a pulse of 500 kV with a rise time of 2 ns and a base of 6 ns was applied to a streamer chamber measuring $21 \times 26 \times 9$ cm^3. The maximum delay between the passage of the particle and the arrival of the high voltage pulse was 400 ns. The chamber has been tested with hydrogen, hydrogen mixtures and other gases.

For the first time, streamers in pure hydrogen have been photographed. The streamers are a brilliant white, 6 to 8 mm in length and about 1 mm in diameter. The tails of the streamers can be reduced by adding small quantities of methane or sulphur hexafluoride to the hydrogen.

Comparative measurements were carried out on a series of chamber gases. For example, the ratio between the necessary electric fields for different gases compared with that for henogal is approximately 3.4 for methane, 2.6 for hydrogen and 1.45 for helium. Methane provides streamers of better quality than those obtained in henogal although the electric field is greater. When hydrogen is mixed with methane (0.5 to 1 %) or sulphur hexafluoride (about 50 ppm) the required field is reduced by 10 to 40 %.

Following this research, there appears to be no fundamental technical obstacle to prevent construction of a hydrogen streamer chamber 2×10 to 2×15 cm deep of any desired width and length. Furthermore, the research has contributed to high voltage technology where applications may be found in several other fields (such as X-ray flash tubes, fast pulsed kickers and very high voltage spark gaps).

Witchcraft in the workshops

B. L. Daniell

One of the main tasks of the CERN workshops is to tackle the production of special items (often just one-off jobs) which are called for by the experimental or accelerator teams. This often demands some applied research involving workshop techniques. The following article describes just one topic from many to show the sorts of skills which can be brought to bear.

Thin foils for magnet shimming

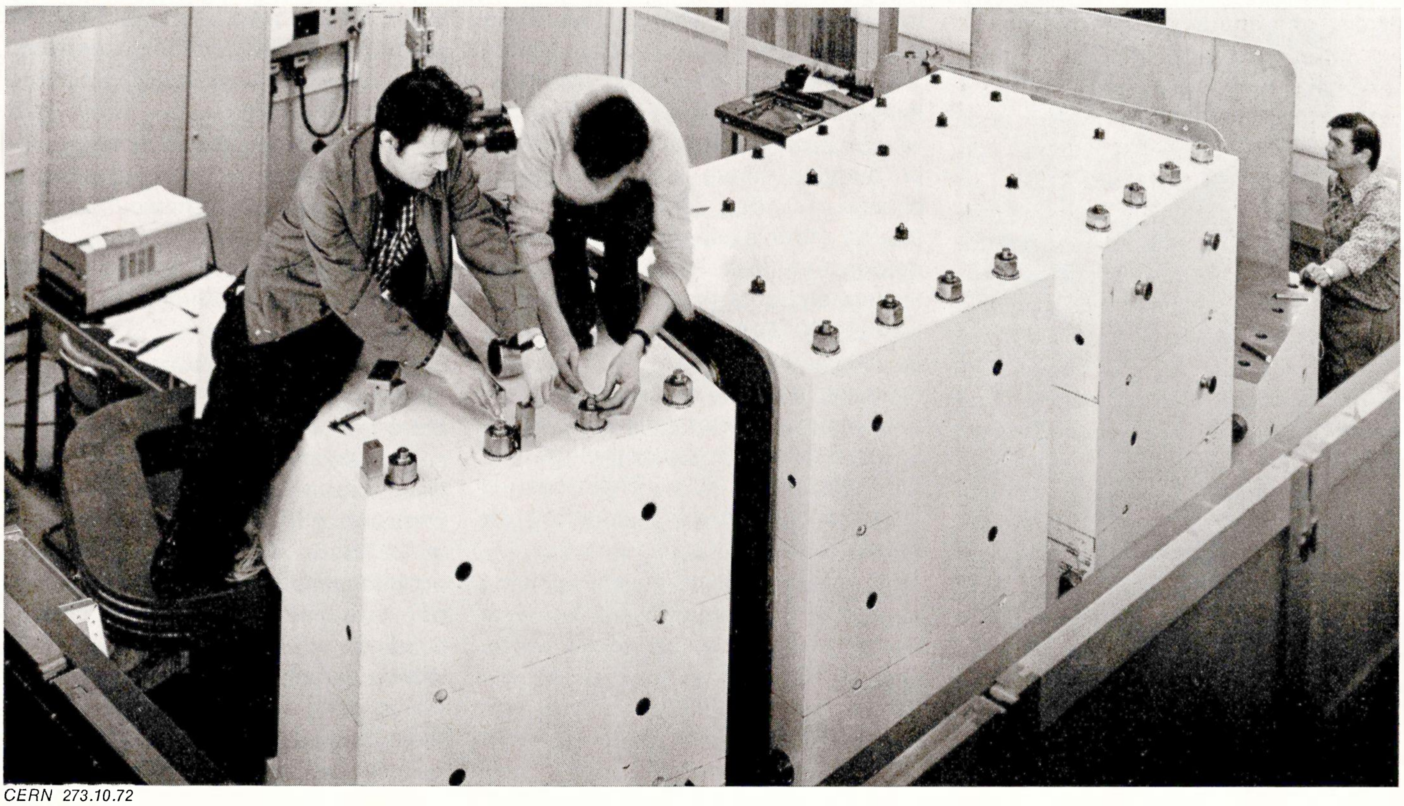
A small storage ring is being built for the measurement of the 'g-2' of the muon to even greater accuracy (see vol. 6, page 152 for the story of the previous experiments). To achieve the required accuracy, the field in the forty magnets of the storage ring (each about 1 m long with an aperture of 12 × 8 cm²) has to be uniform to one part in 10^5. Normal manufacturing processes cannot give such uniformity and a measurement and correction system has been set up at CERN. Some corrections are being achieved by applying extremely thin foils to the magnet pole faces. The foils have been produced using techniques developed in the workshops.

Four magnets are mounted in the test rig, the outer two being to avoid end effects. The field measurements are analysed by computer and from the deviations from a uniform field it can be calculated whether metal should be added or removed from areas of the magnet pole pieces. The computer calculations are accurate to about 30 % and therefore, after the pole pieces have been corrected, a second measurement is taken and analysed and a second correction may be needed. Thus it is desirable to be able to correct the magnets without their being removed from the test rig.

The metal removal technique has not been studied in detail yet but it can be done either mechanically, electrolytically or chemically. For the metal addition several techniques have been studied. For example, three standard electrochemical techniques can be used to deposit metal in situ. However, the possibility of leakage of electrolyte causing corrosion (particularly when applied to upper poles) plus the fact that the deposited layer tends to be thicker at the edges of the plated area (which could cause local field variations) led to the method being rejected.

A second possibility is to plate using a portable anode on the end of which is some absorbent material to

Four magnet units for a small storage ring being assembled in a test rig for careful field measurements. The storage ring is to be used to measure 'g-2' of the muon with extreme accuracy. To achieve the required accuracy the magnets have to be corrected so that they give uniform field across their aperture. The CERN workshops have developed the techniques necessary to produce thin foils for shimming the magnets.



CERN 273.10.72

hold the electrolyte. However the magnet surfaces are not flat and this makes the problem of positioning the anode difficult and also the probe wears away. Alternatively, it is possible to use a jet of electrolyte but then there is a high probability of corrosion.

The selected technique is to shim the magnets by sticking thin iron foils onto the pole surfaces in the required areas. The poles are there generally slightly concave in appearance and a male replica can be machined so that iron foils coated with araldite can be pressed into precise positions on the magnet and the resin cured by heating with an infrared source.

This is a simple way of modifying the magnet pole pieces and it has the advantage that, once the corrections have been made, new field measurements of the magnetic field can be carried out and further corrections applied, if necessary, without delay. The big problem is to make flat iron foils approximately 10 microns thick, 20 cm long and 2 cm wide.

To deposit this thickness of iron on, for example, a copper substrate is a relatively simple operation. However, when iron is plated it is not ductile like normal iron but very brittle. In addition, there are very high internal stresses between the plate and the substrate and if the copper is chemically dissolved in 1 % nitric acid to release the foil, the strip bends and the foil is cracked.

To overcome this a second layer of metal can be plated on top of the iron so that when the two layers are removed chemically at the same time the iron remains flat and unbroken. If the second layer is copper the rate of solution of the plated layer with respect to the rolled copper substrate is difficult to control. It was found by experiment that if a layer of nickel of controlled thickness is plated on the iron both the nickel and the copper can be dissolved at equivalent rates in a sodium cyanide/sodium sulphate bath at 60 °C to produce a satisfactory foil. For a 10 μm iron foil, a nickel coating of 12 μm is needed (other thicknesses produce a cracked foil). The foils are still very brittle and have to be stress relieved before use.

The vacuum furnace in which heat treatment is carried out is in the West workshop while the foils are made in the Godet workshop and the first foils broke in transit. The stress relieving operation is carried out at temperatures between 700 and 900 °C and, since the foils must not be contaminated with either copper or nickel, stress relief cannot be carried out before the supporting layers are removed. The diffusion of nickel and copper into iron at low temperatures is very slow and by experiment it was found that heat treatment at 450 °C gives sufficient ductility to the foils that, after stripping, they can be transported safely. A final stage of vacuum heat treatment is carried out to give complete stress relief while the flatness of the foil is maintained.

Rapid heating or cooling results in temperature gradients in the foil which cause local plastic deformation. In addition, there is an allotropic change in iron at approximately 900 °C, and this can also cause plastic deformation. It is therefore necessary to heat and cool the foils slowly — a rate of 100 °C per hour was found to be satisfactory.

Having worked out how to steer between all these obstacles the workshops finally emerged with very thin, flat, stress free foils. Their cost is about one tenth of that asked by outside industry.

Materials with memory

H. Bargmann

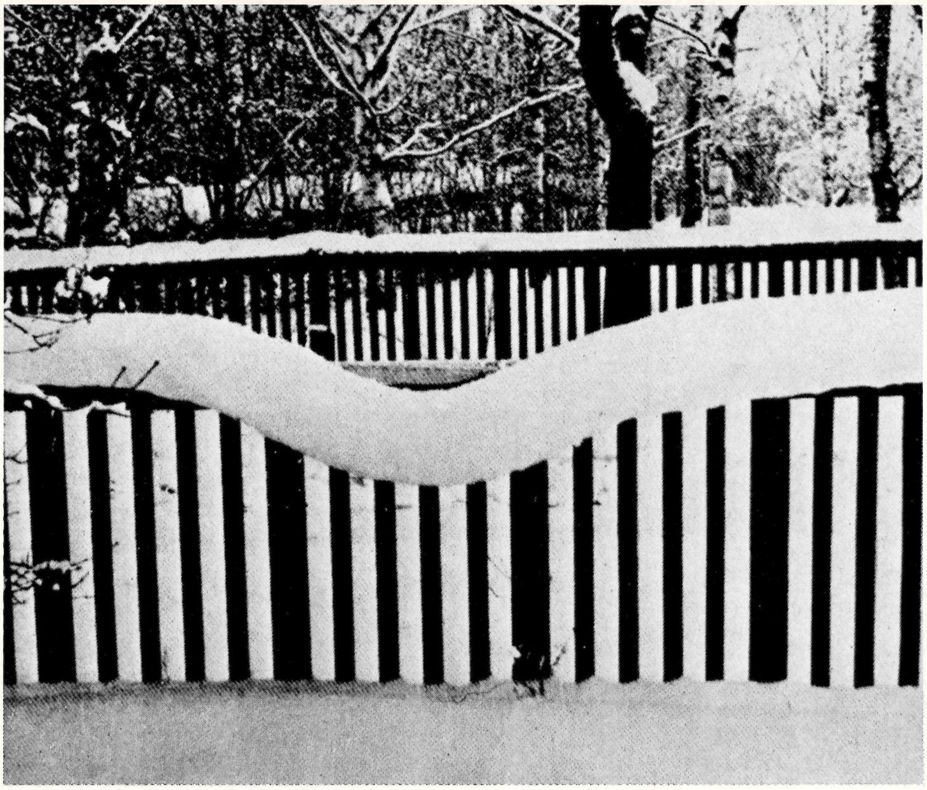
CERN has an obvious interest in the behaviour of materials and structures since it indulges in a great deal of mechanical construction and since it often exposes materials to rather extreme conditions. For the most part the necessary knowledge can be gathered from other fields where applied research has had to be done in order to use materials under still more extreme conditions. For example, a great deal of the necessary knowledge of how materials are going to behave in intense fluxes of radiation has been gathered in the nuclear reactor industry.

In recent years there has been particular interest in knowing how materials will stand up to loads. For instance, the ISR vacuum chambers at intersection regions, must withstand atmospheric pressure and yet must be extremely thin so as to allow the particles emerging from the interactions to reach the detectors outside with as little hindrance as possible. Also there have been material failures which were difficult to understand because large safety factors had been used in the design.

This led CERN to delve into some applied research to try to understand more deeply the behaviour of materials under stress. The research involved development of continuum mechanics — the mathematics of material behaviour.

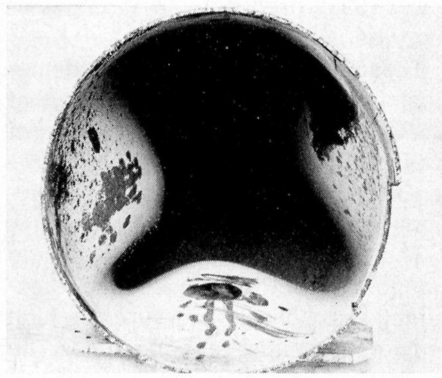
The celebrated theory of elasticity for solid bodies at elevated temperature frequently ceases to hold — the solid becomes viscoelastic. This is well known in modern aero-space engineering in reactor technology, and at CERN (in connection with certain equipment for special heat treatment of vacuum chambers). Viscoelastic solids do not respond only to the prevailing external influences but have a memory of what has happened to them during their entire past.

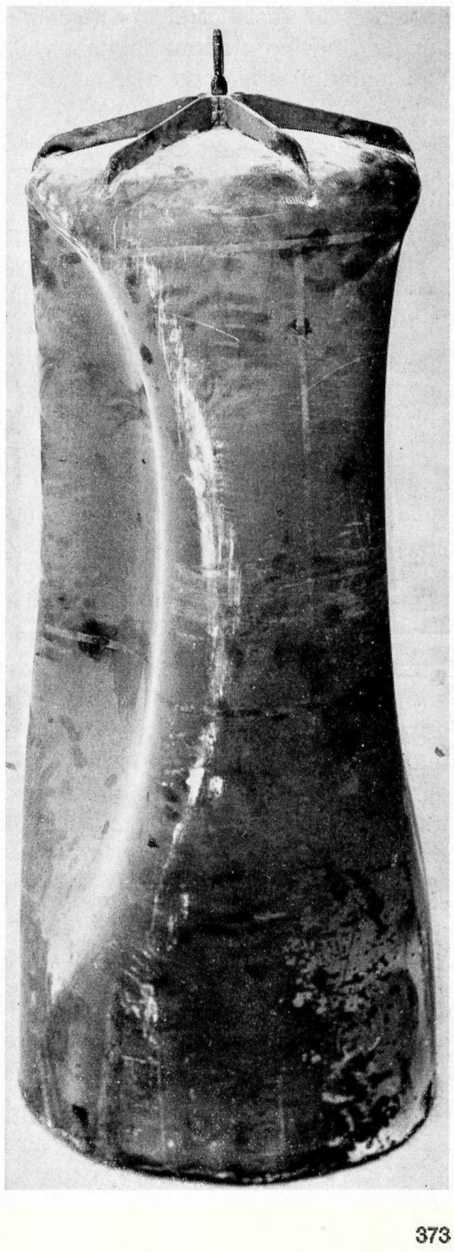
To some extent all structural ma-



An example of creep in crystalline material. The distortion of the snow cap on a garden fence in Sweden developed over a couple of days while the external influences on the snow remained virtually unchanged.
(Photo from F.K.G. Odquist's book 'Mathematical theory of creep and creep rupture' by courtesy of the Clarendon Press.)

A cylindrical shell 50 cm in diameter (made of niomic 75) which has creep buckled under atmospheric pressure after some time, despite no change in the stresses to which it was subjected and despite having a generous safety factor above the strength needed to resist ordinary elastic buckling.





terials possess the property of elasticity — the deformation of a body disappears when the load to which it has been subjected is removed. This was first announced for the special linear case in 1676 by Robert Hooke in the form of the anagram 'ceiiinosssttuv' which he spelled out two years later as 'Ut tensio sic vis' or 'The power of every springy body is proportional to its extension'. Practically all the great mathematical physicists of the following 300 years spent some time elaborating on the terms ' power ', ' springy ', and ' extension ' and the theory of elasticity has found wide application in the solution of engineering problems during the past century. Many good engineers still believe in Hooke's law as the only law describing the behaviour of solid material. And if there are obvious deviations such as when, under constant load, plastic deformations increase with time (so-called 'creep') and so on... these faithful engineers take care of them by adding generous safety factors into their design.

Hooke's simple law is very often violated since creep effects under mechanical stress are observed in most solids. They are known in glass and bitumen (liquids, more or less, with very high viscosity) in concrete and in organic polymer. Organic polymer at low temperatures is a brittle, glassy solid. At elevated temperatures it is a rubbery material, like tangled yarn. At still higher temperatures it becomes like a dish of spaghetti — additional viscous flow appears as the temperature increases, mainly due to shorter segments of chains of molecules sliding more easily over one another (viscoelasticity). Finally, the polymer turns into a viscous fluid. In all these cases, creep has a linear viscoelastic nature and hence can be treated by good clean mathematics.

Metal creep at elevated temperatures is mainly due to time-dependent plastic deformation of grains, grain-boundary sliding, or direct diffusion. Here, non-linear behaviour is predominant and it is also in the corresponding mathematics.

Modern continuum mechanics is now based on non-linear thermodynamics : from the first and second law (together with certain invariance requirements that the material properties should not depend on the observer) all the thermo-mechanical equations emerge and they severely restrict the possible laws describing material behaviour. What remains is still a wide class of functional relations — relating, for example, the present state of stress of a body with its previous history of deformation. From these relations it emerges that a solid at low temperatures obeying Hooke's law has a memory of one state only (the unstressed initial configuration) while at high temperatures, viscoelastic solids have memory of their entire past (frequently a fading memory as with human beings).

These problems and their mathematical treatment have been tackled at CERN since the solutions were not available from elsewhere. The following case will indicate that the solutions are certainly needed.

The cylindrical shell of a vacuum furnace at CERN buckled under external atmospheric pressure, at high temperature, after a finite time. The cylinder was more than adequately designed to resist ordinary (elastic) buckling having a safety factor of 20. The material was good high temperature steel with 80 % nickel, 15 % chromium, and 2 % iron. It should have easily withstood external atmospheric pressure at high temperature, and it did so perfectly for more than a year. But then it collapsed abruptly, as if it were made of paste, though the external conditions were unchanged. Gradual amplification of geometrical imperfections had accumulated and finally led to sudden collapse. The structure had memory and did not respond only to its prevailing load, but also to its loading history and collapsed when its present plus its entire history became too much.

CERN calculations are in excellent agreement with the observed failures and give precise advice on how to ensure safe constructions in the future. Similar problems occur frequently also in aerospace and nuclear reactor engineering and the CERN work will be useful there.

Handling high voltages

a) Voltage holding in vacuum

F. Rohrbach

In addition to the specialized systems which are to be found around the large particle accelerators, there are many other devices which have to operate in vacuum and at high voltage. Apart from electrostatic separators, accelerating columns, deflectors and electrostatic septums, there are other applications such as cathode-ray tubes, electron microscopes, high-power cryolinks, generators for use in interstellar or lunar space, electron guns for industry... This range of applications led many university and industrial laboratories to make a great effort during the past decade to overcome the problems of insulation in vacuum, certain aspects of which remain obscure today.

At CERN the need to obtain good performance from the high voltage pre-injector of the PS and to achieve high-quality separated beams of secondary particles led to an intense programme of technological research beginning in 1961 in order to improve voltage holding in vacuum and to increase the reliability of the existing equipment. CERN thus had the opportunity to do pioneer work in this field.

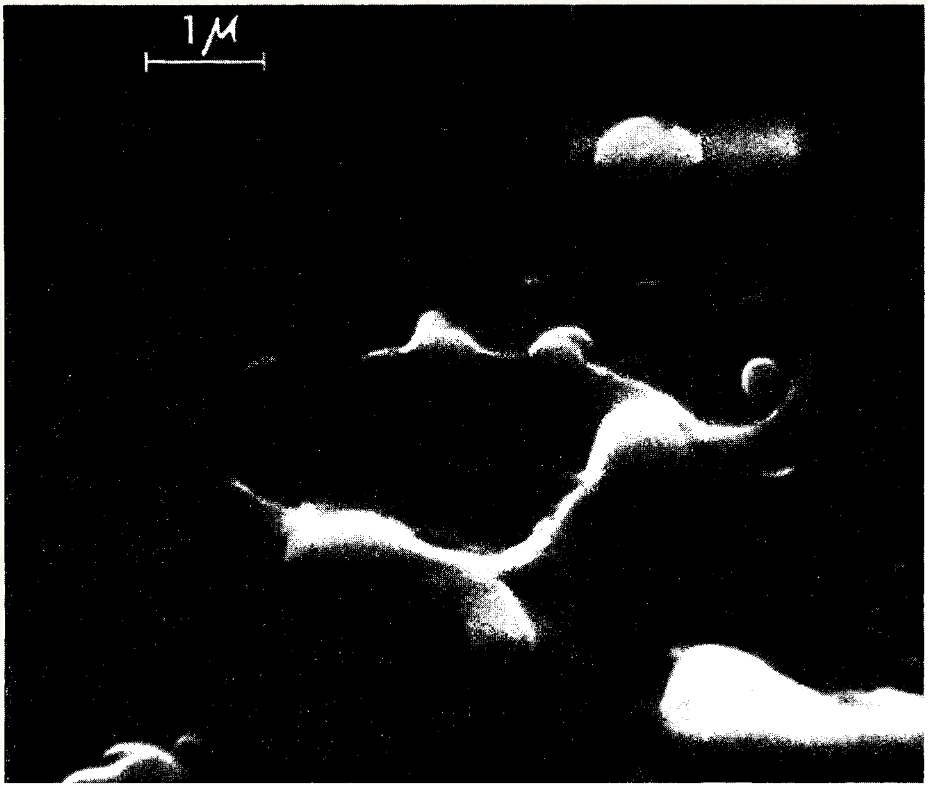
To quote a few figures : in 1961, a maximum electric field of 55 to 60 kV/cm could be obtained using large (about a square metre) electrodes 10 cm apart ; in 1969, 110 to 120 kV/cm was being recorded under the same conditions. Yet this is still surprisingly far from the theoretical limit of 100 000 kV/cm !

An attempt was made to discover the mechanisms which lead to breakdown in vacuum and more especially in ultra-high vacuum (less than about 10^{-8} torr). By measuring the arc formation time accurately as a function of the voltage and the gap between two plane pure titanium discs, information was obtained on the role played in the breakdown mechanisms by field emission and by the impact of charged microparticles. This research has shown that, depending on the gap between the electrodes, one or other of the phenomena predominates.

In the case of short gaps (less than about 10 mm), the electrical discharge is initiated by the explosion of a cathode micropoint (0.1 to 0.5 μm high), caused by too intense a field emission leading to thermal instability of the emitting point. At greater distances, it is the so-called microparticles (from 0.01 to 10 μm in diameter) that cause the breakdown when they are torn from the anode, accelerated (up to velocities of several km/s) and strike the cathode. The impact produces a microscopic flaw which is sufficient to initiate an intense electron emission causing spontaneous breakdown due to the creation of microscopic points.

There is a great difference in the time involved in these two types of mechanism ; in the case of short gaps, the breakdown lasts a few tens of nanoseconds whilst at greater distances, when the microparticle has to be formed as well, it is a matter of microseconds and even milliseconds. The mechanism of formation of microparticles is still under investigation but there can no longer be any doubt as to their existence. It is thought that, apart from the arc itself and the metal fusion that it causes, microparticles may also be created by a mechanism of accelerated surface diffusion at the anode under electron bombardment and the resultant anode heating : the electron bombardment is due to emission from the microscopic cathode points.

We now have a clearer understanding of why it is possible to improve the insulation in vacuum considerably by using cathodes coated in insulating metallic oxide (such as Al_2O_3) or glass ; the use of a cathode coated with an insulating layer prevents electron field emission.



Photograph taken with a scanning electron microscope showing the surface of a cathode made from pure titanium which has suffered breakdown at 600 kV in ultrahigh vacuum. Microparticles were torn away from the anode by the electrostatic forces when the high voltage was applied and have struck the cathode leaving craters. The rough crater regions are then likely points of origin of breakdown.

The study of breakdown mechanisms has shown that it would be better if devices with inter-electrode gaps of more than 1 cm were supplied with a pulsed rather than a d.c. voltage whenever the operating conditions permitted pulse lengths as short as a few microseconds. There would then not be enough time for the microparticles to take effect. This should enable present performances to be doubled.

The main improvements that have been made in the use of high voltage in vacuum as a result of the work done at CERN can be listed as follows :

1) The use of cathodes coated with aluminium oxide in a layer approximately 5 to 7 μm thick doubles the breakdown voltage.

2) A 'good' vacuum is very important to ensure reliability (involving the use of turbomolecular pumps, no rubber seals, clean surfaces, and henogal as a residual gas).

3) Electrodes made from titanium, perform better.

4) Microparticles have been identified as a cause of breakdown in vacuum across large gaps.

In the course of the research, there have also been improvements in ancillary equipment such as high voltage bushings, damping resistances and isolators, in the virtually unexplored megavolt regions. The work has often been done in close collaboration with industry which has thus benefited considerably from the progress achieved at CERN.

b) Application in electrostatic septums

C. Germain

A recent application of the accumulated experience in high voltage technology has been the design, construction and operation of electrostatic septums for the 28 GeV proton synchrotron. This has involved some further applied research because of the special environment and special requirements in the accelerator ring.

A septum is, in accelerator terminology, a thin partition-wall confining a region in which there is a magnetic or electrostatic field. Normally, a septum magnet has a C-shaped yoke closed by a thin wall forming the septum which is one side of the magnetizing current loop. Passing high current through the septum produces a field which is restricted to the magnet aperture. An electrostatic septum usually has a light alloy yoke sealed with taut metal foil or wires. This electrode is earthed and, parallel to it, another electrode (thick this time) is connected to high voltage. Again this restricts the field to the region between the two electrodes so that it is virtually zero on the other side of the foil or wire plane.

A septum of one type or another is an essential element of injection and ejection systems in synchrotrons. The accelerated beam is subjected to progressive sweeping through a resonance region when the current in some auxiliary magnets is modified, and the amplitude of the oscillations made by the protons is increased with successive revolutions until they jump across the septum and are deflected out of the accelerator ring. The septum must be as thin as possible because proton losses are directly proportional to the thickness of the septum they have to jump.

This problem of loss on the septum has been aggravated by the development of synchrotrons towards higher intensities. The fraction of beam which

An electrostatic septum during assembly and prior to installation of the screens which protect the cathode from ion bombardment. Note the external mechanical systems which are linked to the accelerator control room so that the positions and orientations of the electrodes can be remotely controlled.

can safely be lost without exceeding an acceptable radiation level, has become smaller, and the interest in using thinner septums has increased.

The problem with septum magnets is that, if the septum is made thinner, it cannot carry high enough current to set up the required field and hence the deflection it produces is too small for the beam to enter the extraction magnet. The electrostatic septum used as the first element in slow ejection channels is at present the best solution since it can be made very thin. In fact, the electrostatic septum is added upstream of the first 'normal' septum magnet, which can then have a thicker septum and be more reliable to operate.

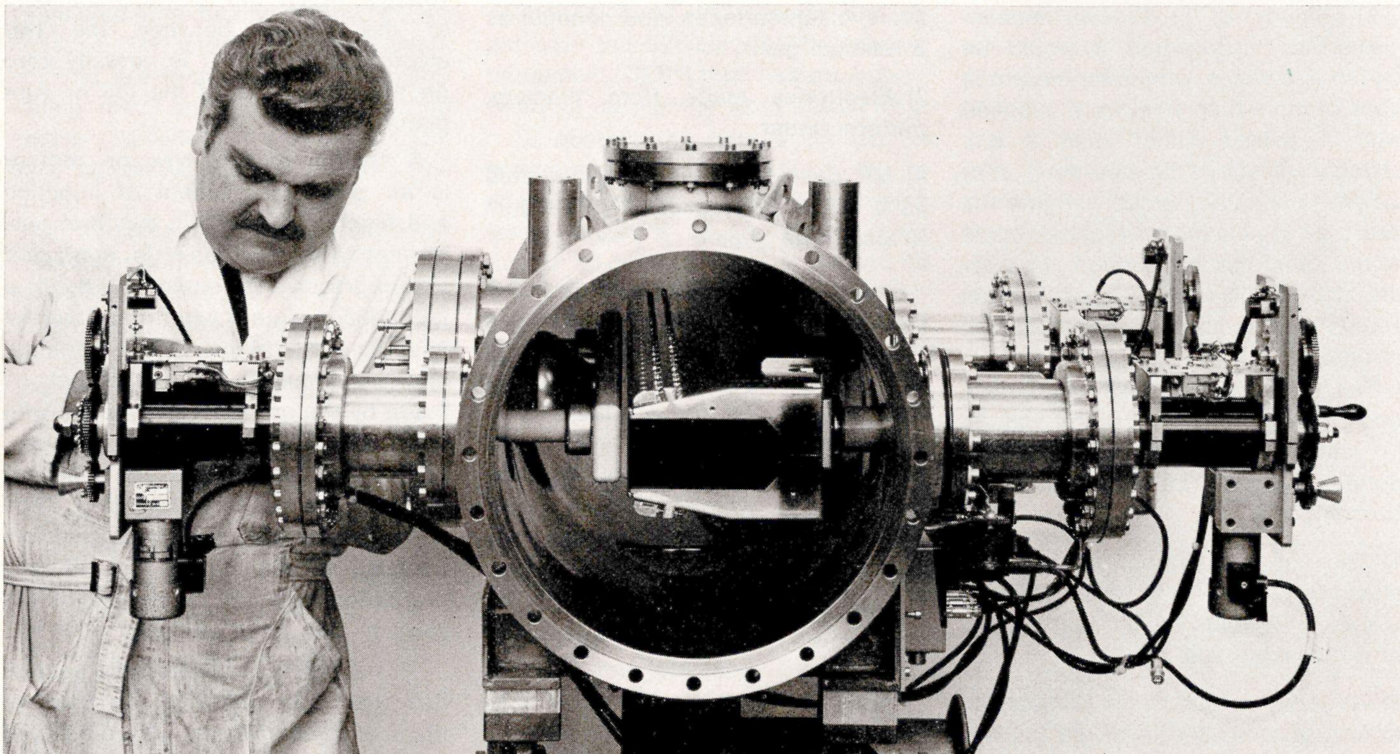
To make the orders of magnitude clearer, we can look at the septum magnet constructed at CERN by R. Bertolotto. The septum has a thickness of 1.5 mm and cooling water flows through it under high pressure. It operates reliably under d.c. conditions at 0.2 T. It is not possible to reduce the thickness and still have water flowing in the septum. Water cooling can then only be done on the edges — the cooling is not as good and the field has to be reduced because of the current the septum can take. With a thickness of a few tenths of a millimetre, the bending strength becomes inferior to that of an electrostatic field, even for pulsed operation in slow ejection.

In the case of the electrostatic field there is no current going through the septum and therefore no heating problems. The septum can be very thin as it is needed just to set up an equipotential surface.

The electrostatic septum method has been used (under different conditions) in certain cyclotrons for about ten years. They were not applied in synchrotrons until recently because it requires a very high electric field to achieve adequate bending of the particles, whereas quite modest magnetic fields are equally efficient. For example, for relativistic protons a weak magnetic field of 0.03 T (300 gauss) is equivalent to a high electric field of 9 MV/m (90 kV/cm).

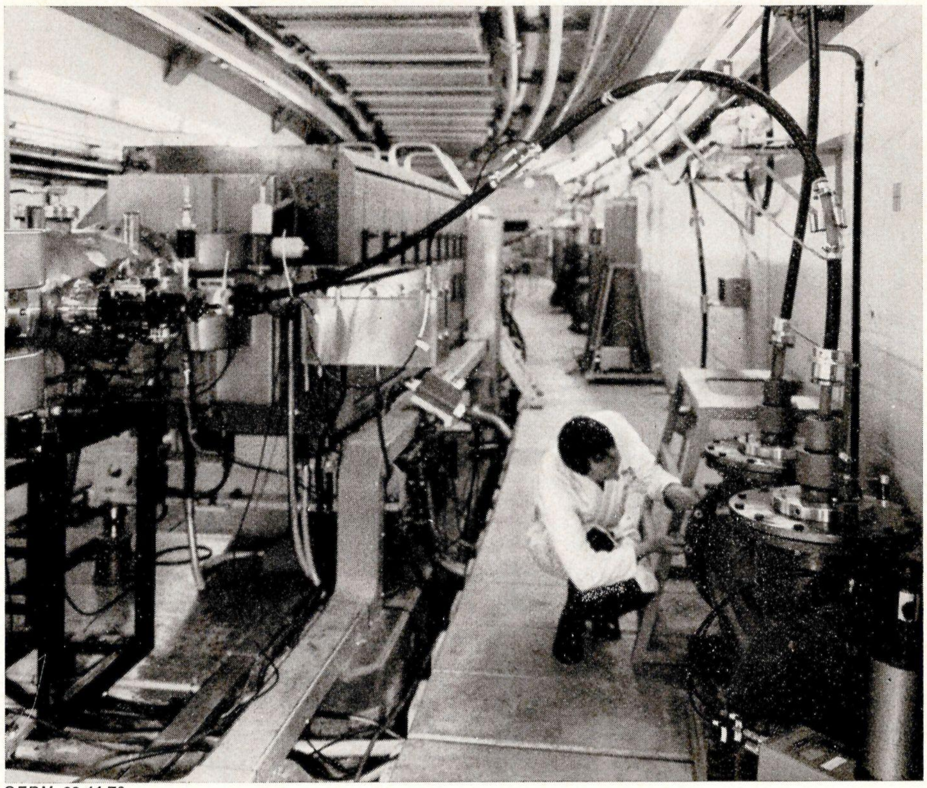
Introduction of the electrostatic septum at the CERN PS

The first proposal for the use of an electrostatic septum in the slow ejection system of a synchrotron was at NAL in 1968 by A.W. Maschke and K.R. Symon. Brookhaven and CERN were interested because their synchrotron improvement programmes were aiming for 10^{13} protons/pulse. A prototype electrostatic septum was made at CERN in a few months and set up in straight section 64 of the PS at the beginning of 1970 for slow ejection tests. Serious difficulties were encountered due to different interactions



CERN 202.11.70

An electrostatic septum installed in the 28 GeV proton synchrotron. This septum is the first unit in the slow ejection system which sends protons to experiments in the East Hall. On the right can be seen the high voltage generator which feeds the electrodes of the septum.



CERN 33.11.70

between the beam and the septum but they were solved progressively. It was nevertheless possible, at the first attempt, to eject a low intensity beam with a record slow ejection efficiency of about 95 %.

After this encouraging start the prototype was set up, in June 1970, in straight section 45 to take part in the development of the new slow ejection system (called SQUARE), which sends beams to the West experimental hall. A second electrostatic septum was set up in straight section 43 during 1971 for slow ejection 62 and, in October, resulted in the first normal physics run using the ejection system for approximately 250 hours. During 1971 the problems of high voltage operation of the electrostatic septum and its coupling with the beam were studied.

This year, SQUARE has come into operation in straight section 16 and its electrostatic septum is located in straight section 83. Up to now this septum has operated for about 730 hours without incident. The electrostatic septum of straight section 83 has also been used successfully for tests on the continuous transfer ejection scheme.

The development problems and their solution

The electrostatic septum, like the electrostatic separator, is basically a flat capacitor working in a vacuum. The techniques in both have much in common but there are some differences in the case of the electrostatic septum which should be underlined :

— One of the electrodes (the anode in our case) must be very thin and yet keep its shape in spite of sparking ;

— The vacuum is that of the synchrotron and therefore gas cannot be injected under controlled conditions so as to work in a semi-vacuum of a few 10^{-4} torr, which gives the best high voltage performance ;

— The proton beam intensity is some millions of times greater than that of a secondary beam ;

— The proton beam strikes the anode septum and, furthermore, secondary ions are created by the protons in the residual gas and act on the cathode, which certainly does not make for good high voltage performance ;

— The distance between the electrodes is smaller, but the field is higher ;

— The radiation level of the environment is much higher, introducing problems of choice of materials and of maintenance.

Different materials were tried and the best results were obtained with the oxide-coated cathodes developed for the separators. For the anode, stainless steel gave the best high voltage performance but was replaced by molybdenum, which is not quite as good but which retains its shape better under sparking. Titanium (with which J. Huguenin obtained very good results in the construction of an accelerator tube) proved less interesting, from the point of view of reliability and performance, for septums.

The apparent thickness of the septum, which is a 0.1 mm molybdenum foil stretched over the C-shaped yoke, is approximately 0.15 mm when all the irregularities in shape are taken into account. The position of the electrodes can be adjusted to 0.1 mm and the septum angle to 0.01 mrad, from the control room. In this way it is possible to optimise the operating conditions with regard to proton loss and operation under high voltage.

It was found that the beam caused sparking even without proton loss despite satisfactory performance without the beam. Analysis of this phenomenon revealed that it was due to the action on the cathode of the secondary ions created in the vacuum chamber by the protons. The problem was cleared by introducing a system of screens to prevent the ions from falling on to the cathode. An improvement in the PS vacuum also helped.

Another effect of the beam is due to the loss of protons at small angles to the cathode, which triggers off sparking by intense secondary electron emission. This occurs if the spacing between electrodes is insufficient for the dimension of the beam ejected. On the other hand, interaction of the beam on the anode septum does not cause sparking with the present intensities of 10^{12} protons/pulse.

Also the anode constitutes a cavity resonator coupled to the beam and can be excited by some of the beam harmonics. The general problem of coupling to the beam has been studied, in particular by H.H. Umstätter, and the resonance modes which were dangerous for the beam have been completely eliminated.

The CERN electrostatic septum uses a thin metal foil but it is also possible to use a row of fine parallel wires and this is being tried in the USA. Wires should enable a good shape to be obtained more easily and should also result in smaller proton loss due to interaction in the septum since the average angle of multiple Coulomb scattering for a row of wires is lower than for a foil. We regard it as a potential improvement for the future but at present the maximum possible efficiency using foil has not been obtained. Furthermore, using foil is much easier, which enabled us to put electrostatic septums quickly into service, and to acquire experience of how they worked in normal operation in a synchrotron.

Tests on wire septums have been carried out in the laboratory and in the PS to pinpoint their specific problems. Briefly, the problems which have to be solved are : increased mechanical complication and cost ; fragility of the wires when sparking (giving lower reliability) ; inferior high voltage performance ; greater distortion under the effect of the electric field ; difficulty of shielding the cathode against secondary ions ; electric fringing field through the wires disturbing the orbiting beam at low (injection) energy.

The seriousness of these problems varies with the specific application. Rows of wires may be used in the second generation of electrostatic septums, when the maximum efficiency of foils has been reached.

Performances to date

The electrostatic septums used up to now in the PS are about 1 m long, so that they can be accommodated in the short straight sections of the machine.

The septums are first tested in the laboratory and the maximum voltage value reached in the laboratory over a spacing of 10 mm is about 240 kV. In short duration tests (a few hours), the septums in the machine have functioned with the same spacing at voltages from 150 to 170 kV with low sparking rates (a few sparks per hour). It was even possible to work at 200 kV a few times.

Several physics runs have used an electrostatic septum as the first element in the slow ejection system. The distance between electrodes was then adjusted to between 10 and 12 mm. With the present beam characteristics, the working conditions required of the electrostatic septum are easily met : over a spacing of 10 to 12 mm, all that is needed is a field of 100 to 110 kV/cm. The corresponding sparking rate is practically nil — e.g. a few sparks per day over a total of 30 working days.

A 2.3 m electrostatic septum has been built by adding extensions on to the standard 1 m model. It has just been installed in the long straight section 61, where it helps out the septum magnet in the version of SQUARE applied to slow ejection 62.

In conclusion the development work on electrostatic septums has already resulted in improvements in slow ejection efficiency. With a spacing between electrodes of 10 to 15 mm and a working field of 100 kV/cm, very stable, reliable operation is achieved. It may be possible in the future to increase the field to 150 kV/cm, without reducing reliability and also to use wires for increased ejection efficiency. The experience acquired at the PS will be very valuable for the applications planned at the SPS and elsewhere.

CERN News

HPDs clock a million

On 23 October the millionth bubble chamber photograph was measured on the HPDs at CERN. This is in addition to about one and three quarter million spark chamber photographs which the machines already have under their belt.

The Hough-Powell Digitizer has been described several times before in CERN COURIER (see for example vol. 10, page 46). Since their invention at CERN in 1959-60 (the only major automatic film measuring system to emerge from Europe in the 1960s), the HPD has become the most widely used of these machines. About thirty of them are in action in different Laboratories throughout the world. The first HPD millionaire was at Berkeley (in March 1968), followed by Brookhaven (1970) and now (as far as is known) CERN.

The HPD is by now a comparatively old device. Newer ideas (especially involving cathode ray tube measuring systems) are being developed and the writing is on the wall for the machines at CERN.

A month earlier, on 20 September, around fifty participants from all the Western European Laboratories using HPDs, gathered at Saclay for the annual informal one-day meeting. The first session was devoted to status reports and, with two exceptions, in general recorded solid production (limited only by predigitizing capacity) giving annual totals of 80 000 to 200 000 measured pictures. The two exceptions are Rutherford, where there is virtually no predigitizing bottleneck and where one HPD measured 335 000 events on film from the 2 m bubble chamber in 1971, and CERN, where there are two HPDs, one of which (HPD2) has hardware problems and the other (HPD1) is also used for spark chamber film. Together, the

To celebrate the measurement of the millionth bubble chamber event on the CERN HPDs we escape from the usual photograph of the machine or of an event and show instead a group of HPD pioneers captured on film at a meeting in 1960. Left to right: D. Maeder, H. Lipps, W.G. Moorhead, L. Kowarski, S. Nilsson, T. Lingjaerde, R.K. Böck, M. de Baets, F. Grard, L. Montanet, I. Derado, B. Aubert, P.V.C. Hough, D. Wiskott, B.W. Powell and Y. Goldschmidt-Clermont.

CERN machines measured 210 000 events from the 2 m chamber plus 65 000 spark chamber events in 1971.

The second session concerned the development of 'Minimum Guidance' systems. The only laboratory currently using this for physics is Amsterdam (60 000 events measured with reasonable success), although some other Laboratories are developing systems or have new ideas.

The session on large chambers grouped technical papers from several Laboratories on digitizing electronics. Test samples from the Argonne 12 foot chamber and from Mirabelle are being used to try out the systems. The conclusion was that, despite different approaches (some using lasers and some not), such film is digitizable on HPDs. There was no paper on software for track recognition. New geometry methods are being used on the first Mirabelle film, they await a large flow of events to be fully tested.

The meeting was a useful means of making contacts and exchanging information and was well and hospitably organized by Saclay. It is hoped to publish the papers early next year.

SKYLAB inaugurated

On 16 November the European Southern Observatory Sky Atlas Laboratory (ESO SKYLAB) was inaugurated at CERN. It is situated in a few ground floor rooms of Building 54 close to the barrack where the ESO Telescope Division is located for the duration of its collaboration with CERN (see May issue). In these rooms the painstaking task of amassing copies of an atlas of the sky in the southern hemisphere will soon begin.

The northern sky was mapped in the early 1950s using the 48 inch Schmidt telescope at Mount Palomar. It involved 1870 plates and copies of these have been used by astronomy research centres throughout the world and have been of great importance in the research. Now the ESO 1 m Schmidt on La Silla in Chile is ready to start an equivalent exercise in the south and will soon be joined by a 48 inch Schmidt to be operated by UK astronomers at a site in Australia.

The ESO telescope will begin with a rapid survey, taking about a year, in the blue wavelength. Each plate will cover a region of $5.5^\circ \times 5.5^\circ$ requiring a total of 606 plates for the entire map. These negative plates will be on 1 mm thick glass and hence very fragile. A positive copy will be made in Chile and it is this positive copy which will travel to SKYLAB. Only a limited edition of thirty copies of this first rapid survey will be made and distributed to centres in the ESO Member States, the UK and USA.

Around May of next year, a longer and more thorough survey will begin in the red wavelength. This will take about two years to complete and involve fast plates to record faint objects. Again 606 plates will be taken and will form the red half of the definitive atlas of the southern sky.

The blue half will be provided by the Schmidt in Australia which will repeat the first ESO survey with greater resolution. Collaboration between the two observatories has ensured that the scale and the centring of the plates at the two telescopes will be identical. SKYLAB will also handle the production of copies of the blue atlas.

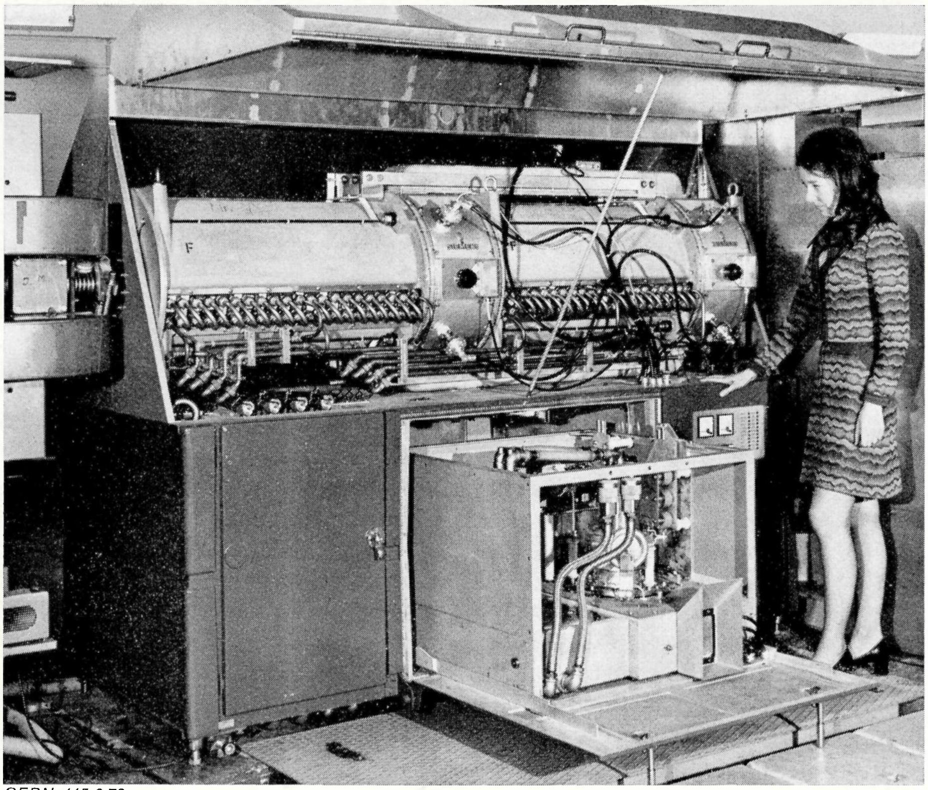
SKYLAB obviously has advanced photo developing and processing equipment with 'clean' enclosures, freon washing baths to remove tiny specks of dust, photometric control of exposures, automatic printing machines with vacuum presses, cold stores, etc... It has work to occupy four people for many years because 200 copies of the atlas are envisaged, each of 1212 films 40×40 cm². This corresponds to a film area of about 200 m² and over this area not one speck of a diameter about 15 μm should either be missed or inadvertently introduced. That would mean a star too few or too many. We wish SKYLAB well as it begins its exacting task.

New r.f. cavities

The 28 GeV proton synchrotron has been operating since the middle of October with new r.f. accelerating cavities. This is the successful outcome of a project to replace the original cavities which was initiated in 1968.

The need for this replacement and the possible solutions which were examined were described in CERN COURIER, vol. 10, page 113. There were two main aspects. The first was the interest in doubling the accelerating voltage of the cavities

One of the ten new r.f. accelerating cavities installed in the main ring of the 28 GeV proton synchrotron. They can cope with the higher intensity beams, shortly to be available from the Booster, and can speed the acceleration cycle compared with their predecessors installed thirteen years ago.



CERN 115.6.72

compared with the cavities with which the PS was fitted when it was built in the late 50s. The second was the need for a system which could accept and accelerate the high intensity beam from the 800 MeV Booster.

The new r.f. stations can accelerate a beam of high intensity (more than 10^{13} protons per pulse) even in conditions which are not ideal. The power of each r.f. amplifier has been increased by a factor of 20 to 90 kW, which is close to that of a powerful radio transmitter. The accelerating voltage per cavity is now 20 kV, the frequency variation rate is 500 MHz/s and the frequency range extends from 2.8 to 10 MHz.

In addition to the above improvements, the number of auxiliary components in the radioactive regions (which are inaccessible while the machine is running) has been reduced to a minimum by bringing components together at the centre of the ring. This will make maintenance much easier. Whereas the original cavities needed twenty tubes each in their amplifier system, the new model has only two and the remainder of the system uses transistors.

The new cavities have been installed one at a time so as not to interrupt the running of the PS and have thus worked together with the old units. At the moment, ten new cavities have been brought into operation and there remain four of the old stations still in place in the ring (but not now in action). Fourteen new r.f. stations in all have been ordered. Siemens built the cavities, amplifiers and power units, while Philips supplied the ferrites.

This part of the PS improvement programme has been carried out on schedule and the new r.f. system is proving very reliable.

Around the Laboratories

BERKELEY
Bevatron heavy ions

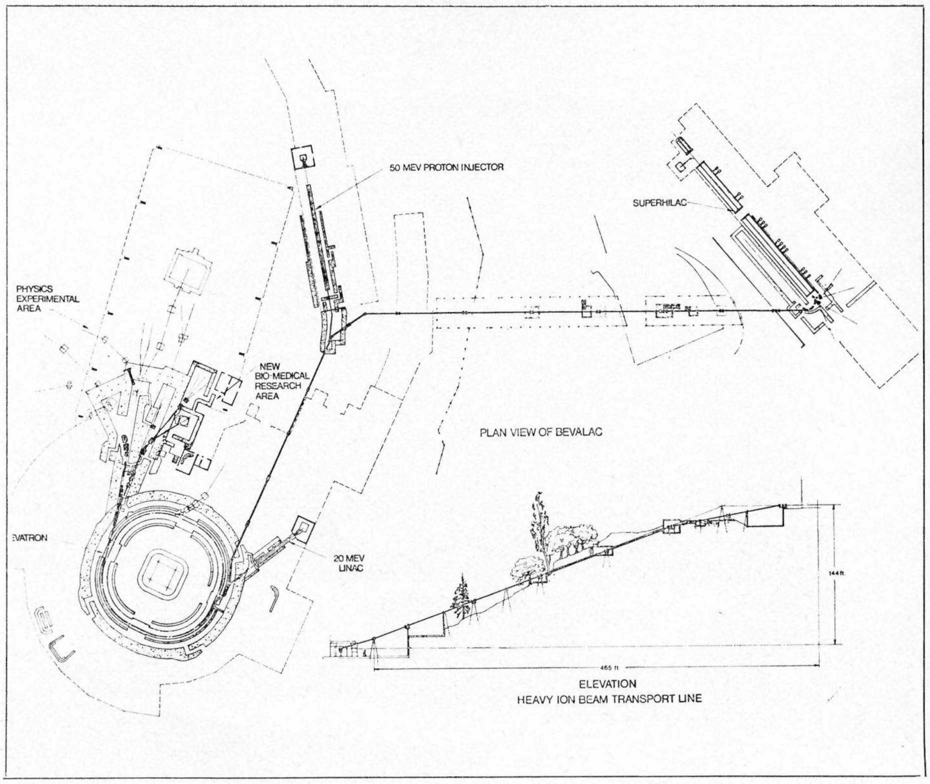
The Bevatron recently completed a very successful three week period of experiments with beams of heavy ions. During this period, beams of record intensities were achieved, a factor of ten up on the initial values. The run marked the first anniversary of heavy ion operation at the accelerator and was the fourth period of development and experimentation in this new area of research.

The run was particularly gratifying because extracted beams of elements up to oxygen were available in sufficient abundances for high energy physics, bio-physics and bio-medical research. It demonstrated the success of a development programme which aimed to increase the intensity of the heavy ion beams and extend to heavier elements. A major part of this programme was to reduce the ion loss due to recombination during acceleration. This was achieved by improving the Bevatron vacuum; cryogenic pumping panels were installed along the inner periphery of the vacuum tank and operated at 20 K. The pressure was reduced from about 1.5×10^{-6} torr to 3.5×10^{-7} torr. Improvements in the ion-source, linear accelerator and r.f. acceleration system also contributed to the increase in beam intensities.

The following types of ion are now available in the energy range of 0.25 to 2.1 GeV per nucleon and the number of particles per pulse at the target is indicated in brackets: ^{2}He (2×10^{11}), ^{4}He (2×10^{10}), ^{12}C (1×10^{8}), ^{14}N (1×10^{7}), ^{16}O (1.5×10^{7}), and ^{20}Ne (1×10^{5}).

With the beam intensities that are now available, and for ions up to and including ^{16}O, the improved beam phase and radius feedback loops of the acceleration system can be used in addition to the pre-determined r.f.

Bevalac, the combination of the heavy ion linear accelerator Super-Hilac with the Bevatron, which will considerably extend the research programme with heavy ions at Berkeley. The beam transport line from Super-Hilac rolls particles down the hill for injection into the synchrotron. Note also the new (ex-Brookhaven) 50 MeV linac which should take Bevatron 6 GeV proton intensities above 10^{13} per pulse.



and magnetic field programme. The basic programme has been obtained and stored in a PDP-8 computer by using an abundant tracer-particle $^4He^{2+}$ having the same charge-to-mass ratio.

The stability of the Bevatron and its ability to operate without phase and radius information was essential for the first heavy ion runs when the beam intensity was too low for operation with the feedback loops. This capability remains important because operation with ions heavier than oxygen is done in an open-loop mode. Open-loop operation is also necessary when the experimental programme needs low beam intensity. The only practical way to reduce intensity, and at the same time maintain purity of the beam, is to reduce the injected beam intensity. This is because collimation of the extracted beam can result in contamination of the beam due to fragmentation when ions strike the collimators.

During the past year about 20 % of the Bevatron experimental programme has involved heavy ion beams, and heavy-ion operation will probably continue at about the same level. Research is being carried out in the field of high energy physics, nuclear chemistry, biology and medicine, and about thirty experiments have been completed. Topics include studies of heavy ion fragmentation, total cross-section measurements, collective effects, cancer research, brain research, space flight radiation biology, biology of differentiation and development, and radiation genetics.

The proposal to use Super-Hilac as an injector for the Bevatron has advanced to the stage when construction could begin. Using this heavy ion linear accelerator in combination with the Bevatron (the combination being known as Bevalac) should enable ions up to calcium to be accelerated with sufficient intensities for experiments — for example, 10^{10} particles per pulse on the target for oxygen, 10^9 for neon and 10^8 for calcium.

DARESBURY
Beam sharing increases utilization

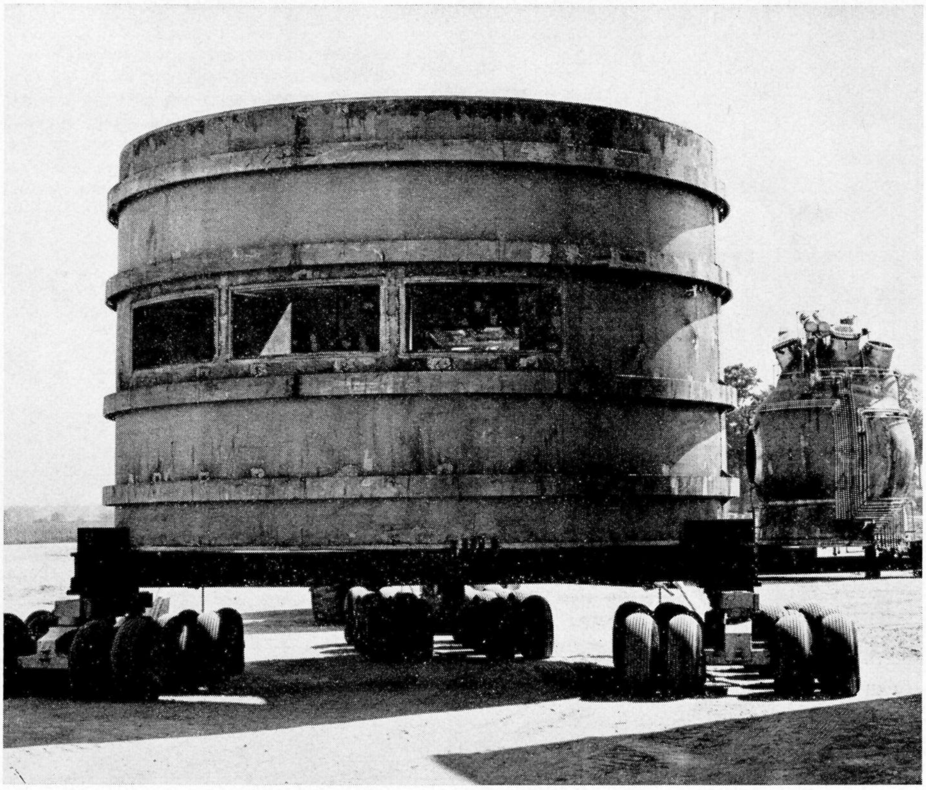
A new technique by which the beam intensity can be shared between two extracted electron beams without altering the duty cycle has been developed at Daresbury. The technique was successfully used for nearly 1000 hours of data taking on the 5 GeV electron synchrotron.

Intensity sharing between extracted beams is more difficult on electron synchrotrons than on proton synchrotrons because of the time-scales involved in the acceleration processes (an electron machine ticking away at many cycles per second while a proton machine takes several seconds). A common solution has been to divert some of the electron bunches down one extracted beam line leaving the remainder for another beam line. This has the disadvantage of altering the duty cycle for the user.

The regenerator method of simultaneously producing two extracted electron beams, pioneered at Daresbury, shares intensity without altering the duty cycle. Two regenerator magnets are placed n/3 betatron wavelengths apart where n is an integer. The internal electron beam is brought to the regenerator magnets by a new form of orbit distortion which gives two outward displacements of the orbit. The regenerator magnets then produce a horizontal resonance which results in the ejection of two electron beams. Physically, each regenerator is a single current strip producing a field which has multipole components which are required and also an unwanted dipole component. The dipole component produces closed orbit distortions which reduce the extraction efficiency. The positioning of the two regenerators, which also act as septa, controls the intensity sharing between the extracted beams and also the extraction efficiency. Careful positioning has yielded an extraction efficiency of 50 % and 2 % for the two beams. These efficiencies are ideal for the simultaneous running of a high intensity electroproduction experiment and a tagged photon experiment.

The beams have been used by the Daresbury-Pisa pion electroproduction experiment, (requiring 10^{12} electrons per s) and by the Lancaster vector meson photoproduction from nuclei experiment (requiring a collimated 10^7 electrons per s). Both experiments have now completed their data taking.

The pion electroproduction experiment selected electron-neutron coincidences using a conventional electron



The large superconducting magnet of the Batavia 15 foot bubble chamber, which operated successfully in October, being transported in its cryostat earlier this year. The chamber body with the camera parts on top can be seen to the right.

(Photo NAL)

spectrometer arm and a neutron counter consisting of a 2×2 m² modular array of 145 elements. The neutron counter is the largest in use anywhere for this kind of work. The experiment studied the details of the electroproduction of the positive pion near threshold in the reaction

$$e^- + p \rightarrow n + e^- + \pi^+$$

Measurements were taken at momentum transfers of 0.08, 0.16, 0.24 and 0.32 $(GeV/c)^2$ and will give total and differential cross-sections for the electroproduction over a range of centre-of-mass energies near threshold. The data will be free from assumptions about the contribution from neutral pion electroproduction or the radiative processes which dominate the threshold region.

The Lancaster experiment studied the reactions

$$\gamma + A \rightarrow A + \omega \text{ and } A + \varrho$$

where A is a nucleus. Data was collected for photon energies from about 1 to 4.6 GeV using solid targets from beryllium to gold and liquid deuterium. The reactions are studied by observing the charged pions and the photons from the neutral pion decay in thick-plate spark chambers. The steel plates of the spark chambers are 0.1 radiation lengths thick and in three stacks each about 4 radiation lengths in depth. The chambers are triggered by a system of 21 scintillation counters placed before and within the stacks and the logic can be arranged to give a trigger corresponding to several possible combinations of charged particles and photons.

Because of the large solid angle subtended by the spark chambers at the target and the sensitivity of the apparatus to photons, the experiment should distinguish between photoproduction of rho and omega mesons alone and photoproduction together with other particles. The importance of this distinction, not made by previous experiments, has recently received considerable emphasis.

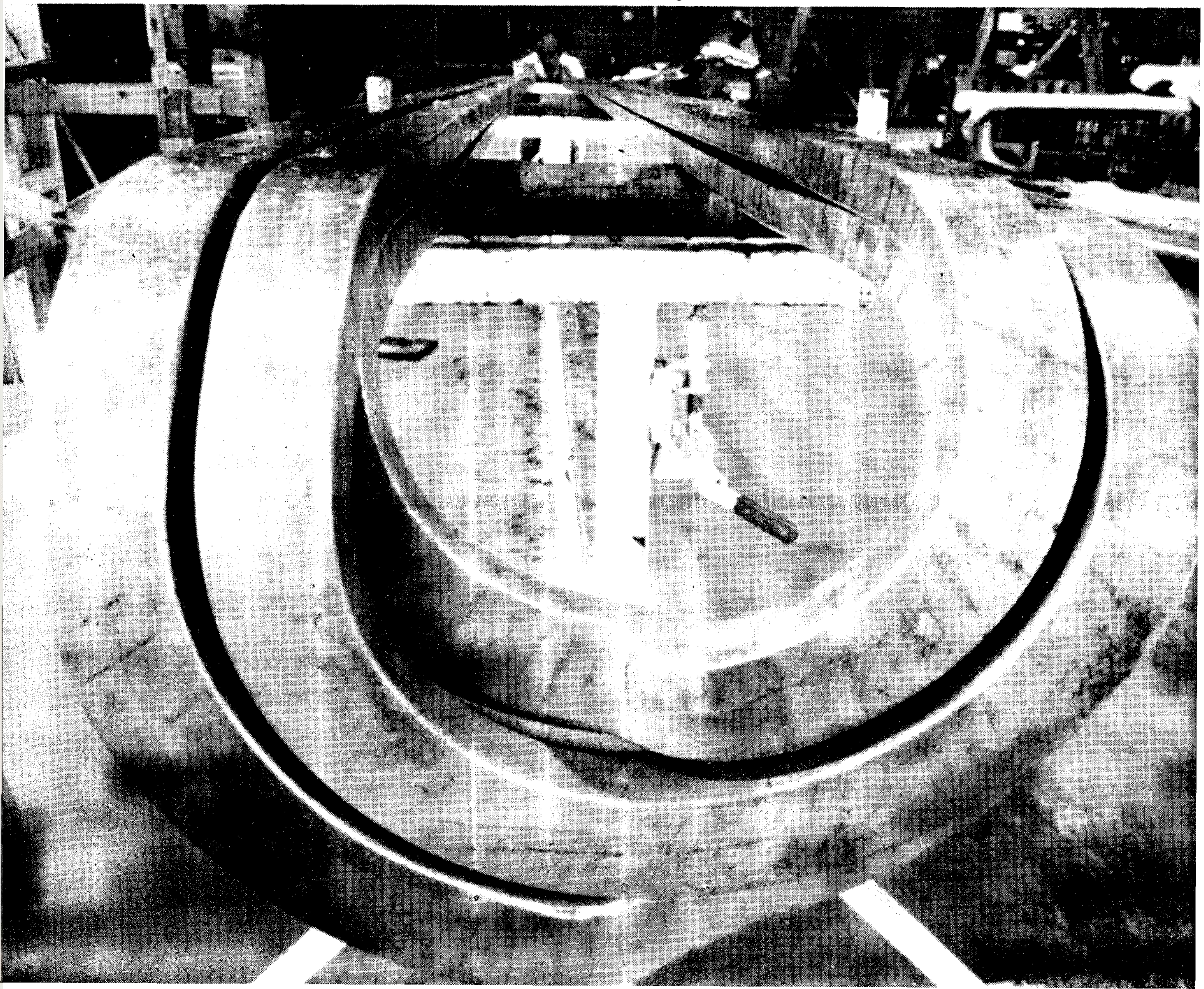
ARGONNE/BATAVIA
Magnet for the 15 foot chamber

As reported briefly in the last issue, the huge superconducting magnet for the 15 foot bubble chamber at the National Accelerator Laboratory, Batavia, operated successfully in October. The magnet was designed and constructed at Argonne.

The specification for the magnet was evolved in the course of the design of the bubble chamber. It was assigned to the Argonne National Laboratory in 1970 since Argonne had proven experience with large superconducting magnets (particularly for their own 12 foot bubble chamber). However the magnet for Batavia is technologically more advanced. It is required to produce a 3 T field at the centre of a volume almost 4 m in diameter and 3 m high.

The magnet consists of 43 coils wound as flat 'pancakes' each with almost 1000 m of conductor strip about 3.75 cm wide and 0.375 cm thick. The conductor contains 60 filaments of niobium-titanium superconductor in a high purity copper matrix (which accounts for 95 % of the volume of the strip). Stainless steel strip is wound in with the conductor to give the coil additional mechanical strength and mylar is used for insulation between the turns. The overall current density is 2 kA/cm². This generates the required field in the chamber volume and corresponds to a maximum field at the conductor itself of 5.1 T. There is no iron yoke or iron shielding which reduces the cost but requires precautions because of the large stray field. The energy stored in the magnet is 400 MJ.

The conductor was supplied by Supercon using copper from American Metal Climax. Winding of the coils was carried out at Argonne where the construction of the magnet was led by J. Purcell. The coils were installed in a helium cryostat manufactured by Stearns-Roger Corp. and the helium system was obtained from Cryogenic Technology Inc. Construction and testing was completed on schedule and the cost (about $2 million) was close to the original estimate.



The TTL line from FAIRCHILD

Standard	Low Power	High Speed	Super High Speed	Description
7400	9L00	9H00	9S00	Quad 2 Input NAND Gate
7401		9H01		Quad 2 Input NAND Gate (O.C.)
7402				Quad 2 Input NOR Gate
7403			9S03	Quad 2 Input NAND Gate
7404	9L04	9H04	9S04/A	Hex Inverter
7405		9H05	9S05/A	Hex Inverter (O.C.)
7406				Hex Inverter (U/BR < 30 V)
7407				Hex Driver (U/BR < 30 V)
7408		9H08		Quad 2 Input AND Gate
7409				Quad 2 Input AND Gate (O.C.)
7410		9H10		Triple 3 Input NAND Gate
7411		9H11		Triple 3 Input AND Gate
7412				Triple 3 Input NAND Gate (O.C.)
7413				Dual Schmitt Trigger
7416				Hex Inverter (U/BR <15 V)
7417				Hex Driver (U/BR <15 V)
7420		9H20	9S20	Dual 4 Input NAND Gate
		9H21		High Speed AND Gate
		9H22	9S22	Dual 4 Input NAND Gate (O.C.)
7423				Dual 4 Input NOR Gate
	9L24			Dual J-K Flip-Flop
7425				Dual 4 Input NOR Gate
7426				Quad 2 Input NAND Gate (O.C.)
7427				Triple 3 Input NOR Gate
7430		9H30		8 Input NAND Gate
7432				Quad 2 Input OR Gate
7437				Quad 2 Input NAND Buffer
7438				Quad 2 Input NAND Buffer (O.C.)
7440		9H40	9S40	Dual 4 Input NAND Butter
7441				One of ten Decoder/Driver
7442				BCD to Decimal Decoder
7443				Excess 3 to Decimal Decoder
7444				Excess 3 Gray to Decimal Decoder
7445				BCD to Decimal Decoder (30 V, 80 mA)
7446				BCD to 7 Segment Decoder (30 V, 20 mA)
7447				BCD to 7 Segment Decoder
7448				BCD to 7 Segment Decoder (Logic High Out)
7449				BCD to 7 Segment Decoder
7450		9H50		Expandable Dual 2 Wide 2 Input A.O.I. Gate
7451		9H51		Dual 2 Wide A.O.I. Gate
		9H52		Expandable 2-2-2-3 Input AND-OR Gate
7453		9H53		Expandable 4 Wide 2 Input A.O.I. Gate
7454	9L54	9H54		4 Wide 2 Input AND-OR Invert Gate
7460		9H60		Dual 4 Input Expander
			9S64	AND-OR Invert Gate
			9S65	AND-OR Invert Gate (O.C.)
7470				J-K Flip-Flop
7472		9H72		J-K-MS Flip-Flop
7473		9H73		Dual J-K-MS Flip-Flop
7474		9H74	9S74	Dual D-Flip-Flop
7475				4-Bit Latch
7476		9H76		Dual J-K-MS Flip-Flop with Clear
7480				Gated Full Adder
7481				16-Bit RAM
7482				2-Bit Binary Adder
7483				4-Bit Full Adder
7486	9L86			Quad Exclusive OR Gate
7488				256-Bit ROM
7489				64-Bit RAM
7490				Decade Counter
7491				8-Bit Shift Register
7492				Divide by Twelve Counter
7493				4-Bit Binary Counter
7494				4-Bit Shift Register
7495				4-Bit Right/Left Shift Register
7496				5-Bit Shift Register
		9H101		J-K Flip-Flop
		9H102		J-K Flip-Flop

Standard	Low Power	High Speed	Super High Speed	Description
74104				Gated J-K-MS Flip-Flop
74105				Gated J-K-MS Flip-Flop
		9H106		Dual J-K-MS Flip-Flop with Clear
74107				Dual J-K-MS Flip-Flop
		9H108		Dual J-K Edge Triggered Flip-Flop
			9S109	Dual J-K Flip-Flop
			9S112	Dual J-K Edge Triggered Flip-Flop
74121				One-Shot
74122				One-Shot without Clear
			9S140	Dual 4 Input NAND Driver
74141				BCD to Decimal Decoder/Driver
74145				BCD to Decimal Decoder (15 V, 80 mA)
74150				16-Bit Data Selector/Multiplexer
74151				8-Bit Data Selector/Multiplexer with Strobe
74152				8-Bit Data Selector/Multiplexer
74153				Dual 4-Line to 1-Line Multiplexer
74154	93L11			1 of 16 Demultiplexer
74157	93L22			Quad 2 Input Multiplexer
74160	93L10		93S10	Synchronous Decade Counter
74161	93L16		93S16	Synchronous Binary Counter
74164				8-Bit Parallel Out Shift Register
74165				Parallel Load 8-Bit Shift Register
74180				8-Bit Parity Generator/Checker
74181			93S41	4-Bit Arithmetic Logic Unit
74182			93S42	Carry Look-Ahead
74184				BCD to Binary Converter
74190				Synchronous Up/Down Decade Counter
74191				Synchronous Up/Down Binary Counter
74192				Synchronous Up/Down Decade Counter
74193				Synchronous Up/Down Binary Counter
74195	93L00	93H00	93S00	4-Bit Shift Register Parallel In/Out
74198				8-Bit right/left Shift Register
9301	93L01			One of Ten Decoder
9304				Dual Full Adder
9305			93S05	Variable Modulo Counter
9306				Up/Down BCD Counter
9307				7 Segment Decoder
9308	93L08			Dual 4-Bit Latch with Master Reset
9309	93L09			Dual 4 Input Multiplexer
9312	93L12		93S12	8 Input Multiplexer
9313				8 Input Multiplexer (O.C.)
9314	93L14			4-Bit Latch with Master Reset
9317				7 Segment Decoder
9318	93L18			8 Input Priority Encoder
9321	93L21			Dual One of Four Decoder
9324	93L24			5-Bit Comparator
9327				7 Segment Decoder/Driver
9328	93L28			Dual 8-Bit Shift Register
9334				8-Bit Addressable Latch
9337				7 Segment Decoder/Driver
9338			93S38	Multiple Port Register
9340	93L40			High Speed Arithmetic Logic Unit
9344				2-Bit x 4-Bit Full Multiplier
9348				12 Input Parity Generator/Checker
9350				Up Decade Counter
9356				Up Binary Counter
		93H72		4-Bit Shift Register with Clock Enable
9600				One Shot
9602				Dual One Shot
9614				Dual Differential Line Driver
9615				Dual Differential Line Receiver
9616				Triple EIA Line Driver
9617				Triple EIA Line Receiver
9620				Dual Differential Line Receiver
9621				Dual Line Driver
9622				Dual Line Receiver
9644				Dual High Voltage High Current Driver

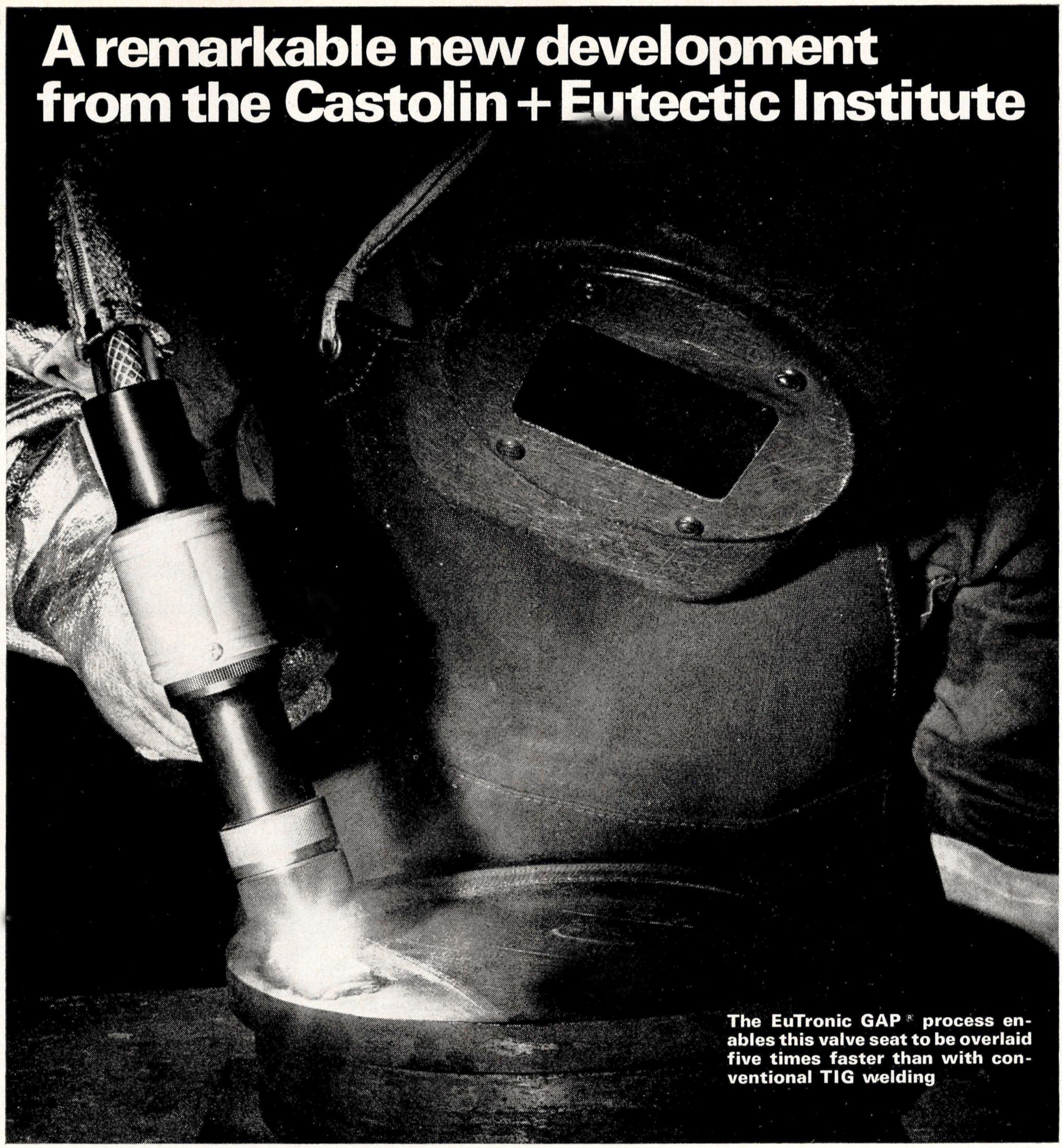
From stock Regensdorf/Crissier
in Plastic and Ceramic Case
temperature range 0 °C – 75 °C, –55 °C – +125 °C

General representation for Switzerland

W·MOOR AG

MOOR HALBLEITER-PROGRAMM
Beratung · Engineering · Service

Halbleiter/Elektronikbauteile/Starkstromzubehör/Metalle
W. Moor AG Elektro-Industriebedarf Bahnstrasse 58 8105 Regensdorf Tel. 01/71 66 44
W. Moor SA Matériel électrique et électronique 3, Avenue des Cerisiers 1023 Crissier/Lausanne Tel. 021/35 54 44



The EuTronic GAP® process enables this valve seat to be overlaid five times faster than with conventional TIG welding

A technological breakthrough in wear protection

The EuTronic Gas Arc Process GAP® marks a turning point in the development of powder alloy protective techniques.

This highly efficient process is ideally suited for welded protective coatings or rebuilding of mechanical equipment and wearing parts used, in particular, for regulating the flow of gases and liquids.

Its versatility enables it to be used on a large range of mechanical parts as well as for the maintenance and repair of heavy equipment. Use of this process not only enables the life of spare parts to be prolonged but also provides a safeguard against the huge losses to which production downtime may lead when a replacement part is not readily available or only after a long delivery delay.

Simple and easy to operate, the EuTronic GAP® process guarantees:

- high deposition rates
- a deposit of outstandingly high quality
- great efficiency
- high versatility
- huge savings by prolonging the life of mechanical parts and tools subject to a combination of different types of wear.

Considered as one of the most important specialists in the world in the field of powder alloy metallurgy, Castolin + Eutectic manufactures a wide range of EuTroLoy® powders, specially designed for use with this new process.

The Castolin + Eutectic Institute

for the Advancement of Maintenance and Repair Welding Techniques

CH-1001 Lausanne • PO Box 1020

Please send me further details on the EuTronic GAP® process.

Name: ____________________

Company address: ____________________

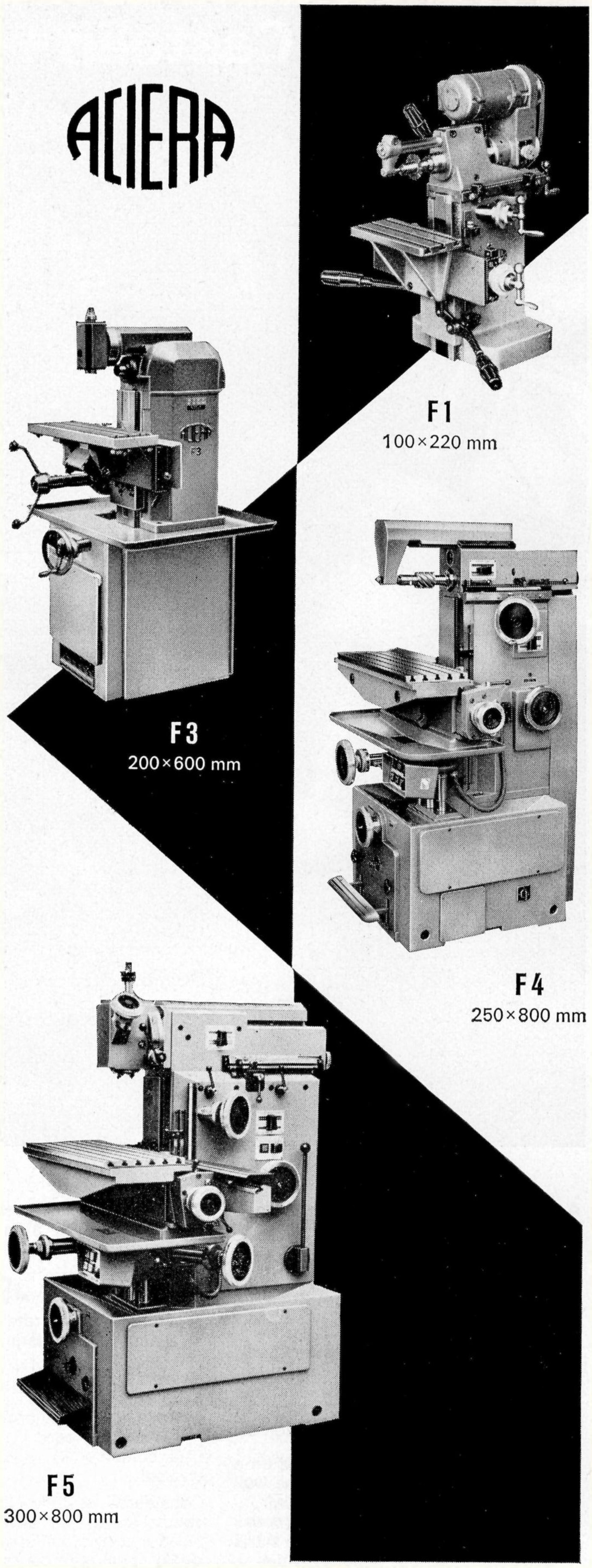
____

Country: ____________________

Proposed applications: ____________________

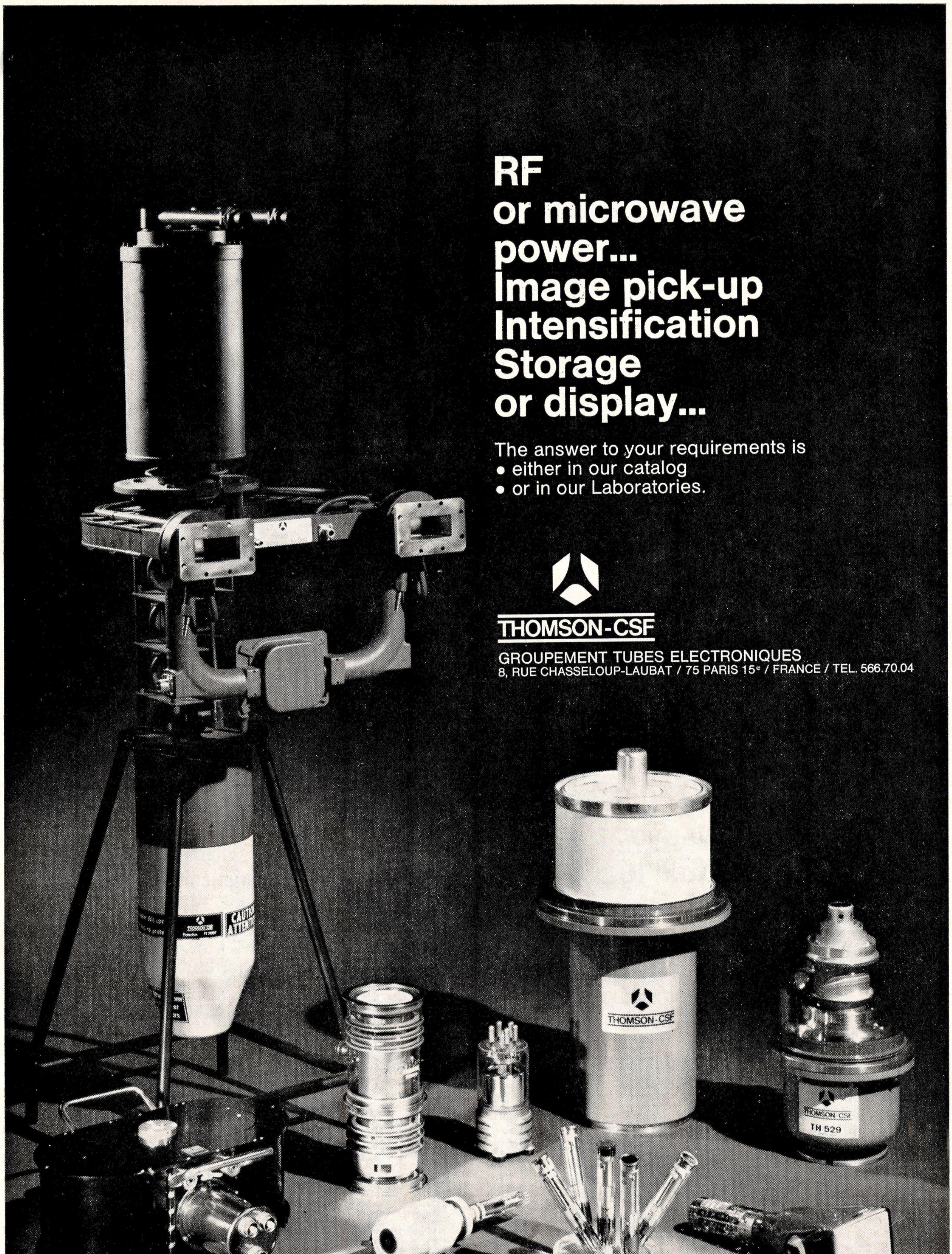
The pioneer in maintenance and repair welding technology

fraiseuses universelles



universal milling machines

ACIERA S A FABRIQUE DE MACHINES CH 2400 LE LOCLE


RF
or microwave
power...
Image pick-up
Intensification
Storage
or display...
The answer to your requirements is
• either in our catalog
• or in our Laboratories.
THOMSON-CSF
GROUPEMENT TUBES ELECTRONIQUES
8, RUE CHASSELOUP-LAUBAT / 75 PARIS 15e / FRANCE / TEL. 566.70.04
THOMSON-CSF
TH 529
TH-CSF / DRP 1592

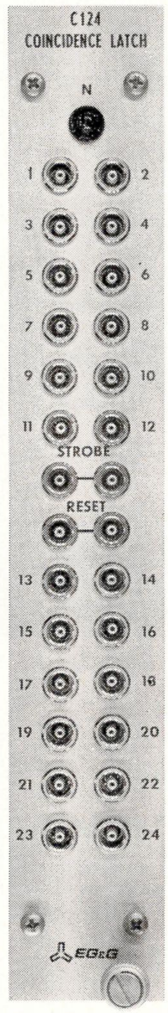
Resolve 200psec/channel with CAMAC Time Digitizer

Replace binsful of NIM electronics with CAMAC Strobed 24-Input Coincidence Latch

For time-of-flight studies, delay-time readout from multiwire proportional counters, and other applications requiring high precision in timing instrumentation. Time resolution is guaranteed at 200psec/channel with excellent temperature stability.

The TD104 Time Digitizer is a single-width CAMAC module which contains four stop channels controlled by a common start, accepting NIM fast logic inputs.

The start input is automatically re-enabled in the event of a time overrun without stop signals.



Here's a most desirable capability you could obtain previously only with our C212 Coincidence Buffer and a couple of binsful of NIM electronics.

We've packaged 24 parallel-connected two-fold coincidences into one double-width CAMAC module called the C124. You'll find it extraordinarily useful when you're working with a large array of detectors and have to sort data on the fly. Its resolving time probably exceeds your specifications: <2nsec overlap is guaranteed, and 1.6nsec is routinely obtainable.

NIM . . . CAMAC . . . EG&G/ORTEC
Three names to keep together in your mind

Crates, power supplies, branch drivers, CAMAC modules, NIM modules, NIM-CAMAC hardware . . . all these products are thoroughly described in technical data sheets available from your local representative or our headquarters in Oak Ridge. Let us respond to your interest in any phase of computer-based CAMAC systems. EG&G/Ortec High Energy Physics Products, 500 Midland Road, Oak Ridge, Tenn. 37830. Phone: (615) 482-4411. In Europe: Ortec Ltd., Dallow Road, Luton, Bedfordshire. Phone: LUton 27557. Ortec GmbH, 8 München 13, Frankfurter Ring 81, West Germany. Phone: (0811) 359-1001.

EG&G/ORTEC
HIGH ENERGY PHYSICS

DANA Dana Laboratories, Inc.

NEW DIGITAL-MULTIMETERS

4300
$4^1/_2$-digit
10 µV
Resolution

3300
$3^1/_2$-digit
100 µV
Resolution

LINE OR BATTERY OPERATED

- LED READOUT WITH INSIGNIFICANT ZERO ELIMINATION AND 100 % OVERRANGING
- PROTECTION AGAINST INCORRECT RANGE AND MODE COMBINATIONS
- DC - AC - Ω - CURRENT CAPABILITY
- OVERLOAD HIGH VOLTAGE PROTECTION IN ALL FUNCTIONS
- AUTOMATIC DISPLAY INTENSITY CONTROL
- UNBREAKABLE - RUGGED CONSTRUCTION

PLEASE ASK FOR DETAILED DOCUMENTATION OR A DEMONSTRATION.

(7012 EE)

Industrievertretungen
Junkholz 333 – CH-8968 Mutschellen
STOLZ AG
Tel. 057 5 46 55

Entreprise de
peinture
bâtiment
industrie

J. Prézioso & Fils S.A.

Fournisseur
C.E.R.N. - GENÈVE

Siège social :

Boîte postale Nº 2
38 - SAINT-CLAIR DU RHÔNE
Tél. (74) 85 53 07
85 52 23
Télex : 30 516-PREZIOSO SCLAR

Sintox®

alumina ceramics
hard facts about Sintox

Hardness (rockwell)	45 N Scale	80–85
Specific Gravity	g/cm^3	3.65–3.83
Compressive Strength	kp/mm^2	160–168
Tensile Strength	kp/mm^2	19
Transverse Breaking Strength	kp/mm^2	28–32
Neutron Absorption Cross Section	cm^3/gram.	FF Grade: .0060 EH Grade: .0029
Deformation Temperature (CVD)	°C	1450–1650
Dielectric Constant		1 Mc: 8.9–9.2 70 Mc: 8.9–9.2
Dielectric Strength	kV / mm (peak)	FA and FF Grade: 20

Based on the above mentioned and other excellent properties, SINTOX is used increasingly in the following industries:

Nuclear, Machines, Pumps, Electrical and Electronic, Chemistry, Textile, etc. etc.

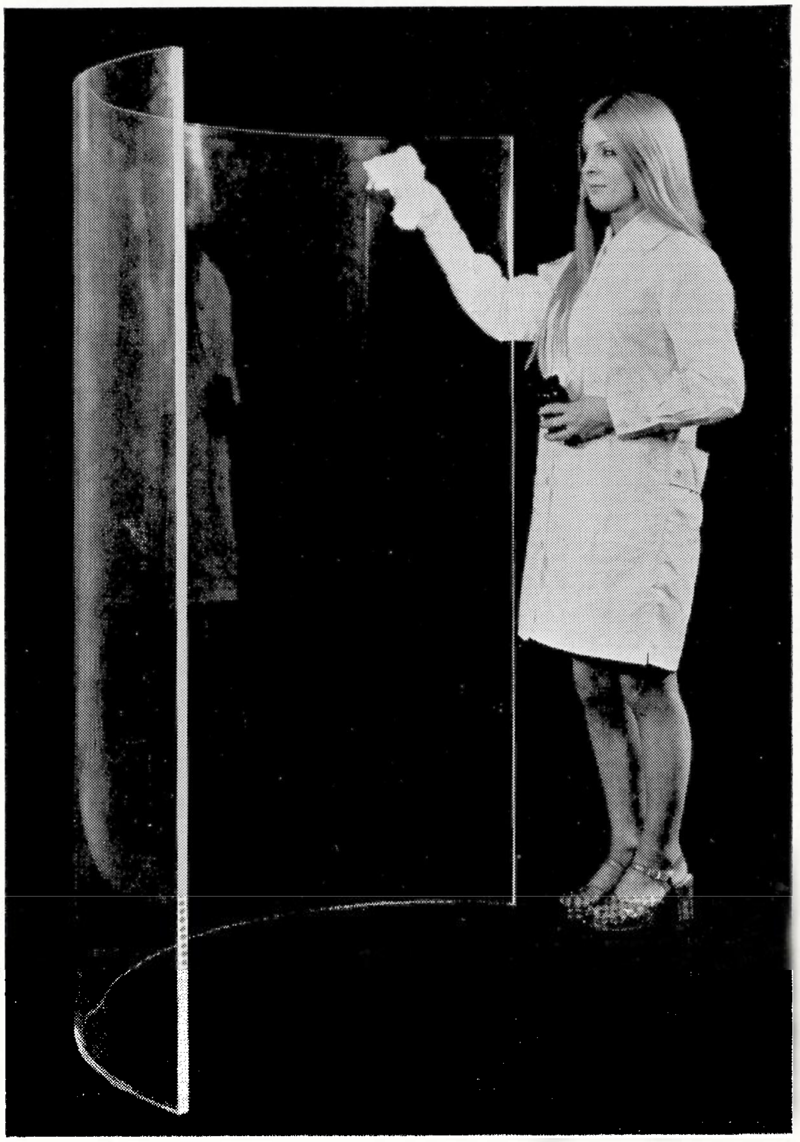
More information through
the Swiss-Agent for Sintox:

FIBAG

Industrial Division
Kernstrasse 57, 8026 Zürich
Tel. 01 39 48 88, Telex 53347

2/72/FI

CURVED SURFACE
PLASTIC SCINTILLATOR SHEETS for high energy physics



Curved plastic scintillator sheets with glass-like finish for use with intersecting beams of colliding particles, and other applications, can now be supplied to any radius. The curved sheets have a surface finish as good as flat sheets from Nuclear Enterprises.

The NE 110 sheet illustrated was produced for CNEN, Frascati. It is approximately 1600mm x 1500mm with an external radius of 600mm. NE 110 sheet is the most widely used in high energy physics laboratories in Britain, Europe and the United States, because of its glass-like finish, high light output, and remarkable light transmission corresponding to an attenuation length of 4 metres.

Similar detectors up to 3 metres in length in NE 102A, NE 104, NE 113 and other outstanding scintillators can also be supplied.

Full details on request.

1966

NUCLEAR ENTERPRISES LIMITED

Sighthill, Edinburgh EH11 4EY, Scotland
Telephone: 031-443 4060   Cables: Nuclear, Edinburgh
Telex: 72333

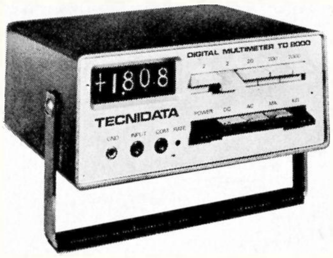
Associate Companies : Nuclear Enterprises GmbH,
Karlstrasse 45, 8 Munchen 2, Germany
Telephone : 55 30 03   Telex : 529938

Nuclear Enterprises Inc., 635 Terminal Way, San Carlos, California 94070
Telephone : 415-593-1455   Telex : 348371

Swiss Agents : High Energy and Nuclear Equipment S.A.
Tel. (022) 98 25 82 - 98 25 83
2, chemin de Tavernay, Grand-Saconnex, 1218 Geneva

TECNIDATA

Quality, Design and Performances are exclusive and so are the prices !



Sfrs. 1380.—
V=, Vac, I=, Iac, Ω

Our best reference :
more than 230 instruments sold in Switzerland, in 1972, and dozens of them being in use at the CERN !

- — 2000 measuring points
- — large display, lisible at more than 10 m
- — very easy operating
- — modular construction with metal housing
- — accuracy 0,1 p.c.
- — BCD-output in standard version
- — 24-hours-service.

tme

Technique Moderne	Electronique S.A.
1844 Villeneuve	Tel. 021 / 60 22 41
8055 Zurich	Tel. 01 / 54 01 33

The tapered slabbing and reaming drill is economical and very useful

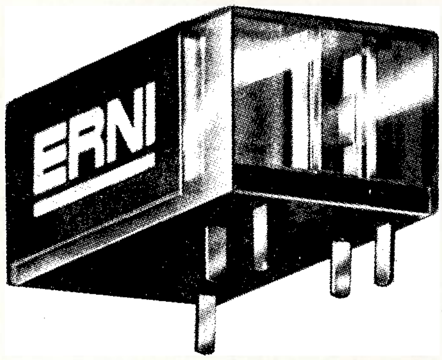
DRILLFILE

special drill

for the economical mounting of car aerials and car radios, car calling units as well as telecommunication devices **DRILLFILE** is recommended by leading firms all over the world. In its measurements **DRILLFILE** accommodates all requirements.

TIPSWITOOL
1564 DOMDIDIER / Switzerland

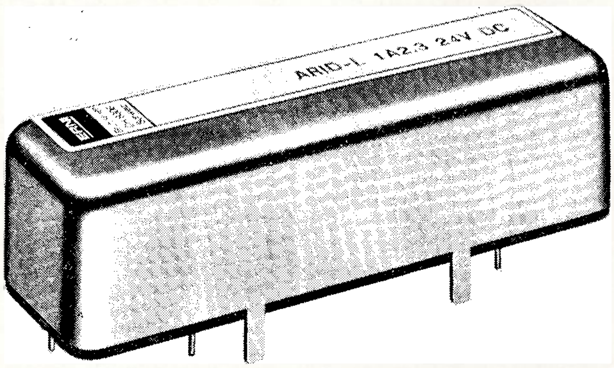
Relais pour circuits imprimés Série REL 14



Nouveau relais, d'encombrement extrêmement réduit, pour montage direct sur cartes à circuits imprimés.
Haute capacité de commutation. Exécution en boîtier « Makrolon » étanche à la poussière.

Tension nominale :	6 ... 60 VDC
Equipement de contact :	1 inverseur à contact jumelé
Matériau de contact :	AgCdO ou Ag-doré dur
Charge de contact :	4 A, 250 VAC, max. 1000 VA 2 A, 30 VDC, max. 60 W
Tension d'essai :	2 kV_{eff}
Encombrement :	27,5 x 12,5 x 10,5 mm
Connexions :	trame standard 1/10"

Relais «REED» de puissance Série ARID-L



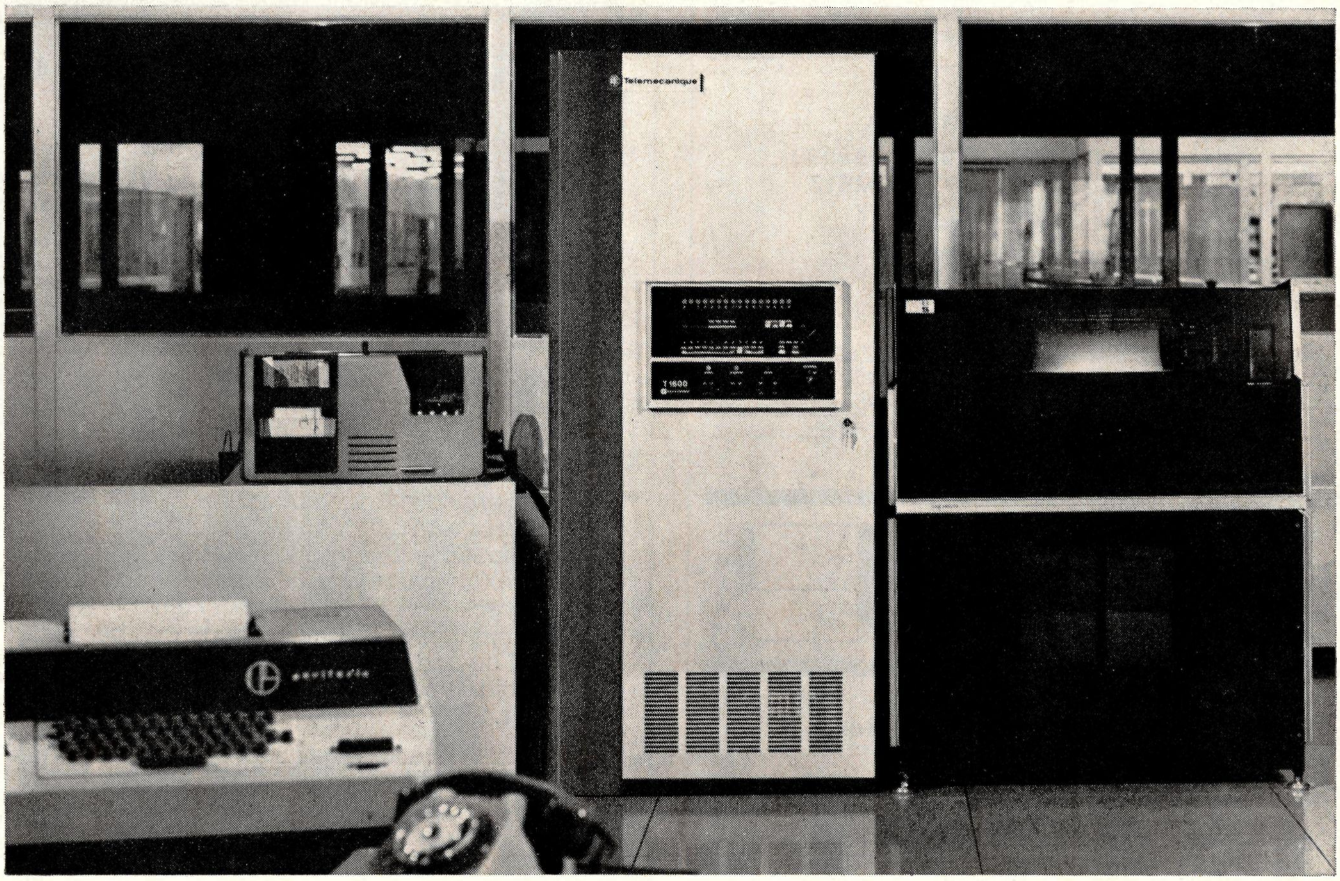
Nouveau relais de notre série ARID, avec contact « Powerreed » ou contact pour haute tension. Magnétiquement blindé et hermétique.

Tension nominale :	6 ... 110 VDC
Equipement de contact :	1 contact de travail
Charge de contact :	
— Powerreed	3 A, 250 VAC, 350 VA
— Haute tension	1 A, 3500 VDC, 50 W
Encombrement :	82 x 21 x 20 mm
Connexions :	trame standard 1/10"

ERNI

ERNI + Co. Electro-Industrie
CH-8306 Bruttisellen/Zurich
Téléphone 01/93 12 12
Télex 53 699

calculateurs Telemecanique : la solidité informatique



Système T 2000 :
Automatisme industriel et contrôle de processus
Calculateurs T 1600 :
Téléinformatique et saisie de données
Enseignement
Instrumentation et laboratoires

Telemecanique

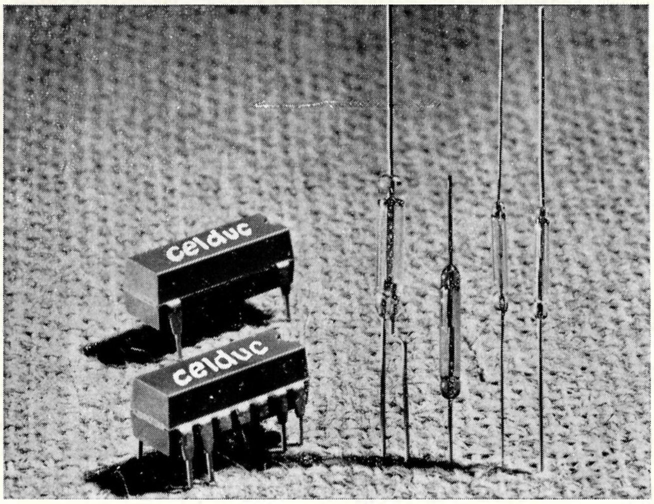
France : rue de Provence
38130 - Echirolles
Tél. : (76) 09 80 55

Suisse : Südbahnhofstrasse 14 C
3000 Berne
Tel. : (031) 45 66 81

d-p-industrie

qui fabrique ?

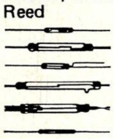
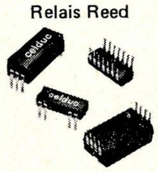
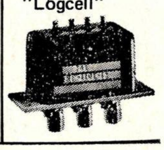
LE RELAIS REED "DUAL-IN-LINE"



ENTIÈREMENT COMPATIBLE MÉCANIQUEMENT ET ÉLECTRONIQUEMENT AVEC LES CIRCUITS INTÉGRÉS
NOMBREUSES VERSIONS DISPONIBLES :
1 FORME A (T) Résist. Bobine (500Ω)
2 FORME A (2T)
1 FORME C (RT)
1 FORME B (R)
CONTACT MOUILLÉ MERCURE (LOGCELL)
SANS POSITION PRÉFÉRENTIELLE

...celduc

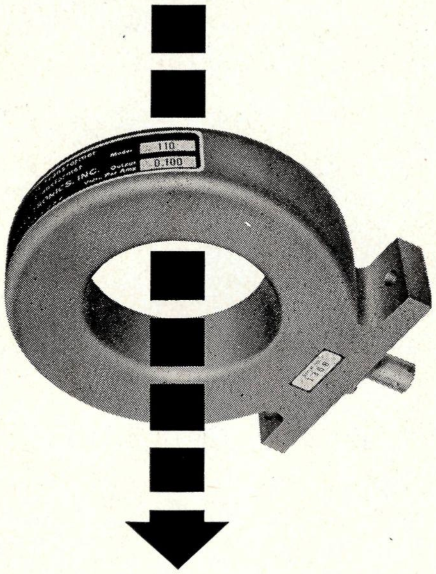
celduc fabrique :

Interrupteurs Reed	Relais Reed	Relais statiques Reedac	Relais mercure sans position préférentielle "Logcell"
			

Industrievertretungen
Junkholz 333 – CH-8968 Mutschellen

STOLZ AG

Tel. 057 5 46 55



Wide Band, Precision

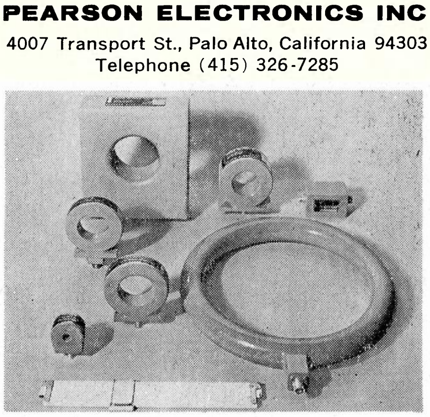
CURRENT MONITOR

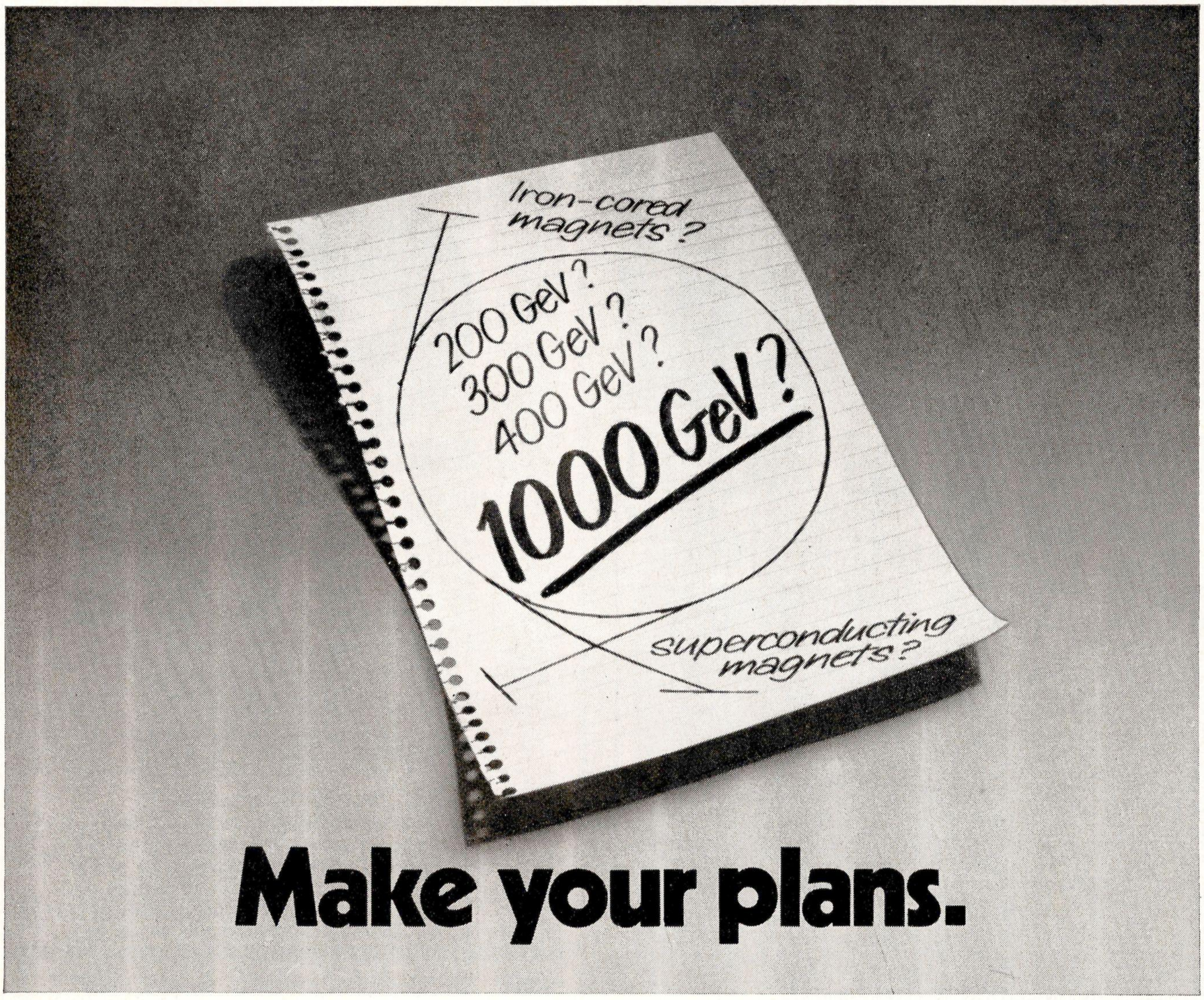
With a Pearson current monitor and an oscilloscope, you can measure pulse or ac currents from milliamperes to kilo-amperes, in any conductor or beam of charged particles, at any voltage level up to a million volts, at frequencies up to 35 MHz or down to 1 Hz.

The monitor is physically isolated from the circuit. It is a current transformer capable of highly precise measurement of pulse amplitude and waveshape. The one shown above, for example, offers pulse-amplitude accuracy of +1%, −0% (typical of all Pearson current monitors), 20 nanosecond rise time, and droop of only 0.5% per millisecond. Three db bandwidth is 1 Hz to 35 MHz.

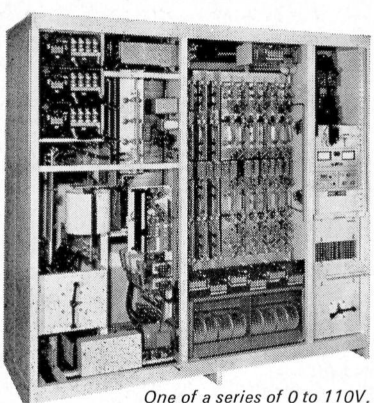
Whether you wish to measure current in a conductor, a klystron, or a particle accelerator, it's likely that one of our off-the-shelf models (ranging from ½" to 10¾" ID) will do the job. Contact us and we will send you engineering data.

PEARSON ELECTRONICS INC
4007 Transport St., Palo Alto, California 94303
Telephone (415) 326-7285





We are ready with the stabilised DC power


One of a series of 0 to 110V. 2000 ampere (220kW) thyristor regulated highly stabilised DC power supplies for Rutherford Laboratory of the British Science Research Council.

Experience builds on experience. Your beam line magnets demand DC power supplies with high long-term stability, and since the '50's we have been meeting that need in research establishments throughout the world.

The development in our technology has kept pace with yours. Ten years ago we were able to stabilise DC currents to one part in a thousand, long term. Today, we are achieving six parts in a million.

Throughout the world many hundreds of Brentford power supplies, ranging from 10 to 10,000kW are relied on to provide highly stable currents in spite of coincident variations in voltage, frequency, temperature and load resistance. Call us and tell us your plans—we can help you to realise them.

Brentford

THE QUEEN'S AWARD TO INDUSTRY 1971 FOR TECHNOLOGICAL INNOVATION

Brentford Electric Limited, Manor Royal, Crawley, Sussex, England, RH10 2QF
Telephone: Crawley (0293) 27755. Telex: 87252. Cables: Breco Telex Crawley Sussex.
A member of the GHP Group.

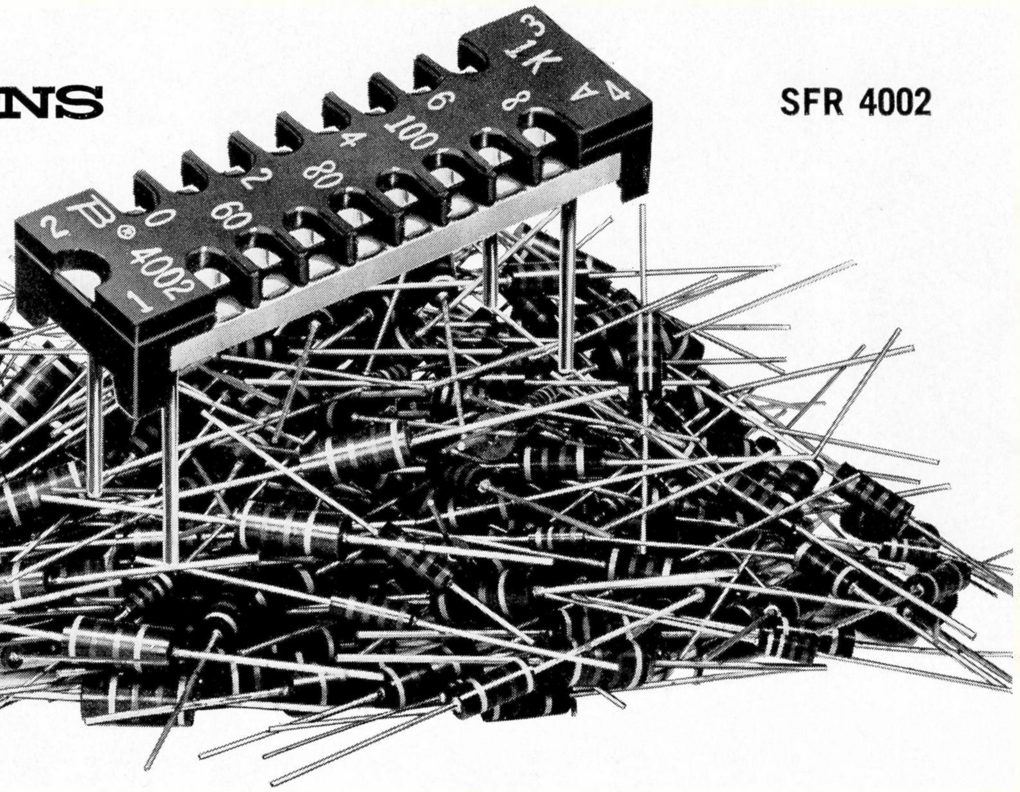
A NEW CONCEPT IN RESISTIVE COMPONENTS!

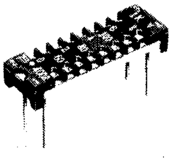
- **A STABLE, FIXED RESISTOR...**
- **WITH SELECTABLE RESISTANCE VALUES...**
- **PERMANENTLY, RELIABLY SET BY SOLDERING.**

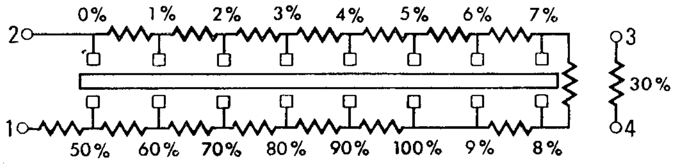
SELECT FROM 90 RESISTANCE VALUES IN A SINGLE PACKAGE — OCCUPYING SAME MOUNTING SPACE AS ONE FIXED RESISTOR

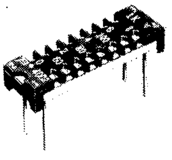
BOURNS

SFR 4002





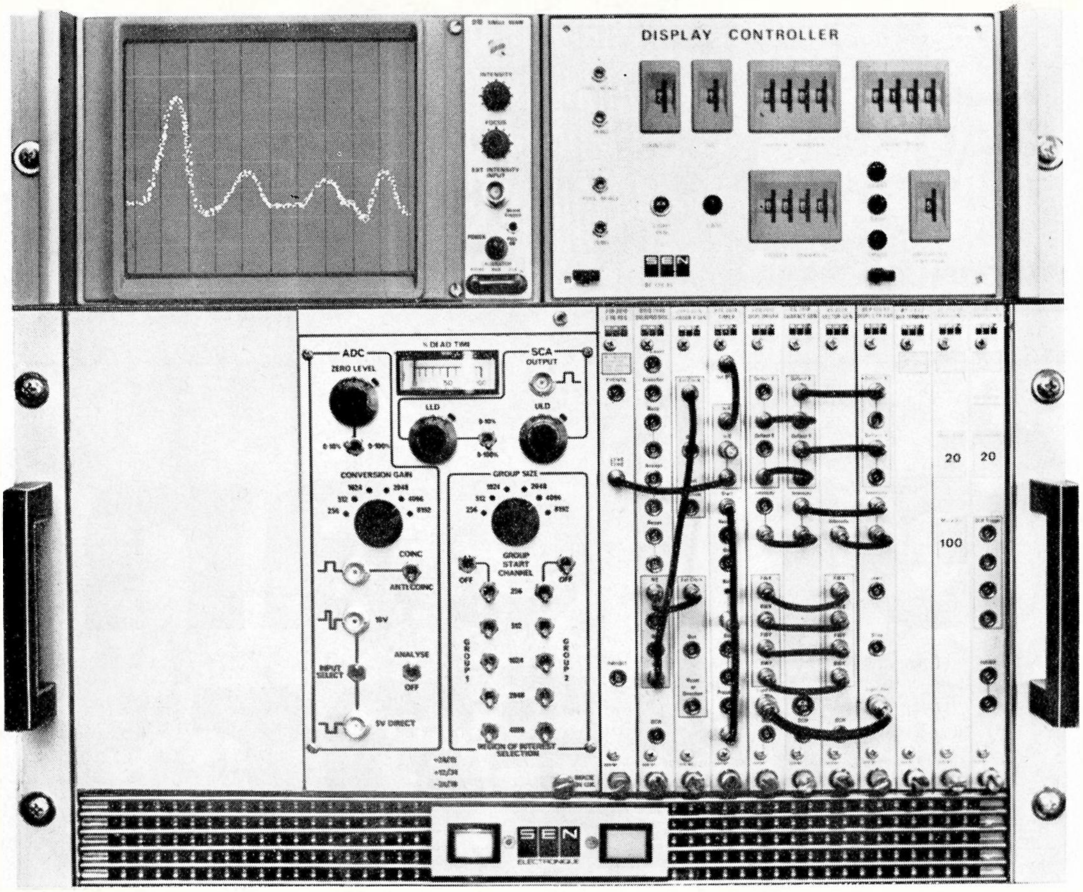




- Adjustability of ± 1 %, or better, without pressure-type contacts or moving parts.
- Ability to select and permanently set a precise resistance value at any point in adjustment range with an accuracy of 1 % or better.
- Provides functional printed circuit board adjustment for optimum tuning after final component assembly.
- Exhibits the stability of a fixed metal film resistor.
- Exhibits temperature coefficient of ± 50 PPM average.
- Designed to meet MIL-R-55182 performance.
- Replaces large inventory of precision fixed resistors. Eliminates precise selection of individual resistors.
- Occupies board area equal to 1/2 watt industrial metal film resistor.
- Fifteen standard values of the Model 4002 cover a resistance range from 33 ohms to 1.25 megohms in selectable steps of 1 % or less.
- Has short circuit protection because minimum resistance setting is approximately 1/2 of nominal resistance.
- Provides open circuit protection prior to adjustment by having the nominal resistance in the circuit.

BOURNS AG Baarerstrasse 8 6301 ZUG Tel. (042) 232 242 Telex 78 722

SEN **SPECTRUM ANALYSER**



A CAMAC SYSTEM FOR PULSE HEIGHT ANALYSIS

This system was developed in CAMAC in order to achieve the versatility required to fulfil the varying needs of the nuclear physicist. The basic system may be expanded to perform any specific tasks covered by the current range of CAMAC modules*. Additional computer peripherals may be used to increase the power of the system. Included in the basic system is a dual cassette recorder to facilitate fast data handling and program loading. The computer memory is expandable to 64K, but only 8K is required for use with the standard system programs.

16K of system software is currently available. This includes programs for acquisition and analysis of spectrums up to 4096 channels and a Basic enabling the computer to be used as a powerful desk calculator. All programs include a facility for fully automatic operation by means of a macro-programming technique.

* *The current range of SEN CAMAC consists of 37 different modules.*

For further information contact:

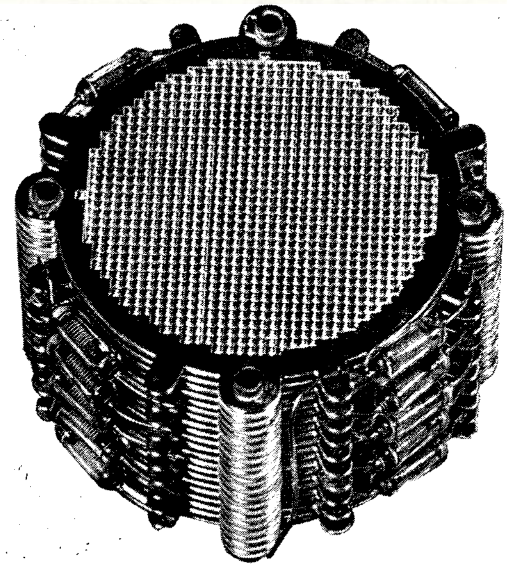
SEN
ELECTRONIQUE **31, av. Ernest-Pictet - 1211 GENEVA 13 - SWITZERLAND - Tel. (022) 44 29 40**

GERMANY BENELUX : **SEN Elektronik** - Haidbrook 23 - Postfach 223 - D-2 Wedel/Hmb.

REPRESENTATIVES :

Denmark: J. FJERBAEK i/s, Ingenior, M. AF I Hoeghsmindevej 23, 2820 Gentofte/Copenhagen
France: ORTEC SARL, 2, Quai du Parc, F-94 Saint-Maur
Italy: ORTEC-Italia S.p.A., Via Monte Suello 9, I-20133 Milano
South Africa: DENBIGH SMITH & PHILLIPS LTD., Honiton Road 33, Plumstead, Cape

Sweden: POLYAMP AB - Fack - S-163 04 Spanga
UK: ORTEC LTD. - Dalroad Industrial Estate - Dallow Road Luton Lu11su/Beds
USA & Canada: EG & G / ORTEC - 100 Midland Road - OAK Ridge, Tenn. 37830



You can't wear it out

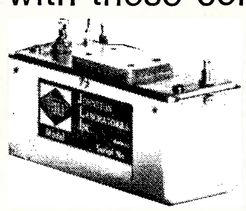
A focused mesh electron multiplier that's guaranteed reactivateable over and over again.

Model MM-1 For use in mass spectrometers, electron and ion velocity analyzers, X-ray and vacuum U.V. spectrometers, and neutral particle experiments. Detects electrons, ions, protons, UV, X-ray photons, energetic neutral atoms and molecules. Guaranteed delivered gain. Typical electron gain: 10^6 at 2.5 kv., 10^7 at 3 kv., 10^8 at 3.5 kv. Gain is stable with count rates in excess of 10^6 per second. No ion feedback or spurious pulses. Non-magnetic. Low noise: less than 1 count/minute at 10^7 gain. Ultra high vacuum operation: bakeable to 350° C. Rugged. Flight proven in many rocket launches. Size: 1.25" high, 2" diameter. **Model MM-2.** Similar characteristics as MM-1 but only half the diameter (1").

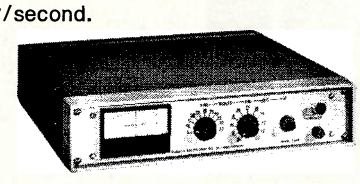
Johnston Laboratories, Inc.

3 Industry Lane, Cockeysville, Maryland 21030, USA
Phone: (301) 666-9500 Cable: "JOHNLAB"

Build the system you need with these components.



Preamplifier-Amplifier-Discriminator (Model PAD) Rugged. Miniature. Charge sensitive input. Risetime: 3 nsec. Adjustable discriminator: 20:1 range. PAD-1: lowest power consumption. Pulse count rates to 10^5/second. PAD-2: for pulse count rates to 10^7/second.



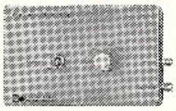
Regulated High Voltage Power Supply. (Model HV-4R) All solid state. Output: 500v to 6.1 kv. Low noise: less than 300 microvolts RMS. Low drift: less than 0.01%/hour, 0.02%/day. Lightweight. Rack mounted.

For more information and detailed data call or write Dept. C-11

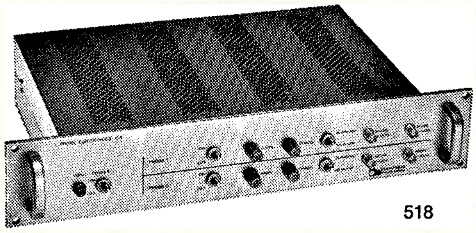
Do you operate an Isotope Separator-Particle Accelerator-Mass Spectrometer-Cyclotron?

DANFYSIK
JYLLINGE·DENMARK

Do you demand and get accuracy, reliability and ease of operation?
If not, then what you need is the Danfysik/High Voltage BEAM PROFILE MONITORING SYSTEM, COULOMB/AMPERE METER AND MASS METER

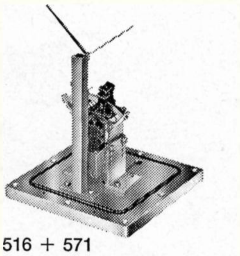


536

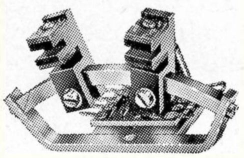


518

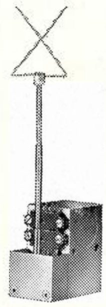
516 – pin-type



516 + 571

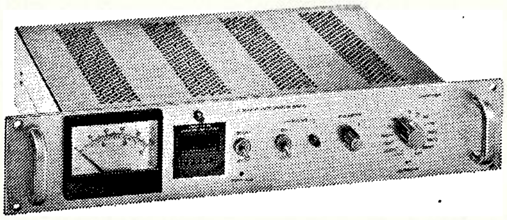


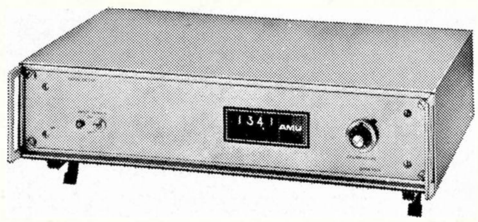
571



New 516 x-type

These are some of the vital components of the beam profile monitoring system that gives you all information on the intensity, profile and position of ion or electron beams. The heart of the system is the **probe unit 516** (vane or **pin type** or the very latest x-type) – sweeping through the beam region and delivering the information for display on an oscilloscope. This is housed in a st.st. **housing, model 562A** (not shown), and perhaps also mounted with a **position marker 571.** The driving unit is the **electronics, model 518,** and should you require it we have a **preamplifier, model 536.**





The **coulomb/ampere meter** (current integrator) measures your ion or electron beams with an accuracy of ± 1% **of full scale for the ampere meter and** ± 2% of reading for the coulomb meter – **drift** less than 1% after warm up.

The **mass meter** provides you with a continuous read-out of the masses under separation in your plant – an invaluable device with a resolution of 0.1 amu and an accuracy of 1% or 0.1 amu, whichever is the greater.

And what about a **telemetering system** to complete the picture?

For more detailed specifications and descriptions of these instruments, please write or call:

DANFYSIK A/S
Jyllinge, DK-4000 Roskilde
Denmark
Phone: 03-388150
Cable: Danfysik-Roskilde
Telex: 43 136

HIGH VOLTAGE ENGINEERING
(EUROPA) NV
Amsterdamseweg 61
Amersfoort, Holland
Phone: 03490 – 19741
Cable: Eurovolt
Telex: 47 275

HIGH VOLTAGE ENGINEERING
CORPORATION
Burlington, Massachusetts 01 803
USA
Phone: 617–272–1313
Cable: Hivolt
Telex: 710–332–0245

or any of our local representatives.