CERN COURIER

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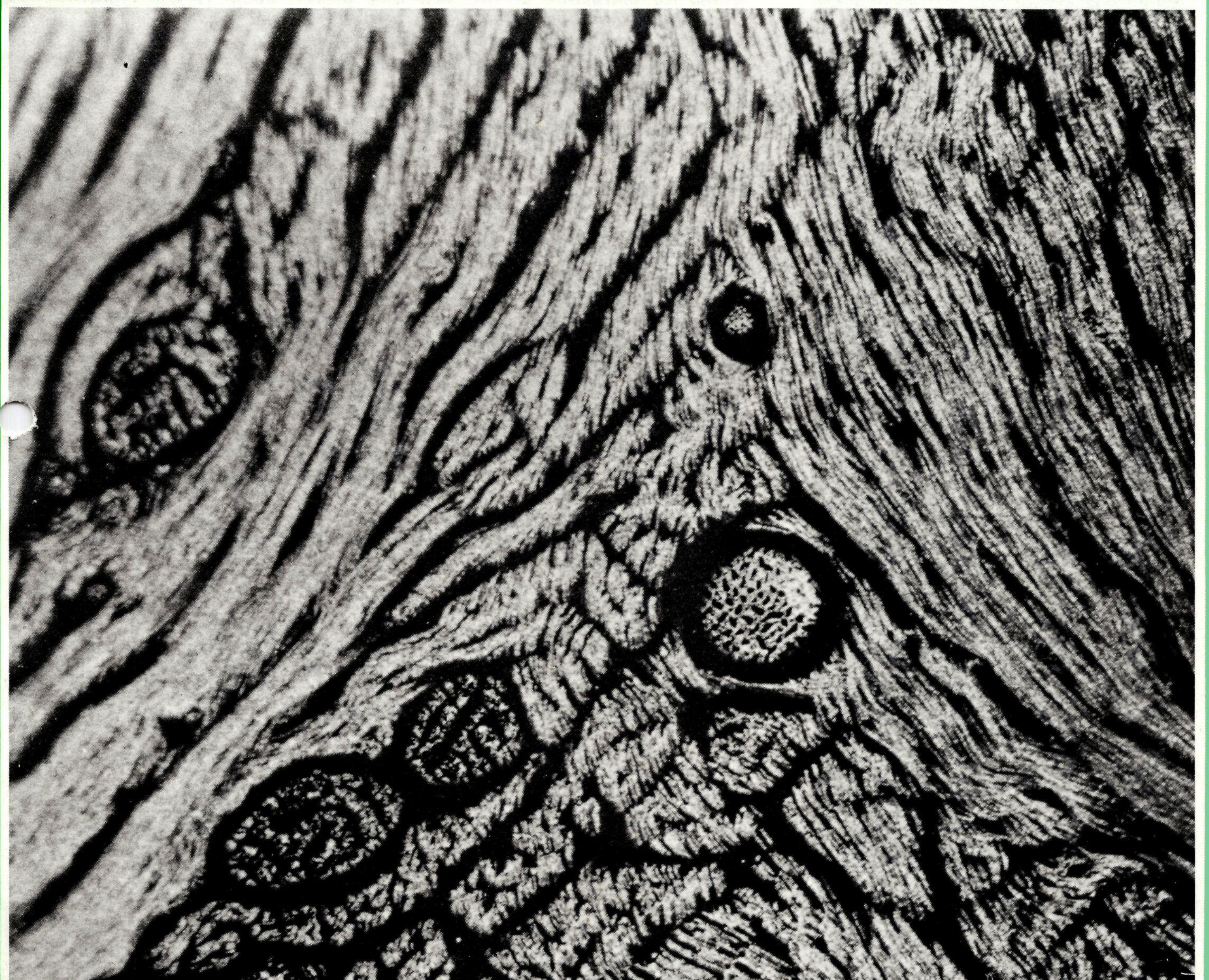

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research,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

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC), and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1500 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3200 people and, in addition, there are about 1000 Fellows and Scientific Associates. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 410 million Swiss francs in 1975.

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 400 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 1975 is 237.9 million Swiss francs and the staff totals about 450.

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Contents

Psichology 259
More discoveries related to the famous 3.1 GeV particle, more evidence that 'charm' is behind the findings, and a new maverick particle which might be the first sign of a heavy lepton

Magnetic monopole 261
Observation of a particle track on a balloon flight leads to conjecture that it was caused by a monopole

Paying our way 262
An analysis of the 'economic utility' of CERN quantifies for the first time the impact of CERN on European industry

CERN News

Racing the beam around 264
Stochastic cooling technique for reducing beam height tested in the ISR by racing the protons across an arc of the machine

Restart of the 2 m bubble chamber 265
Chamber back in action after being moved; information on the work of the Central Development Service

First extraction system goes into SPS 266
Units for extraction of the 400 GeV proton beam to the North experimental area installed in the main ring tunnel

CEDAR looks good for SPS experiments 267
Cherenkov counter of new design, to cope with very high energies, is successfully tested

At the machines 268
Accident time at the ISR and PS

Around the Laboratories

ORSAY: Flipping detector 269
Novel detection technique, involving superconducting granules and transition radiation, works in experiments at DESY

RUTHERFORD: Waxing on about training 270
Suggestion that the use of wax as a magnet potting material could reduce training problems in superconducting magnets

KARLSRUHE: Superconductivity put to use 271
Programme covers superconductivity applied to linacs, magnets, separators, energy stores and switches

BROOKHAVEN: ISABELLE Summer Study 272
Study on 200 GeV colliding beam machine, which has renewed support from HEPAP, and news on superconducting magnet development

HARWELL: Line drawing with protons 274
Proton scattering technique gives radiographs with edges very cleanly delineated

Conferences 275

DESY: Four view HPD 275
New, interactive, film analysis chain nears completion

HARVARD/RUTHERFORD/FERMILAB: Medical applications 277
News on medical applications of accelerated particle beams

GANIL authorised 278
Construction of heavy ion accelerator approved in France

Cover photograph: A 'decorating' technique tells where flux lines are lying in a superconductor. The technique is being used at Karlsruhe in basic research into the phenomenon of superconductivity. It involves evaporating ferromagnetic material in an inert atmosphere. The material settles on the superconductor where the magnetic flux lines penetrate the surface. The photograph shows an instability where the flux (picked out by the white lines) has been partially torn away from its initial configuration by applying a pulse of heat. (Photo Karlsruhe)

Psichology

Here we go again. Almost every other month this year we have had some new story to tell stemming from the particle discovery at the Brookhaven synchrotron and the Stanford SPEAR storage ring in November of last year. The Brookhaven/MIT team baptised the particle 'J', the Berkeley/Stanford team 'psi' (ψ). It was under the title 'Psichology' that H. Harari reviewed the present situation in a brilliant lecture at CERN at the beginning of September.

He brought the latest information from a dramatic conference at Stanford (1975 International Symposium on Lepton and Photon Interactions at High Energies, 27-28 August) where the discoveries of several more particles were announced — one of them possibly blowing the whole field of high energy physics wide open again. The excitement crossed the Atlantic without attenuation and it was a packed and humming (acoustically speaking, of course) CERN auditorium which absorbed the new findings and their possible interpretations.

Rapid recap: the J/ψ particle has a mass of 3.1 GeV, three times heavier than the proton, and is exceptionally stable for such a heavy object, taking a thousand times longer to decay than any particle of comparable mass. The present favoured explanation is that the particle is built up of a new type of quark and its antiparticle, the quark having a special property given the name of charm. It is because the particle cannot easily divest itself of charm, in breaking up into the particles we know well, that it hangs around for so long. Since the 3.1 GeV discovery, at our last time of writing, similar particles ψ' and ψ'' had been found at Stanford with masses of 3.7 GeV and 4.1 GeV and a related particle at 3.5 GeV had been found at the DORIS storage ring at DESY.

The new information on the J/ψ particles

At the Conference, Stanford were able to announce the identification of ψ''' at 4.45 GeV. DESY and Stanford have observed the 3.5 GeV particle in many decay modes and some of the Stanford data suggests that there are two particles close together near that mass. Similar to the 3.5 GeV particle(s), Stanford has found another at 3.4 GeV and, finally, DESY has evidence of a different but related particle at 2.8 GeV.

Some months ago we had a measurement of the J/ψ interaction probability from a photoproduction experiment at the Fermilab. The measurement, 1 mb, said that the particle is a hadron (sensitive to the strong force). This interpretation has now been reinforced since we have a family of seven or eight particles which looks exactly like a typical family of hadrons. At lower energies, we are familiar with groups of particles of similar properties, such as the pi mesons and K mesons or the nucleons and the hyperons. These are hadron families and the family likenesses have been traced to the existence of three types of more fundamental objects called quarks.

All the known hadrons can be built up from the three quarks and adding a 'charmed quark' makes it possible to build the new family taking the J/ψ as a meson constructed of a quark and antiquark. This exercise was done last December in theoretical speculation immediately after the first discovery. It is remarkable to see the agreement which has now emerged between the group of particles that has been found and the family that the theoreticians built up on paper on the basis of the charmed quark.

The idea of the new quark has brought with it a lovely symmetry between the leptons, the particles sensitive to the weak force, and the hadrons. There are four leptons — electron, electron neutrino, muon, muon neutrino. There are four subhadrons — proton quark, neutron quark, strange quark, charmed quark. The way in which the lepton interactions go can be expressed in a set of mathematical rules. The way in which the quark interactions go seem to respond to the same set of rules. The total charge of the leptons is —2 (negatively charged electron plus negatively charged muon). The total charge of the quarks is +2 (three coloured varieties — see March issue — of the proton quark with charge —1/3, neutron quark —1/3, strange quark +2/3 and charmed quark +2/3).

Things which are not quite so charming

So are we happy that we have found something that we understand and that brings new simplicity and beauty to our picture of Nature? Not quite. There are many observations which fit the charm interpretation. There are some that don't.

First of all, the ways in which the ψ particles decay or do not decay can be predicted from the quark model and the rules we have mentioned above. Among the decays that are actually seen there are some that seem in line with the predictions and some that are not. In particular, there is something funny about the ψ' (3.7 GeV) decays. These are expected to be similar to the J/ψ but, trying to count them in comparison to the J/ψ, about 40 % seem to be different.

Secondly, there is no convincing sign of actual charmed particles. The J/ψ itself has 'hidden charm' (the charm of the quark and antiquark cancel one another out) but its decays ought in many cases to give two mesons — one with charm and one with anticharm. The ψ'' (4.1 GeV) is less stable than its lighter relations and it is thought that this is because it has sufficient mass to break easily into the two mesons. This sets the meson mass at around 2 GeV.

The mesons, usually referred to as D particles, are expected to go predominantly to strange particles such as kaons, when they themselves decay (this again is a prediction of the mathematical rules) but no such outburst of strange particles in association with the ψ'' is seen. Many other searches for charmed mesons and charmed baryons have also been fruitless (though single events which may be charmed particles have been seen in bubble chamber pictures at Brookhaven and CERN). If there really are charmed quarks, where are the charmed particles that could be built from them?

And finally, another puzzle is one which has been with us for about two years. The electron-positron colliding beam experiments at the Cambridge bypass and then at the Stanford SPEAR storage ring found that the ratio, R, of the production of hadrons in the collisions compared to the production of muons, rose as the energy of the collision was increased. The quark models predicted a constant value much smaller than was seen. It is now known that R does settle down again to a steady value of around 5 after the energy has passed through the turbulent J/ψ production region. But even adding the charmed quark, the quark model can only push R to about 3.3.

First sign of a heavy lepton?

There is now a further finding which might help sort some of the deviations from the charmed quark expectations while at the same time blowing wide open the tidy picture of four leptons and four sub-hadrons which is such a satisfying feature of the recent theories. The finding was the most exciting of all the fresh information spilled out at the Stanford Conference.

In analysing the data from SPEAR there are events which show just two leptons — an electron and a muon — and nothing else emerging from the electron-positron collisions. These were spotted in the shower counters and muon chambers of the Berkeley/Stanford magnetic detector. This detector is not optimised for spotting electrons and muons. Many events which seemed to be two lepton events were therefore ignored because of possible confusion with hadrons giving the same signal as an electron or muon and for other reasons. Nevertheless, when all these 'cuts' have been made to the data, there remain 85 electron/muon events which will not go away.

These events are too new and too surprising for any scientist to make strong pronouncements about them yet but the COURIER is allowed literary licence spurred on by the speculation of H. Harari in his lecture. The events set in above 4 GeV and the first temptation is to assign them to the decay of two charmed particles around 2 GeV which we have already seen is something we expect to find. But that does not seem to fit; there should be kaons, etc. around.

The guess is that the electron and muon are coming from the decays of two 'heavy leptons' never seen before. The leptons have been dubbed 'U' and the sequence then goes

$$e^+ + e^- \rightarrow U^+ + \hat{U}^-$$
$$U^+ \rightarrow e^+ + \nu_e + \bar{\nu}_u$$
$$(\text{or } U^+ \rightarrow \mu^+ + \nu_\mu + \bar{\nu}_u)$$
$$U^- \rightarrow \mu^- + \bar{\nu}_\mu + \nu_u$$
$$(\text{or } U^- \rightarrow e^- + \bar{\nu}_e + \nu_u)$$

If such heavy leptons do exist, they can make sense of some of the decay confusions in the observations on the ψs. They could also crank up the value of R nearer to 5. They would, however, really open Pandoras' box in other directions. If there is a heavy lepton then we almost certainly have its associated neutrino and if there is the U why not still more at higher energies?

What happens then to our lovely lepton-hadron symmetry? Well, we could preserve it by adding two more types of quark and after recent events and what seems to be the startling appearance of the charmed quark, what is to stop us mentally adding to the quark list.

PEP/PETRA/EPIC (the proposed higher energy electron-positron storage rings which could put fact behind these speculations) we have need of you!

Magnetic monopole

High energy physics is obviously a very attractive subject these days — when we are not writing about charm we are writing about magnetism. A Berkeley/Houston group (P.B. Price, E.K. Shirk, W.Z. Osborne, L.S. Pinsky) maintain that they have detected a monopole, the basic unit of magnetism, and E.K. Shirk described their evidence in a lecture at CERN at the end of August.

Two years ago the team dangled a balloon over Iowa loaded with a stack of plastic (Lexan) plates, nuclear emulsion layers and a Cherenkov counter. They were looking for very heavy nuclei in cosmic rays and particularly for 'super-heavy' nuclei which might exist around atomic number 114.

Their first information on the possible existence of the monopole came from the nuclear emulsion which was scanned at Houston. A black core surrounded by a halo suggested the passage of a very heavy particle with atomic number around 80. The diameter of the halo gave an estimate of the velocity of the particle as about half that of light, 0.5 c.

This data was passed to Berkeley and guided the chemical etching of the Lexan sheets in the region where the particle passed. The depth to which the etching occurs and the rate at which the etching takes place gives more precise estimates of particle charge and velocity.

The etching indicated that the particle passed through the sheets giving almost constant ionization regardless of depth in the stack. The best estimate was for a particle of charge around 137 and velocity about equal to that of light, in contradiction to the nuclear emulsion data.

Attention then turned to the fast film of the Cherenkov counter. A particle of high velocity should have recorded a black core with a ring around it where the Cherenkov light emerging at an angle to the particle direction intercepted the film plane. No evidence of Cherenkov light was found which said that the particle velocity was not higher than 0.7 c. This was in line with the data from the nuclear emulsion that a low velocity particle was involved. How then was it possible to explain the data from the etching of the Lexan sheets which indicated a highly ionizing, high velocity particle?

A magnetic monopole is predicted to cause ionization at a rate proportional to its strength, g, and its velocity. The etch rate seemed consistent with the interpretation that a monopole with g = 137 and a velocity which was sufficient to penetrate all the plates, was responsible for the track through the detectors. To have passed through all the plates it must have had an energy of over 32 GeV which means that its mass must be greater than 200 times that of the proton.

Some checks on the detectors were, of course, carried out. For example, the tracks left by iron nuclei were used for calibration. The film from the Cherenkov counter was examined in the region of the possible monopole track to ensure that fast particles were giving the ring signal of Cherenkov light. And so on. Other interpretations were tried, particularly the possibility that a couple of nuclear interactions took place along the track, giving changes in particle identity which could fit the data. The Berkeley/Houston team believe this possibility to be very remote (1 in 10^5 level).

Monopoles were first suggested by P.A.M. Dirac in 1931 as the magnetic counterpart to the role played by the electron as the basic unit of electricity. He predicted that its charge would be at least 68.5 times that of the electron.

It was perhaps the estimate of the detected particle charge at 137, twice the Dirac prediction, which lent extra weight to the monopole interpretation of what was seen in the balloon detector. Since the result was first announced there has been a re-calibration which has taken the charge to 121 and at the same time taken a lot of credulity with it.

To catch one monopole in the duration of the flight with the area of the balloon detector gives a figure for the number of monopoles possibly flying around in the upper atmosphere. It comes out much higher than that emerging from other unfruitful searches for the monopole, though just one track makes statistics very dodgy. A few more are obviously needed before the monopole interpretation receives acceptance.

Nevertheless it is an intriguing observation which has served to give the high energy physics world another stir and to bring magnetic monopoles onto the front pages of the newspapers.

Paying our way? An analysis of the 'economic utility' of CERN

CERN's main purpose is to provide Europe's scientists with excellent facilities for high energy physics research. All justification of the investment that is called for from the twelve Member States begins with a belief in the value of such research. There are, however, many other aspects of CERN's activities which contribute to the European scene. It has been 'a source of European spirit'. It has played a key role in re-establishing the stature of European science. It has a continuing impact on science teaching in Universities. It has promoted and helped sustain technical excellence in scientific equipment.

Stemming particularly from this last point, there has been a rather vague belief that, because CERN demands advanced technology in so many fields, there must be some benefit to European industry as a result of its dealings with CERN. Over the past three years, this possible benefit has been investigated to see if it could be measured.

Such exercises have been conducted before by large organizations but the results have usually not been convincing. First of all, technological 'fall-out' is rather difficult to quantify and, secondly, there is the obvious danger of bias since the organization has an interest in promoting the belief in high benefit.

The technique adopted at CERN was suggested and implemented by H. Schmied. It attempts to avoid the two pit-falls by having European industry itself measure the outcome of its dealings with CERN. The study has tried to determine the 'economic utility of CERN'. In principle this is the financial difference between the present situation and the hypothetical situation which would prevail if CERN did not exist.

The economic utility resulting from CERN contracts is the increased sales or the cost savings in firms which came about because they dealt with CERN. There are several things to stress immediately: The economic utility does not include any profit from the contract itself. The economic utility is identified and is estimated by the firms themselves and not by CERN. The economic utility came about, again in the opinion of the firms, because of dealing with CERN rather than from any other source.

The utility can come from sales of new products developed as a result of a CERN contract, from increased sales because of an improvement in product quality, from sales of products emerging from a collaboration initiated in a CERN contract, from increased sales of existing products because of their use at CERN... Cases of 'negative utility', where a firm believed that some income had been blocked because of being involved in a CERN contract, were also included in the survey.

Cost savings can come from production improvements due to acquaintance with CERN expertise, from research and development savings due to CERN covering the necessary 'R and D', from marketing and promotion savings by being able to use CERN as a reference,...

The figures from the firms were calculated from the time that such secondary effects of a CERN contract became evident through to the time when the link with the CERN contract was no longer clear or when the product's lifetime was over. For recent contracts, where the secondary effects still carry on, the figures were estimated by the firms through to the end of 1978 (since few firms planned beyond that date).

About 130 European firms which had received CERN contracts (involving almost half the total contract expenditure) were interviewed at managerial level. The discussions proved to be quite remarkably open and co-operation was always forthcoming to work out the secondary effects and the corresponding figures.

In general, firms were contacted where it was expected that increased sales or cost savings were likely to be found. It emerged, however, that the list of firms was effectively random — there was no way of predicting the effects. A particular example of this was a firm which was contacted despite knowing that it had suffered considerable financial pain in fulfilling a CERN contract. The firm came down very much on the positive side in terms of the subsequent economic utility of having dealt with CERN. A few case histories will indicate the diversity of the effects which were uncovered:

To transfer the precision built magnets of the Intersecting Storage Rings from their assembly hall to the machine tunnel required a special transporter. A manufacturer was found with a suitable prototype and an improved version was evolved, after some initial difficulties, which carried all the magnets without damage. The vehicle is capable of starting and stopping without jolting, keeps its platform horizontal even on quite steep slopes and can move sideways. The owner of the firm maintained that the CERN contract had advanced marketing of the transporter by at least three years. It found application in the shipbuilding industry solving the problems of moving prefabricated sections. The transporter achieved this much more cheaply than previous techniques. The shipbuilders stated that they would not have bought the untried prototype. The economic utility in this case was taken as the transporter sales during the three years by which production was advanced thanks to the CERN contract.

Another firm moved into the manufacture of bubble chamber film scanning tables using a CERN design. Not only did they market the tables widely, opening up routes into other countries which they were then able to exploit for other products, but they developed other applications such as scan tables for measuring salt content in human bones in vivo with X rays and computer controlled drafting tables used in road building, car design, shipbuilding etc... The economic utility in this case, due to the 'know-how' acquired in fulfilling the CERN contract, was estimated by the firm as a percentage of the subsequent sales figures for these products.

There are many cases where the CERN contract has influenced the ability of firms to produce high quality products. This comes about in the exchange of expertise, in the insistence on meeting a tough specification, in the contact with thorough project management techniques, etc... Examples have included —

The production of low carbon steel and the techniques for measuring its properties which were developed in collaboration with the steel industry at the time when the magnets of the proton synchrotron were built. The steel is now widely used in small motors, such as in washing machines and refrigerators, and is up to 20 % cheaper than the previously used silicon steel.

CERN opened the door to the manufacture of stock handling equipment for a firm which now has a full new Division so employed. CERN design, experience and prestige were involved in developing and marketing the products.

A plastic retaining its properties at liquid helium temperatures was identified at CERN and a manufacturer is now marketing components made from the plastic for such use much cheaper than the previous materials used.

The list is very long.

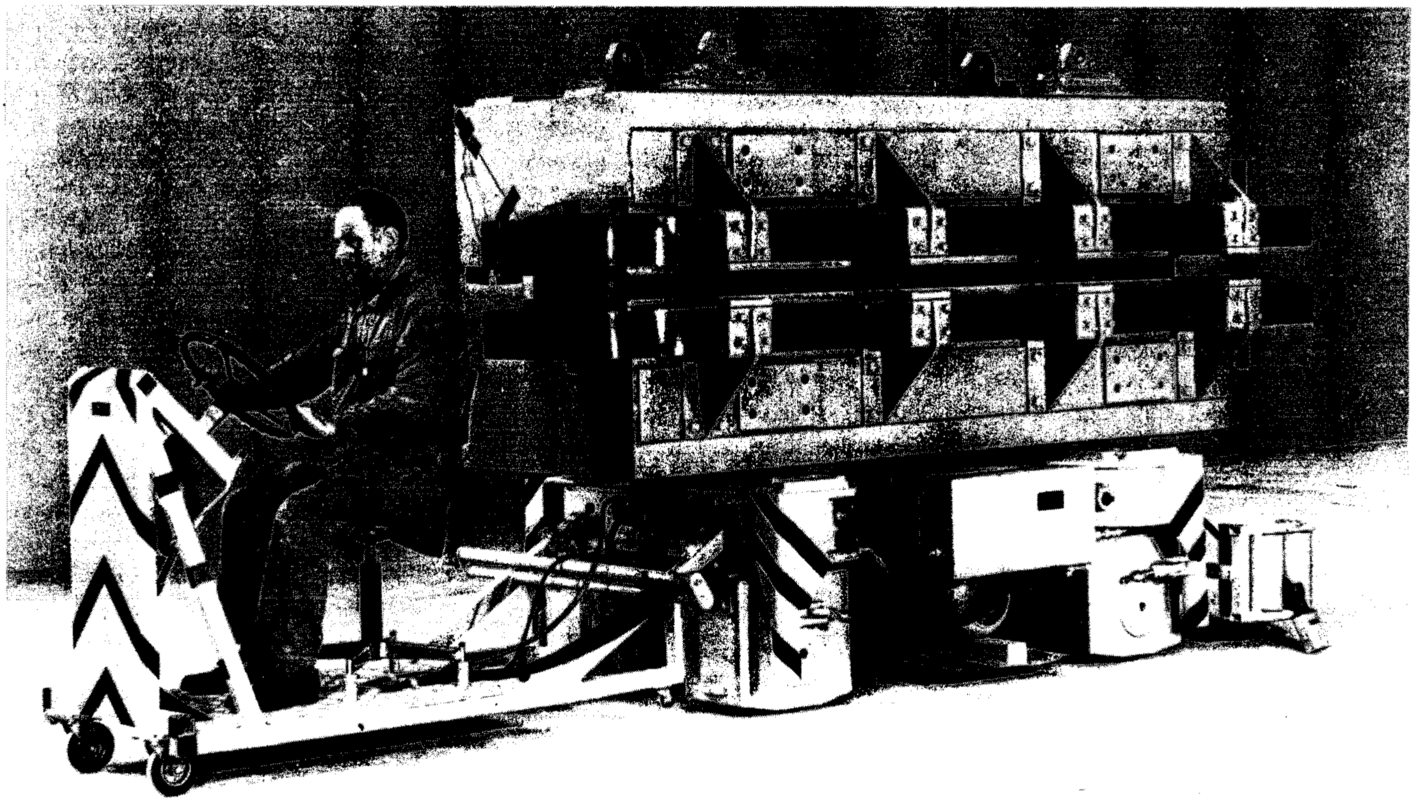
In treating the data assembled in the course of the study, firms were distributed in eight categories and the calculated economic utility divided by the value of the CERN contracts emerged as follows. The ratios tell us how many Swiss francs of benefit were generated by 1 Swiss franc spent by CERN.

In Computers the ratio is 17.5. When European companies succeed in selling to CERN, the impact on susequent sales is considerable. They also gain from CERN expertise.

In Cryogenics and Superconductivity the ratio is only 1.7. It seems that the markets in these advanced technological fields have not really opened up yet.

In Electronics the ratio is 4.8. CERN has pushed the development of electronics technology in Europe considerably.

In Electrical industry dealing with magnets, power supplies and cooling equipment the ratio is 2.2. Industry



The versatile transporter which was used to convey the precisely assembled and measured magnets of the Intersecting Storage Rings to their positions in the tunnel. Vehicles of this type are now in common use in the ship building industry.

CERN 290.10.68

CERN 309.6.69

The magnets of the 28 GeV proton synchrotron incorporated low carbon steel. This has since become standard material for the small motors of washing machines and refrigerators.

already has broad know-how in this field and CERN does not contribute much extra.

In Electrical industry dealing with r.f. equipment, cables and condensers the ratio is 0.9. Purchases are usually standard products and there is comparatively little technological contribution.

In Precision Mechanics the ratio is as high as 31.6. Here the contracts often involve complex components which generate know-how and technological potential.

In Steel production the ratio is 7.3. It is in this category that the use of low carbon steel appears.

In Vacuum the ratio is 3.2. Though CERN has pushed ultra high vacuum techniques to new limits, they have not yet found wide application elsewhere.

On the basis of the figures given by those firms investigated, and using the ratios emerging in the different categories above, for each Swiss franc spent by CERN in European industry, 5.5 Swiss francs of economic utility were generated. During the years 1955 to 1973, CERN spent 877 million Swiss francs on purchases in the eight industrial categories. The calculated utility is 4 860 million Swiss francs. This compares with a total expenditure at CERN by the Member States during these years of 3 500 million Swiss francs. The impact, however, should not be exaggerated, either in the taking or the giving. For example, the utility generated by CERN represents only one thousandth of the total turnover of the firms involved.

Some degree of personal interpretation comes inevitably into any system of collecting and analysing data of the sort used in the study. The CERN study has attempted to steer clear of the more obvious sources of bias and its results are more valid because of this. They seem to demonstrate that, aside from fulfilling the scientific tasks that it has been set by its Member States, CERN is paying its way in the European economic system.

A detailed account of the study has been written by H. Schmied as a CERN Yellow Report available from the Scientific Information Service — 'A study of economic utility resulting from CERN contracts'.

CERN News

Racing the beam around

The ISR team have been indulging in some sophisticated accelerator physics to confirm ideas on a new method of reducing the size of a stored particle beam. It has involved looking at the proton beam in one intersection region of the storage rings and then taking electrical signals in a straight line across an arc while the beam continued at near the speed of light around the ring. There is just time to race the beam to the next intersection region and to give it a nudge in consequence of what was seen upstream.

The method is known as 'stochastic cooling' and aims to reduce the vertical size of the orbiting beam. This is important because the height determines the 'luminosity' of the colliding beams which is a measure of the number of proton-proton interactions which are seen by the experimenters. The Intersecting Storage Rings have been mastered to such a degree of perfection by now that it takes very refined techniques t squeeze out any more luminosity.

As the protons orbit a ring they are moving from one side to the other of their ideal orbit by a few millimetres, swinging up and down several times in one turn. If there was just one proton it could be brought to the ideal orbit by observing how it is moving and nudging it back to the orbit by electric fields. But when there are many protons, any nudge that favourably affects some of them will have an unfavourable effect on others which are moving in the opposite direction. The stochastic cooling idea, which originated with S. Van der Meer, wins out by giving the nudge in such a way that the majority of protons are favourably affected.

Looking at a slice of the beam at any one time will reveal a density

A map of Europe with lines radiating out from CERN to the national centres which draw some of their research material from the bubble chamber experimental programme.

CERN 39.6.75

distribution of the protons. The aim is to apply electric fields so as to move the 'centre of gravity' of the density distribution to the orbit. This cannot be done in exactly the same place that the beam is observed because, obviously, the protons will have moved on before the correcting fields could be applied. Neither can it be done by looking at a slice of the beam and then waiting for the protons to make a full turn before applying the fields — the protons are moving at very slightly different speeds and it is a different batch of protons that arrives in any slice of the beam acted on a turn later. If, however, the beam is raced to the next intersection region (one eighth of the way around the ring), the slice which was observed has not changed very much and applying correcting fields, as prompted by the observed density distribution, should help. Once this correction has been applied it becomes an advantage to have the mixing that takes place during a turn — having pushed the centre of gravity of one slice of the beam to the axis, a different batch of protons is needed in order to repeat the exercise usefully. The improvement of the beam which is achieved each time a correction is applied is minute and it takes millions of turns to yield an observable effect.

The ISR tests became possible with the development of electronics sufficiently fast to enable the beam to be monitored, the appropriate signals to be transmitted and the kicker magnets in the next intersection region to be powered to the extent needed to apply the correcting fields, all in the time that the protons travel just one eighth of the circumference of a ring. Two directional loop pick-ups connected to a differencing transformer were used to observe the density distribution and their amplified signal was sent to a kicker magnet power supply. The beam heights were checked with the sodium curtain beam profile monitor (see November issue 1971, page 324) and the cumulative effect of the kicker magnet fields accurately measured by observation of the collision rates at three intersections. It proved to be close to that predicted theoretically. Over seven hours the cooling rate was about 2 % per hour.

A better stochastic cooling system is now being built with a higher fidelity pick-up and kicker structure installed in special vacuum chambers. For the ISR it is largely an academic exercise in accelerator physics since the luminosity gain with high intensity beams is unlikely to be significant. However, there is considerable interest in the technique for use at the higher energy storage rings such as have been studied at Brookhaven (ISABELLE), CERN (LSR) and FermiLab (POPAE). At these machines it seems feasible to store antiproton beams and to achieve acceptable interaction rates in antiproton-proton collisions. Any help towards increasing the luminosity of antiproton beams would be of great importance. Now that it has been demonstrated at the ISR that stochastic cooling works, it will no doubt be considered into all plans for stored antiproton beams.

Some further details on the stochastic cooling tests can be found in a paper by P. Bramham, G. Carron, H.G. Hereward, K. Hubner, W. Schnell and L. Thorndahl in Nuclear Instruments and Methods 125 (1975).

Restart of the 2 m bubble chamber

The CERN 2 m bubble chamber, which was shut down on 19 December last, has been moved 13 m to the North to allow a better layout of counter experiments in the East hall of the proton synchrotron.

For the move, the chamber was dismantled to clean the optical system and maintenance was also carried out on the expansion system, cameras, cooling plant and compressors. The cooling plant has been slightly modified to use the 520 m^3 safety sphere as a buffer tank for the supplies to the compressor. Consequently, only metal surfaces will be in contact with the hydrogen in the circuit, and the membrane-type gas holder will be used only for recovery purposes. A new photograph titling system has been incorporated which can print in 40 to 60 ms, so that triple cycling becomes possible — the chamber will be able to take three photographs during each PS pulse.

During dismantling, the window on the camera side (2 m × 60 cm × 17 cm) was chipped along one edge, and a replacement window was fitted after inscribing the fiducial marks on it. After a false start at the end of June (halted by a hydrogen leak) the chamber is back in action. The photographs are of good quality though certain fiducial marks are not visible to all of the cameras. This does not seem to affect the accuracy of the measurements since made with the ERASME and LSD scanning systems.

The chamber is booked for use through to the end of 1976. During this period 7.5 million photographs are programmed. This is the tenth anniversary year of the 2 m bubble chamber (it first operated on 22 May 1965) and it has already taken more than 31.5 million photographs.

Central Development Service

Film from the 2 m bubble chamber as well as from Gargamelle, BEBC, the optical spark chambers and streamer chambers is developed at CERN by the Central Development Service. It copes with a large volume of work. In 1974, 4 400 km of film (35, 50 and 70 mm wide) were developed, entailing the use of 130 000 litres of developer and 90 000 litres of fixer. With this quantity of solution, special attention is devoted to recovering the silver deposited in the baths.

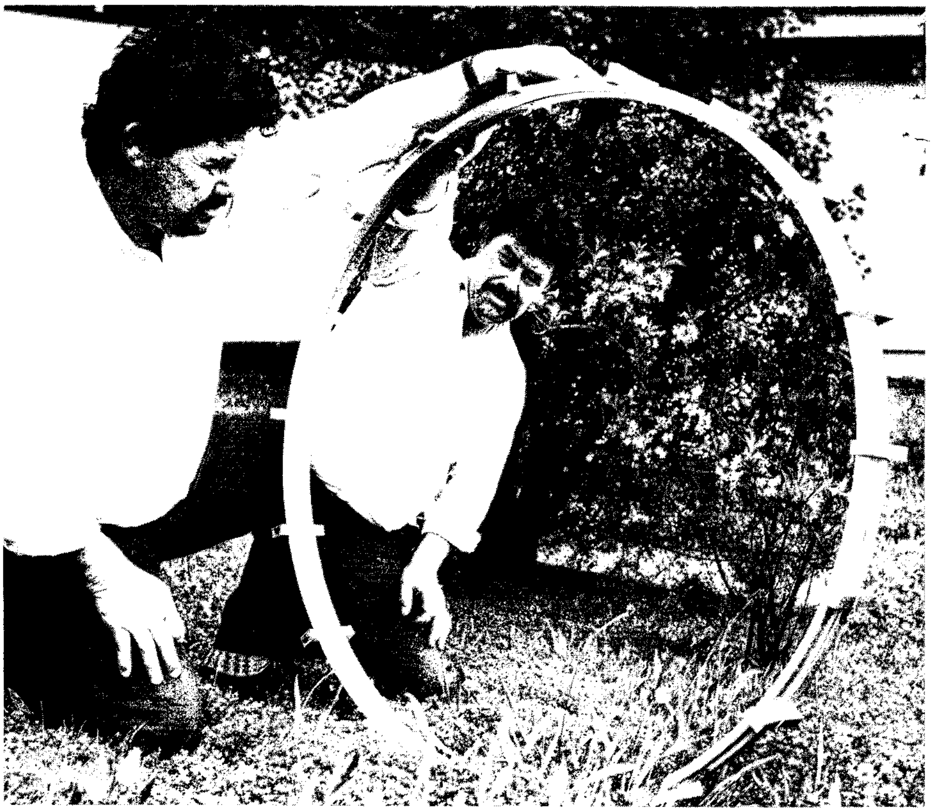
The facility, with its equipment for handling all types of black and white emulsion (at present ten different types) has two high output machines; a third is being installed and a fourth one will be fitted in Autumn. The latter will be capable of handling up to 1.8 km of film per hour for negative development and about a kilometer in the case of reversal film. Film is prepared for CERN and for dispatch to participating Universities and Laboratories throughout Europe.

To cope with the expansion of the facility and to ensure that the high quality necessary for automatic analysis is preserved during film processing, a small computer is shortly to be incorporated. Automatic development of emulsions will then be possible and the computer will be responsible for quality control, based on the use of densitometry and microdensitometry techniques. It will also be used in managing chemical and film stocks.

First extraction system goes into SPS

Elements of the extraction channel, through which the 400 GeV proton beam from the SPS will be extracted into tunnel TT20 towards the North experimental area, are now in place in straight section 2 of the ring. The components for the second channel, for extraction to the West experimental area, are now being assembled and will be installed this Winter in straight section 6.

The components are identical in the



An inflatable mirror made from an aluminised mylar membrane 25 µm thick, which has been developed at the CERN West Workshop. By varying the pressure applied to the membrane the mirror takes up varying quasi spherical forms. The focal length can thus be varied for use in a Cherenkov counter.

CERN 33.6.75

two channels and will be used for both the slow extraction to the North and West areas and fast extraction to the West area. Each channel comprises a group of four electrostatic septa, which act as a knife to separate the circulating beam from the part to be extracted, bending the latter by means of an electrostatic field. The knife must be very thin and very straight to minimise the number of particles interacting with it. Each septum consists of 2080 tungsten wires 0.12 mm in diameter, vertically stretched over 55 mm height at 1.5 mm intervals.

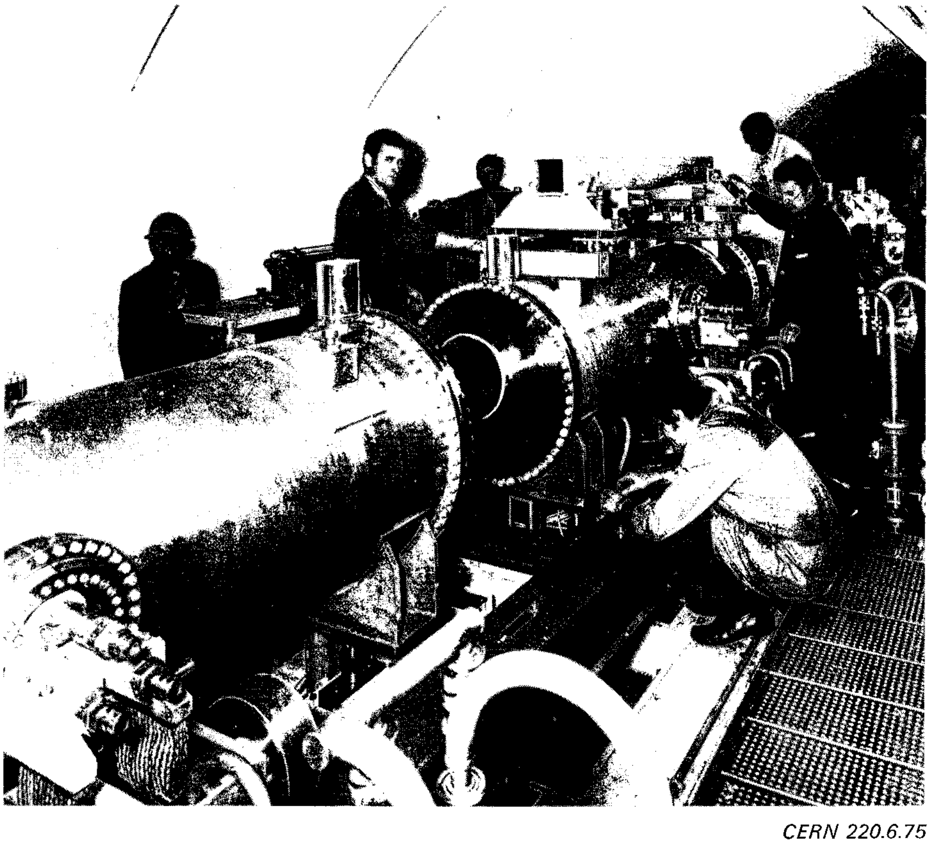
The electrostatic field of 100 kV/cm is set up between the anode row of wires and a 3 m long cathode, the distance between them being adjustable between 10 and 30 mm so that the system can be adapted to the beam dimension and the various operating modes.

Each electrostatic septum is contained within its own vacuum tank and four of the tanks are aligned on a girder which can be moved by remote control so that the knife can be taken to, or removed from, the machine aperture and oriented with respect to the beam.

Some 50 m downstream are four pairs of thin septum magnets with 4 mm thick septa. Their magnetic field is confined by a copper conductor, the septum, and does not affect the circulating beam. These magnets will be pulsed to eliminate any effect, even from a very low fringing field, on the injected beam. The current in the septa will reach 7.5 kA. The magnets sit in pairs in vacuum tanks and are fitted and aligned on a girder which can be moved sideways by remote control.

Bending of the extracted beam is further enhanced by another group of five pairs of septum magnets with 16 mm thick septa in which the current reaches 24 kA. These magnets are also fitted in a vacuum tank in pairs on a girder adjustable by remote control. After these thick septa the beam passes between the windings of a special quadrupole before it travels outside the next main ring magnet and extraction is completed.

At the beginning of August, the electrostatic and thin septa passed their initial tests to check that, after installation in the tunnel, they operate as required while controlled from the auxiliary building on the surface.



Part of the extraction system being installed in straight section 2 of the 400 GeV SPS tunnel. A vacuum tank housing a pair of thin septum magnets is being moved into place. The installation and removing of these components have been simplified as far as possible by the use of quick-release connections. In the middle of the tank may be seen the power supply which can be disconnected by applying compressed air.

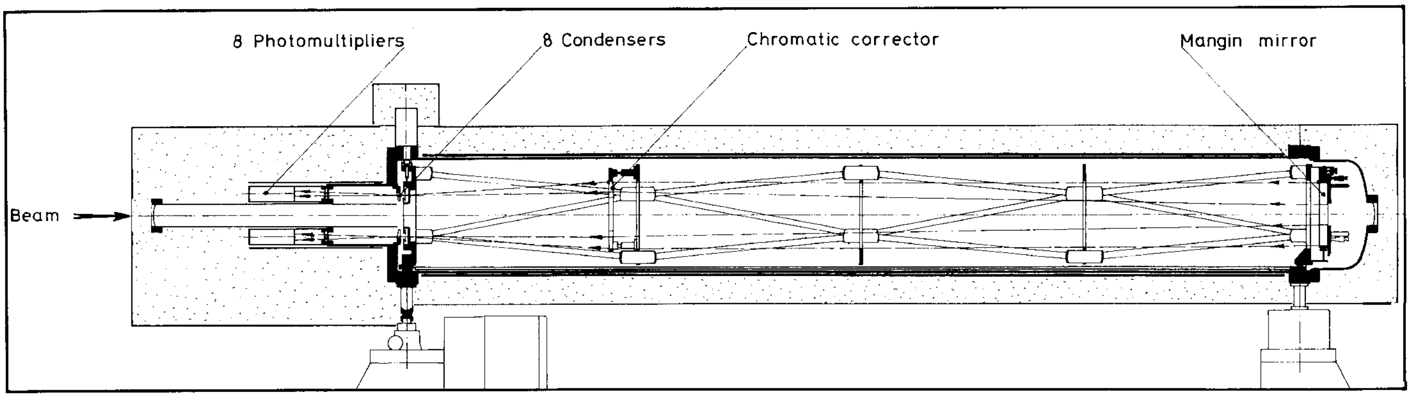
CERN 220.6.75

CEDAR looks good for SPS experiments

Cherenkov counters are among the most useful detectors in the high energy physics armoury in particular because of their ability to distinguish between different types of particle. When a particle of selected momentum (having passed through a magnetic field which allows only particles of a fixed mass multiplied by velocity to remain in the beam) travels through the counter, it emits light at an angle to the direction in which it is travelling. This angle is directly related to beta (the velocity of the particle divided by the velocity of light) and if it is measured, the mass of the particle can be determined.

The need for particle identification continues into the hundreds of GeV range now opened up at the FermiLab and soon to extend to CERN with the SPS. It then becomes much more difficult to extract information from a Cherenkov. The differences in beta are very small (in the 10^{-6} range) and the measurement of the slightly different angles becomes very difficult. The difficulties were overcome in a counter built at CERN for the FermiLab (see October issue 1973, page 300) but the costs involved were high and

Diagram of the new type of Cherenkov counter developed for use at the SPS which has recently been successfully tested at the PS. Light emitted at an angle by particles in the beam is reflected by the mirror and focused on a ring shaped aperture which allows it through to photomultipliers.



seemed unacceptable when ten such counters were called for in the experimental programme of the SPS. C. Bovet therefore took a fresh look at the problem. The aim was to simplify the design so as to cut costs while still achieving acceptable results.

The first simplification was to limit the abilities of the counters to cover only the energy ranges that they will confront. Thus there will be two types — one for the West experimental hall to cover the energy range 15 to 150 GeV for particles generated by protons of up to 200 GeV which is the maximum energy usable in the hall, and one for the North experimental hall to cover the energy range 60 to 340 GeV for particles generated by protons of up to 400 GeV, which is the maximum energy of the machine. In each case the optical system is optimized for the top energy rather than being adaptable over a wide energy range. This should still give acceptable performance down to the lowest energy.

The second simplification is to use the same mechanical construction for the two types so that the counters will be transferable between the experimental halls with a change of the optical elements. Helium will be used in the North type and nitrogen in the West type.

The refractive index of the gas also appears in the equations which give the particle velocities. To avoid using a refractometer to measure the index, it is obtained simply by pressure and temperature measurements. Great care has to be taken to ensure an even temperature along the 6 m length of the counter. It is built of iron in an aluminium coating insulated by a polyurethane jacket and achieves temperature uniformity to better than 0.1°C.

The trickiest component is the optical system which should bring the light to the same ring focus where an aperture in a diaphragm allows it through to eight photomultipliers. To collect all the light, the optical system has to have chromatic correction so that, regardless of wavelength, photons emitted by a given particle will come to the same radius at the diaphragm. In the previous design a most elegant corrector was incorporated involving a triple lens with fused silica and sodium chloride elements. Unfortunately no firm was prepared to tackle its manufacture. It was therefore decided for the new counters to divide the corrector putting one lens directly onto the mirror which reflects the Cherenkov light. This can be made in industry and leaves a fairly simple quartz lens along the counter to complete the correction. R. Wilson of the European Southern Observatory gave considerable assistance in the design of the optics.

The first ChErenkov Differential counter with Achromatic Ring focus, CEDAR, built following the ideas discussed above, was recently tested in a beam at the proton synchrotron. It demonstrated clear separation of electrons, muons, pions and kaons as the pressure was varied up to eight atmospheres (higher pressure would have been needed to see protons). A NORD-10 computer was used to vary the gas pressure and to measure it. The computer also controlled the opening of the diaphragm in steps of 20 μm and the alignment of the counter in the beam in steps of 2 μrad.

When only six of the eight photomultipliers were asked to record that light had passed through the ring aperture in the diaphragm, the efficiency in pion detection was 98 % and the background away from the ring focus was down a factor of 10^{-5} compared to the signal given by pions. Overall, the agreement between the measurement and the calculated performance was excellent. (One slight worry about the number of light photons detected per beam particle was removed when it was found that the coatings on the optical elements had not received enough attention.) Six of these counters are now being prepared ready for the start of the SPS physics programme next year.

At the machines

We are accustomed to reporting new records achieved in the performance

Around the Laboratories

of the Intersecting Storage Rings (ISR) with regard to both the luminosity and intensity of the beams stored in the rings. Obviously, the further beyond the design figures that the peak performance is taken, the less spectacular, and harder to come by, are the subsequent improvements. Here are the record figures since our last review.

On 24 May, the luminosity recorded for 26 GeV beams was 1.5 × 10^{31} per cm^2 per s during a physics run, whilst the intensity in rings I and II was 21.2 and 24.8 A respectively. On 30 May, a record intensity of 32.5 A was achieved in ring II, with a 26 GeV beam and on 3 July an intensity of 31.5 A was recorded in ring I again with a beam energy of 26 GeV.

Operation continued until 25 July, when the storage rings were shut down for maintenance. They were due to be started up again on 27 August but, because of an incident in the vacuum system, this could not take place. There was an implosion of a titanium bicone which had just been installed at intersection I-7. It had successfully passed laboratory tests and an enquiry has been opened to determine the cause of the accident.

It is obviously accident time at CERN because the usual remarkable machine reliability was violated at the PS also shortly after the ISR incident. On the evening of 29 August, a fire broke out near the South Hall and damaged a distribution board connecting the electrical power supplies to the auxiliary magnets of the PS together with supply and control cables. Work started immediately to repair the damage but the PS is likely to be out of action for about three weeks. The delaying factor is not so much the direct fire damage but the fact that burning PVC insulation gave rise to hydrochloric acid, helped along by the water used to extinguish the fire, and the acid has penetrated everywhere.

ORSAY
Flipping detector

Yet another novel way of detecting high energy charged particles has been thought up by A.K. Drukier and C. Valette of Orsay. They suggested that granules of materials in the superconducting state could be flipped normal by the energy deposited by a passing particle. Drukier went one further and suggested that transition radiation (a phenomenon first identified at Yerevan and studied in detail at Brookhaven) could do the flipping. The granules could thus both initiate the radiation and detect it. These ideas have been successfully tested by an Orsay/Brookhaven/DESY team on an electron beam at the DESY synchrotron.

Re-reading this opening paragraph brings home yet again how intermunity. No doubt this is a comment that we could make about many of the topics that we cover but taking this particular one — An idea emerging at Orsay in France incorporates the results of work at Yerevan in Soviet Armenia and Brookhaven in the USA and is tested in a French/American/German collaboration (the American, L.C.L. Yuan, actually being temporarily based at CERN) on the synchrotron at Hamburg in the Federal Republic of Germany.

Transition radiation is produced when a charged particle travelling at relativistic energies crosses the boundary between two media of different refractive index. The radiation can be detected in the optical and X-ray region. It is not easy to measure this radiation since the materials used to produce it (such as closely spaced metal foils) tend to absorb the radiation themselves. The granule idea gets around the problem.

Type I superconductors, such as tin or indium are able to retain their superconducting property beyond the critical conditions (temperature, and magnetic field) where they usually flip to the normal state. This is known as superheated superconductivity and, as with the supercooled liquid in a bubble chamber, the depositing of a comparatively small amount of energy is enough to flip the system normal.

The proposed new technique was tested by making a small target (3 mm diameter, 10 mm long) detector consisting of granules of tin (5 mm or 3.4 mm in diameter) embedded in paraffin wax. As a relativistic electron from the synchrotron crosses each metal-wax boundary, transition radiation is emitted and this radiation is then predominantly absorbed by other surrounding granules. It can be arranged that the energy deposited by the initial electron (about 1.25 keV/μm in tin) is not enough to flip the granules while the photoelectrons from the transition radiation, depositing more energy (for example, 3 keV/μm at 40 keV and 6 keV/μm at 15 keV in tin), do flip the granules. This is achieved by adjusting the strength of the magnetic field applied at the detector, which adjusts the conditions at which the superconducting tin goes normal.

The number of granules affected due to transition radiation is a function of the 'gamma' of the high energy particle (which relates its mass to its rest mass). Measuring the number of granules which go normal determines gamma. One way of carrying out the measurement is to put the detector inside a coil which is part of a resonance circuit. As granules go normal they change the inductance of the coil (since in the superconducting state they exclude magnetic field) and the resonant frequency in the circuit changes accordingly.

The tests at DESY demonstrated that transition radiation does cause flipping. The threshold was set above the energy where it could be caused by ionization loss alone and the subsequent frequency change in the resonant circuit was seen to increase as the energy of the electrons was increased (whereas it should remain constant if ionization loss were the sole cause). With electron energies from 0.4 to 2 GeV a linear dependence on energy was observed as has been found before for transition radiation in the X-ray region. Above 2 GeV, the energy dependence becomes quadratic as was predicted above a critical value (when multiple scattering becomes important) by V.E. Pafomov.

The set-up for these experiments was comparatively crude. It nevertheless was adequate to show that the basic idea works.

RUTHERFORD
Waxing on about training

One of the frustrations in developing superconducting magnets has been in the struggle against the phenomenon of training. A magnet built from superconductor hardly ever gives the peak field that can be anticipated from the maximum current achieved through a small piece of the superconductor (the short sample current). Instead it goes normal (or 'quenches') at much lower currents — perhaps initially at 50 % of the short sample current. The magnet can then be 'trained' to go higher, repeated powering leading to progressively higher currents being sustained before the magnet goes normal. After many quenches, the magnet is able to take say 90 % of the short sample current. (This is a generalized account of the phenomenon — some magnets have performed better, some worse).

Until training can be mastered, the design of superconducting magnets for an accelerator, beam-line or detection system has to be rather ponderously conservative in order to ensure that the desired performance and adequate reliability is obtained.

The popular interpretation of what is happening in such a magnet is that small amounts of energy are being liberated as it is powered due to the release of stored energy in the coil impregnation and movement of the conductor. This results in local heating taking the superconductor beyond the critical temperature at which it goes normal. (There are other ideas as to the origins of training such as the release of strain within the conductor itself).

The attack on training has mainly concentrated on achieving high mechanical rigidity in the magnet so as to prevent movement and the release of energy when a coil is powered. This has certainly resulted in magnets of better quality (see May issue page 153) but it has not been successful to the point of eliminating training. For example, at the Rutherford Laboratory, training was still experienced with the pulsed superconducting dipole, AC5, even though it was built with special emphasis on mechanical rigidity. Its overall performance, nevertheless, was excellent. Also at Rutherford a first small pressure-impregnated coil needed a great deal of training.

The magnets have epoxy resin impregnation of the coils which, in different mixes, is virtually the universal 'potting' medium. P.F.Smith and B. Colyer from Rutherford have pointed out (see 'Cryogenics' April issue) that epoxy resin systems store energy during cooldown and that there is around 100 times more energy per cm^3 than is necessary to make a typical superconducting magnet go normal. They suggest that for many applications, instead of building rigid magnets, aiming to prevent the energy in epoxy resin systems from being released, another approach would be to change to a potting material which does not store energy. One such material is wax.

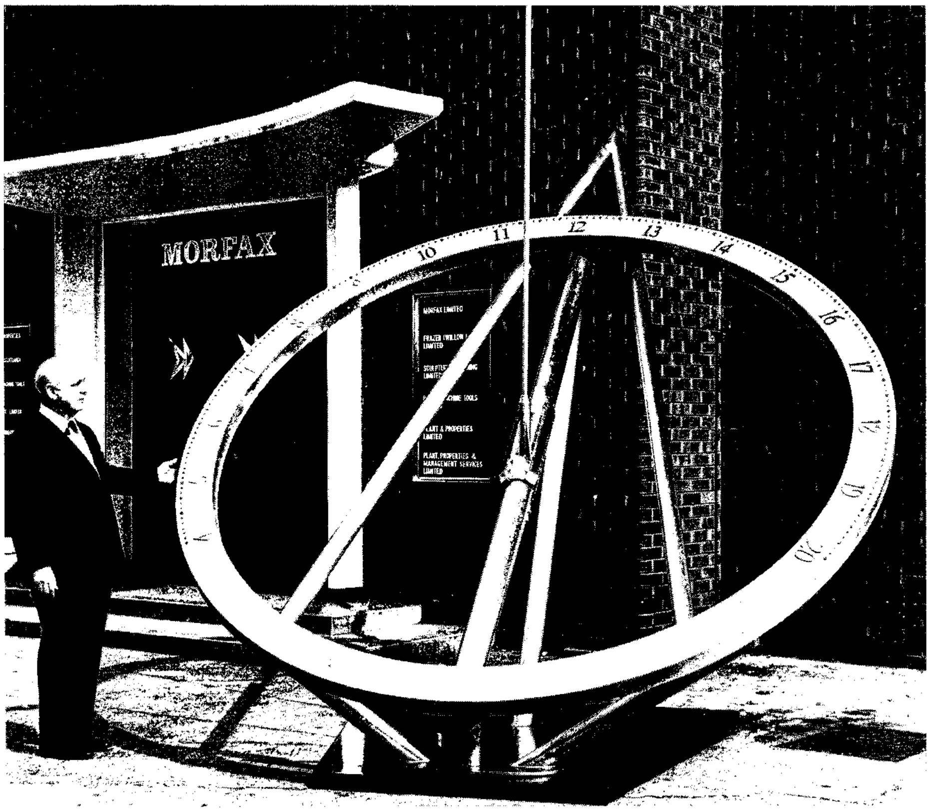
Almost everyone's vision of wax is a melting candle and orthodox magnet builders would tend to run away immediately from the idea of using such a soft material. However, given a suitable structure, potting a coil in wax could have several advantages. With regard to training, the essential fact is that wax will not store much energy during cooldown. It will yield (becoming crazed with tiny cracks) rather than hold built in strain. At the same time its mechanical properties can remain good enough to hold the conductor precisely in place as required for a quality magnet and it can transmit the coil forces to a containing shell without problem.

At room temperature, the mechanical properties are not so favourable but can be adequate. There are toughened waxes (such as Technimelt) usable for potting a coil which will withstand handling without a containing vessel if necessary. The main disadvantage is that the thermal conductivity of wax is very poor and indirect cooling of wax potted coils would be very difficult. They are probably therefore unsuitable for pulsed magnets where the powering cycle produces a small amount of heat in the coil which it is vital to take away.

Four years ago there was a series of tests on wax impregnated quadrupole coils at Rutherford culminating in a 4 T, 9 cm bore magnet. The wax filled coils showed very little training by comparison with their epoxy resin equivalents. In June of this year the dust wraps were taken off the quadrupole and it was reimpregnated with paraffin wax. Its first quench was at 90 % of short sample current and all subsequent quenches at 96 to 97 %.

The mechanical properties of the magnet were checked in August measuring the change in total inductance as the field increased. This gives an indication of coil movement and, up to 4 T, the change was only 1 in 10^3. The field errors will, in general, be smaller.

Wax has also been successfully used in a 6 T solenoid but these conductor configurations are less susceptible to training in any case. It has not been tried in a full scale 5 or 6 T magnet but there is no reason to expect different performance. Perhaps the use of a potting material which cannot store strain energy deserves some more attention in superconducting magnet construction.



Multi-disciplinary sundial. It commemorates the tercentenary of the Royal Greenwich Observatory in the UK. G. Simmonds of the Rutherford Laboratory acted as engineering consultant and the sundial was built by Morfax Ltd. who have supplied the cores of the CERN SPS magnets. It is installed in an Elizabethan walled garden at the new Observatory site at Herstmonceux Castle. A small arched entrance provided the only access to the garden and manoeuvring the completed sundial to its position involved entertaining conversations concerning helicopters and Navy gun teams. A delicate 'heavy gang' finally took it over the wall with no reproach from the Department of the Environment.

KARLSRUHE

Superconductivity put to use

At the Institut für Experimentelle Kernphysik, Karlsruhe, a high proportion of the research and development programme is devoted to different aspects of the understanding and application of the phenomenon of superconductivity. In the June issue we reported the latest results from the work directed towards producing a superconducting linear accelerator. This article briefly reviews some of the other activities in the same field.

The work is underpinned by a huge refrigeration installation. Two refrigerators capable of 300 W at 1.8 K are available. It implies a room temperature power of 0.3 MW each and this is among the most powerful refrigeration installations in the world.

Karlsruhe participates, with Saclay and Rutherford, in the GESSS collaboration and has worked on pulsed superconducting magnets appropriate for use in a synchrotron. Their latest completed model D2a (see September issue 1973) had a 6 cm aperture and was composed of five cylindrical shells of superconductor. It was tested initially with epoxy resin ring clamps and reached 5.1 T d.c. and 4.5 T when pulsing at a 10 s pulse rate. About a quarter of a million pulses were applied; considerable training was observed and the performance of the magnet deteriorated with time. The epoxy clamping was then replaced by strong aluminium rings shrunk on to the magnet. This resulted in much less training, a peak d.c. field of 5.3 T, a pulsed field of 5 T and no sign of deteriorating properties over 100 000 pulses. It is intended to build a further pulsed dipole, D2b, and it may be made mechanically rotatable so as to take a look at the problems of superconducting a.c. generators.

Among the d.c. superconducting magnets are two sets of quadrupoles. One set is for use with the superconducting linac where the available space makes it necessary to use focusing magnets which are axially very short — hence the use of superconducting quadrupoles capable of giving higher fields along a shorter length. The other set is for use on the hyperon beam at the CERN 400 GeV machine. Again the interest is in short axial length so as to operate on the hyperons, produced by the high energy protons in a target, bringing them into a usable beam during their short lifetime. Winding of the coils has started and it is hoped to begin assembly of the magnets at the end of the year and to have them installed in the CERN West experimental hall by the Spring of next year.

Another project for CERN is the construction of superconducting r.f. separators also for installation in the West experimental area in a beamline to the Omega spectrometer. Like all the other attempts at building large scale superconducting cavities this is

✱ *Mid-September, two joined sections of twenty cells operated excellently. A Q value of 2.2×10^9 was achieved (four times higher than is needed) with a magnetic field of 360 gauss. This corresponds to a deflection field of 2.4 MV/m.*

proving much more difficult than initially expected. There will be two cryostats (both now under test) each with a cavity built up of five sections. The tests on individual sections yielded excellent results (see February issue 1974) but when two sections are joined together the same performance is not yet reached. ✱

It is not clear whether the problem is due to the additional length or to an unsatisfactory joint between the two sections. Refrigeration is by superfluid helium which has excellent properties as far as heat conduction and specific heat are concerned. It does, however, also find leaks much more readily and the cooling system has to be carefully built to avoid leaks. In compensation for these problems there are other aspects of superconducting r.f. separators which are trivial by comparison with their conventional equivalents. For example, the electrical systems have to cope with only 1 kW of d.c. power compared with megawatts of pulsed power.

It is hoped to have the separators at CERN by the end of 1976 but there remain several problems to overcome before this pioneering project meets its specification.

The application of superconductivity in fusion devices, such as a Tokamak, is also being studied. The work is being done in association with the Max Planck Institute for Plasma Physics at Garching and in collaboration with the other two GESSS Laboratories. Fusion reactors, in addition to the magnetic confinement coils, require large energy storage and transfer systems with pulse cycle times comparable to those of a synchrotron. Storage and transfer systems are being developed at Karlsruhe and the first small experiments have been carried out on two 15 kJ superconducting storage coils linked to a superconducting switch. A second experiment with a 100 kJ store is now under way. The aims are to learn the behaviour of high current, high voltage systems in cryogenic environments so as to be able to design the large systems which will be needed in a fusion reactor.

Finally, there is basic research into the phenomenon of superconductivity. This involves the investigation of new superconducting materials and of sputtered thin films, and the study of the properties of the known materials. Topics of the research include the determination of the local flux distribution in hard superconductors, flux flow experiments, the behaviour of superconductors under pressure, their mechanical properties at cryogenic temperatures and the effect of radiation (in particular, the effect of neutron fluxes such as would be experienced around a fusion reactor). By means of a 'decorating' technique, information about the static flux distribution and its dynamic behaviour is obtained. The technique involves evaporating ferromagnetic material, in an inert (helium) atmosphere, which is deposited on superconductor at regions where the flux penetrates the surface.

BROOKHAVEN ISABELLE Summer Study

From 14-25 July over a hundred high energy physicists and accelerator physicists gathered at Brookhaven to examine again the project for the construction of the 200 GeV Intersecting Storage Accelerator, ISABELLE. The proposed machine will take protons from the existing 33 GeV Alternating Gradient Synchrotron and accelerate and store them at energies up to 200 GeV for very high energy colliding beam experiments. The design, up-dated in June, involves two concentric rings in the same plane, 2960 m in circumference, built with superconducting magnets capable of 4 T. Eight intersection regions will be incorporated where a luminosity up to 10^{33} per cm^2 per s is anticipated with 10 A stored in each ring.

ISABELLE recently had renewed support from the Subpanel on New Facilities set up by the High Energy Physics Advisory Panel (HEPAP) which reports to the USA Energy Research and Development Administration. The Subpanel was chaired by F. Low and has re-examined the recommendations of the Subpanel of 1974 chaired by V.F. Weisskopf (see July issue, 1974), in the light of the dramatic developments which have occurred in high energy physics during the past year. The Low Subpanel retained the three major recommendations of the Weisskopf Subpanel — they give first priority to the construction of the Berkeley/Stanford 15 GeV electron-positron storage ring project, PEP, urging an immediate start; they recommend a start on ISABELLE in 1976 which is a much more positive position than the Subpanel felt able to adopt a year ago; they support the FermiLab programme of research and development aiming at energies of 1000 GeV and above.

The Low Subpanel urged that Brookhaven double the research and development effort applied to the superconducting magnets and cryogenic systems for the ISABELLE project. An ISABELLE Division has been set up within the Accelerator Department with H. Hahn as Division Head and J. Spiro as Deputy Head. They will be looking harder at ways of cutting costs on the project, again following a recommendation of the Low Subpanel.

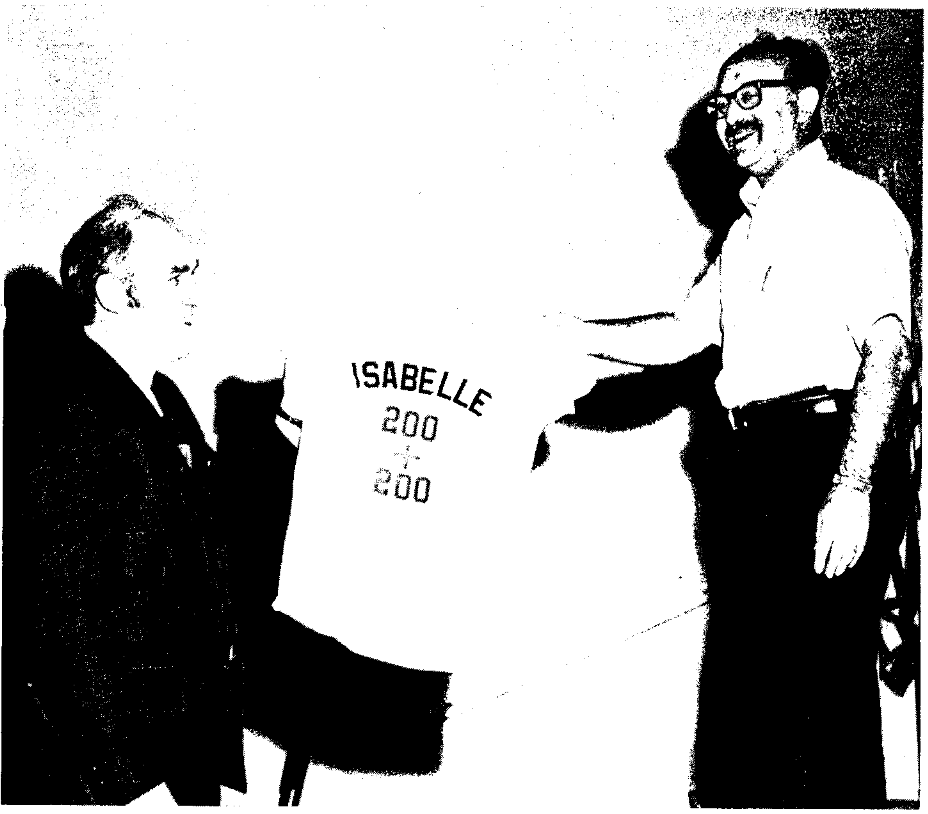
The ISABELLE Summer Study took place in an atmosphere of great enthusiasm reflecting the excitement pervading the whole world of high energy physics at the moment to which a machine like ISABELLE would certainly contribute greatly. No major changes to the existing project design emerged from the Summer Study but the specifications of a number of components could be made sharper as a result of the discussions.

For example, recent observations at the CERN ISR and PS concerning longitudinal instabilities have considerable impact on the ISABELLE injection conditions and vacuum system. It has been shown that the stability criteria normally applied to unbunched beams can be relevant to bunched beams in which an instability can grow quickly before the particle feels the effect of being in a bunch. The instabilities can happen at microwave frequencies. Landau damping, due to the different revolution frequencies of the individual protons, inhibits these instabilities from growing, but in a large circumference machine where the aperture has not increased correspondingly, the damping does not act as much. For ISABELLE it seems necessary to inject with the highest beam intensity possible from the AGS, to do some bunch predilution before injection, and to present the beam with as smooth a vacuum pipe as possible to travel in around the rings.

The working group considering the superconducting magnets recommended an all out effort during the coming year to build several full-scale bending magnets and a focusing quadrupole. One such magnet, 4.25 m long, was built in a hurry in May/June in an attempt to have it operational prior to the meeting of the Low Subpanel. The coils for the magnet were made in only six days. This pace seems to have been a little too fast for the magnet performance is not high.

Considerable training was experienced. The first quench occurred at 3 T and peak fields later climbed to 3.59 T. The problems concerned the

Brookhaven making full use of the 'T-shirt' to get their message across —



1. During the ISABELLE Summer Study, the Chairman of the Organizing Committee, A. Pevsner (right), presented an ISABELLE shirt to W. Wallenmayer of the ERDA Washington office — money from Washington for the 200 GeV storage rings would be welcome.

2. Members of the team of S. Ting, who discovered the new particle at Brookhaven at the same time as the Berkeley/Stanford team, project their selected name for the 3.1 GeV particle. M. Barton, Chairman of the Accelerator Department, also sported a J-shirt when addressing the ISABELLE Summer Study saying 'We have had a tradition at Brookhaven of very good relations with the user community; we provide them with protons and they provide us with T-shirts'.

leads (which can be easily improved), the slow speed at which a quench propagated (which can be cured by replacing some stainless steel inert turns by copper) and a mismatch in expansion coefficients between Microy post pieces and the rest of the coil (which can be cured by using other material). Nevertheless, the field quality of the magnet was good.

The magnet is being rebuilt with the improvements mentioned above. Tests have continued with the latest in the 1 m long series of pulsed superconducting magnets, ISA IV (see January issue) to study the relationship between mechanical rigidity and training (see the article on page 270). With an iron core of honed bore and an interference fit of 0.4 mm, no training was experienced in reaching a maximum field of 4.4 T.

HARWELL
Line drawing with protons

The use of proton beams in radiography has been treated several times in our pages in recent years. Two techniques have been covered in some detail (absorption radiography and scattering radioscopy) and this month we turn to a third technique which produces the remarkable 'line drawings' of objects such as are shown in the photographs.

We have reported the absorption radiography work at Argonne (see September issue 1974). Like conventional X-radiography, it uses the absorption of protons passing through different thicknesses and densities of material to give pictures with shadows and intensity variations. A particular advantage is that the rapid change in absorption near the end of the protons range produces dramatic changes in the picture related to variations in a small thickness of the object.

Scattering radioscopy is in its infancy and we reported last month the preliminary experiments at CERN. It uses nuclear scattering of the protons and the remarkable abilities of drift chambers to trace particle trajectories very precisely so that a three dimensional picture of the nuclear locations in the object can be extracted from the computer.

The third technique is the outcome of some puzzling observations which were made when higher energy proton beams became available in the 1950s. When film was used to check the beam alignment, not only did the film show the outline of massive objects such as magnets (which was expected since the magnet poles completely absorbed the protons) but also the outline of thin objects such as slivers of targets (which was not expected since the protons should pass straight through).

The reason for this phenomenon was deduced by C. Whitehead and lies simply in the realization that the protons do not, in fact, pass straight through the object, they experience some coulomb scattering from the positively charged nuclei. (Note that this is not the same as the scattering due to nuclear forces mentioned above.) If we think of a thin block of material in the path of a proton beam with a film behind it — in the geometrical shadow of the block, the protons are fanned out a little due to scattering. Beyond the edge of the block the protons pass to the film unhindered. The edge is therefore picked out because on one side, the film sees increased intensity due to direct protons plus scattered protons and, on the other side, sees diminished intensity due to less scattered protons (not supplemented, to even out the intensity, by scattering from the other side of the edge). Thus an edge appears on the film as whiter and blacker lines alongside one another.

The use of this phenomenon for radiography has been pursued by D. West and A.C. Sherwood at the Harwell 160 MeV synchro-cyclotron and at the 7 GeV proton synchrotron, Nimrod, at the Rutherford Laboratory.

The experiments showed that the edges are picked out almost regardless of the thickness of the objects. The width of the light and dark bands depends on the distance to the film, the proton energy and the density and thickness of the object. The magnitude of the intensity jump is from 1.5 to 0.5 times the incident proton intensity (which can be deduced by thinking about the scattering phenomenon).

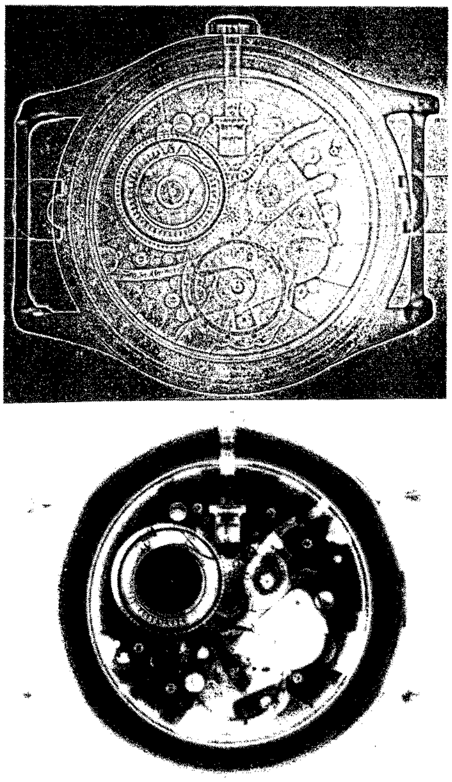
The technique is not particularly sensitive to material, energy or exposure time (which can make X-radiography so tricky). For example, the 160 MeV synchro-cyclotron beams can give good pictures of objects ranging from 16 mm thick aluminium to 5 mm thick uranium. The 7 GeV Nimrod beams can cope with 150 mm of aluminium to 50 mm of uranium. A step of between 1 and 2% in the thickness of a block of steel over a thickness range of 6 to 75 mm is detectable.

The distance of the film from the object is important. If it is too close, the eye cannot distinguish the intensity pattern. This does, however, make it possible to examine successive slices through an object by varying the film distance.

Similar experiments were squeezed parasitically into the experimental programme at the Los Alamos 800 MeV proton linear accelerator, LAMPF, just before the 'great shutdown' began at the end of last year. J. Jackson led some rapidly assembled tests using x-ray film to record the radiographs. The results were a long way from optimized but still clearly demonstrated

Photographs of objects taken using proton scattering radiography in contrast to conventional X-rays:

1. *A radiograph of a watch (watch face in contact with the film) taken in a 160 MeV proton beam with its X-ray equivalent (280 kV) below.*
2. *A radiograph of a mouse (back in contact with the film, feet 2.5 cm away) again taken using 160 MeV protons with its X-ray equivalent (22 kV) below.*



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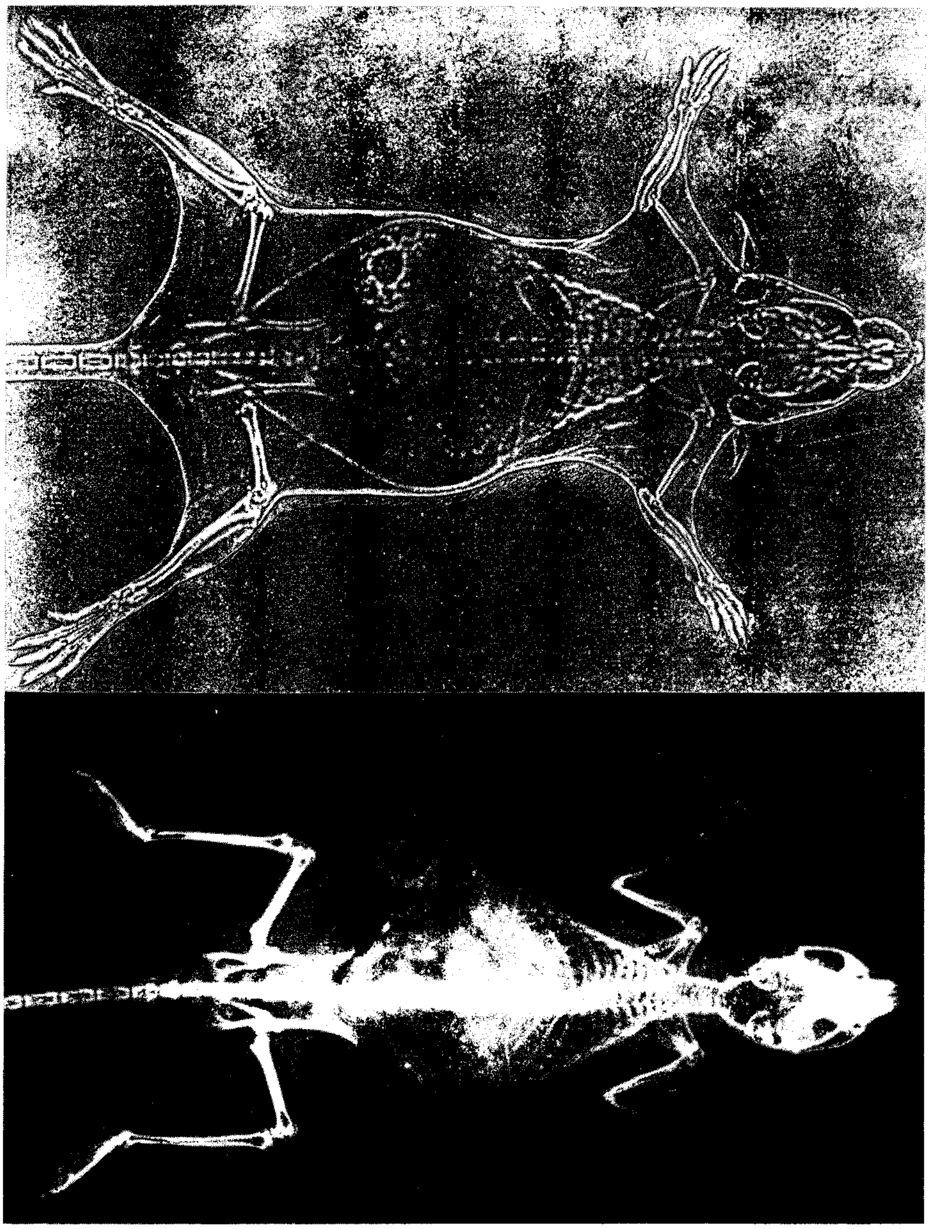

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the abilities of the technique. The Los Alamos team also think of doing the proton count electronically rather than on film so that a computer could bring out the image using much less proton flux.

The 'edge enhancement' effect can also be achieved with X-rays using a charged selenium plate rather than a film. The change in the charge distribution which the X-rays produce is made visible by dusting the plate with a fine powder. The process is known as Xero-radiography and has become widely used in the USA for breast radiography.

Proton scattering radiography has yet to assert itself as a clearly preferable alternative to the other techniques. Its features are, however, sufficiently different and its results sufficiently convincing that it will be suprising if applications do not emerge for the technique somewhere during the next few years.

Conferences

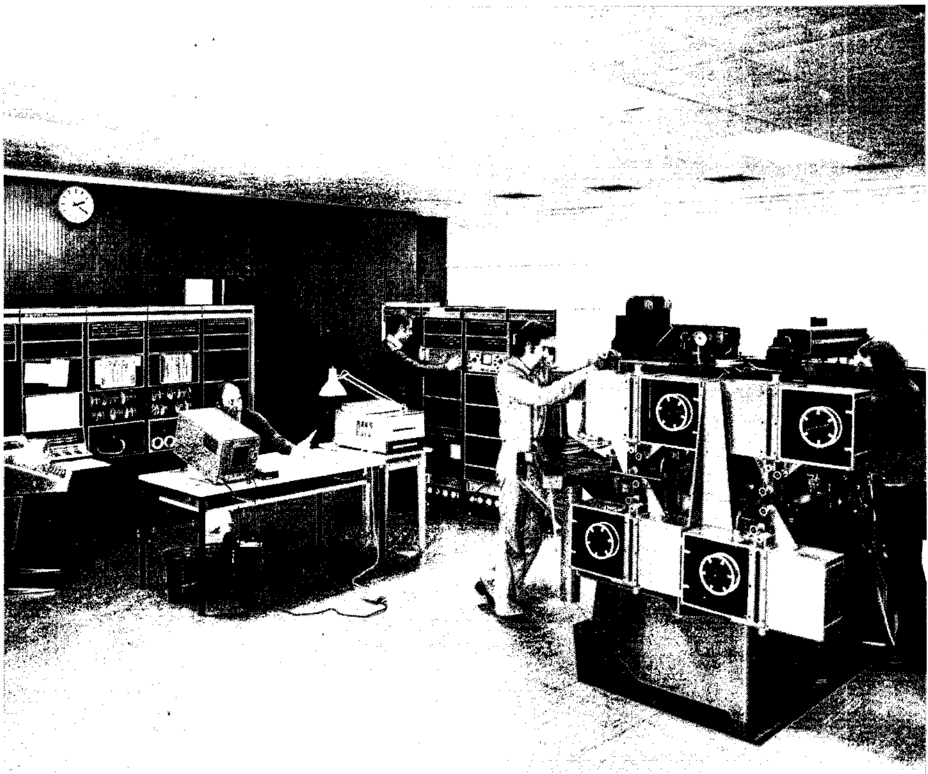
Three forthcoming conferences which may be of interest to some readers: On 25-27 November, the 'INS Symposium on Electron and Photo Interactions in Resonance Region and on Related Topics' will be held in Tokyo. Further information is available from S. Homma, Institute for Nuclear Study, University of Tokyo, Tanashi, Tokyo 88. On 22-24 April 1976, an 'International Conference on the Production of Particles with new Quantum Numbers' will be held at the Wisconsin Center in Madison. Further information is available from J.J. Kolonko, Department of Physics, 1150 University Avenue, Madison, Wisconsin 53706. On 29 June-1 July, the '1976 Topical Conference on Weak Interactions' will be held at the Univ. of Sussex, UK. Information: from L. Lawrence, Meetings Officer, Inst. of Physics, 47 Belgrave Square, London SWIX 8QX.

DESY
Four view HPD

The building of a new bubble and streamer chamber evaluation chain, based on the HPD flying spot digitizer, began at DESY in 1973. With this new chain DESY will be able to handle data reduction for all the track chamber experiments in which it will be involved.

The increased pattern complexity in the pictures from the new generation of bubble chambers, such as the 3.7 m European bubble chamber at CERN, as well as the faintness of the track images of current streamer chamber events, make it necessary to have an interactive system in measuring the tracks. Furthermore the use of discharge chambers (such as streamer chambers) in complex hybrid systems is becoming more and more common since better time resolution and higher

The four view HPD nearing completion at DESY It is a fully interactive system designed to cope with the complexities of measuring the tracks on film from large bubble chambers and from streamer chambers.



data rates are possible. This led to the consideration of a filmless evaluation chain directly coupled to the experiment but this is the 'next generation'. For 'this generation' the three crucial parameters become accuracy (because of higher beam momenta), speed of throughput (because of higher statistics), and high integration of image digitizing, track finding and rescue (because of track complexity and image quality).

With these requirements in mind, a group from DESY and the University of Hamburg has built an optical-image recognition system in which a four view HPD is the nucleus of the evaluation chain. The four view HPD is connected online to a big computer in which measuring, filtering, geometric reconstruction and patching of failed tracks will occur nearly simultaneously in time. This is a great advantage compared to the single view HPD which has two operating modes. One is the so-called Automatic Mode where nearly no measurement problems of single events are indicated to the operator; it gives measurement without feedback of all tracks in the three stereoscopic views. The alternative is the Operator Mode, where tracks are measured again if they fail certain criteria in the geometry program; in this mode the operator is able to help the filter-program via display, lightpen and telewriter/reader. This second mode proved successful in recent years because, at reasonable measuring capacity (about 20 000 events per month), the proportion of badly measured events could be kept small (10 to 15 %). Flexibility was limited, however, mainly due to the core restriction of the old DESY computer, an IBM 360/75. There are now two IBM 370/168s available and limitation of core memory is no longer a problem.

In the operation of the four view HPD it is planned to avoid a second pass for the film and, instead, to combine the Automatic and Operator modes. This is possible since the event measurements of all the stereoscopic views of the same event are made directly one after the other. With the more efficient central computer, the events can be reconstructed immediately and operator assistance for failed events can be given at once. The operator reads his information from up to four displays corresponding to all stereoscopic views. This is a necessity due to the picture quality and the complexity of events in the new chambers. As a result, faster feedback for the results is expected. It is hoped that digitizing, filtering of tracks, their spatial reconstruction and the operator's intervention can take place nearly simultaneously.

The four view HPD was designed in co-operation with the manufacturers SOGENIQUE from England, who delivered and installed the machine in September 1974. The machine can accept up to four 300 m film spools (70 mm, 50 mm, 35 mm, perforated/unperforated) and has four film transports with a speed up to 10 m/s. The standard CERN 70 mm universal film gate was replaced by a fourway horizontal fast acting film gate similar to that used at Rutherford. For highest light intensity in the scanning spot the mercury arc illumination system has been replaced by a laser system.

Installation is almost complete. In August, testing of nearly all interfacing and control electronics was finished (except for the film transport electronics). Data management and control systems in the computer (IBM 370/168 and PDP-15) have been successfully tested. Programming on the computer-computer communication as well as on the rescue system incorporating the four displays and two mini-computers is still being done. The first checks on accuracy revealed

Some idea of the complexities which present measuring systems have to face can be gained from the three photographs taken in:

1. *The CERN 2 m hydrogen bubble chamber,*
2. *The 3.7 m European bubble chamber,*
3. *The streamer chamber at DESY.*

a precision of 2 to 3 μm (in the film-plane). The performance of the digitizing procedure was tested on a variety of pictures (BEBC, 2 m HBC, DESY streamer chamber). The results indicate that the four view HPD will perform well; it will start production measurements next year.

HARVARD/ RUTHERFORD/ FERMILAB
Medical applications

The use of accelerated particles for medical diagnostics and therapy is under investigation at many research centres. We have information from three of them this month.

Among the longest used machines for medical research is the 160 MeV synchro-cyclotron at Harvard University. Such research began there in 1961 and when the machine ended its nuclear physics life in 1967 it continued to be used on a part-time basis for the treatment of patients and for other medical studies. Its operation is funded by users' fees at the rate of $1440 per 24 hour day. Operations are supervised by the High Energy Physics Committee of the Harvard Physics Department. Scientists particularly involved at the Harvard Cyclotron Laboratory are A.M. Koehler and W.M. Preston.

The external proton beam has an energy of 160 MeV (lower energies being available by using absorbers) and an intensity of a few times 10^{10} per second. It runs about 50 days per year providing protons for about a dozen institutions. Since patient irradiations started way back in 1961, over 700 people have been treated and the present rate is around 70 per year.

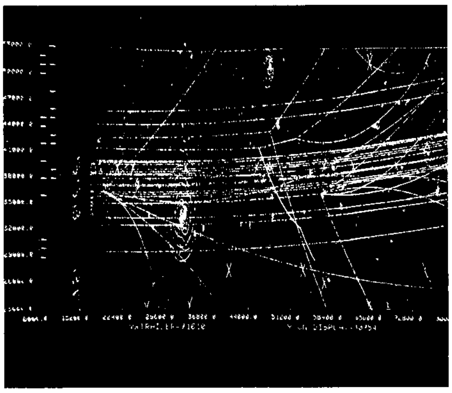
The major activity, under R.N. Kjellberg of Massachusetts General Hospital, has been irradiation of the pituitary gland using the Bragg peak of the proton beam. The aim is to suppress overactivity seen in such disorders as acromegaly or Cushing's disease. In both these cases improvement has been achieved in over 80 % of the patients treated with complete remission for over 50 %.

Proton radiography (like the work reported from Argonne in September 1974 issue) has been investigated by V.W. Steward and A.M. Koehler, including live patient radiographs. Proton radiation therapy has been studied by H.D. Suit and M. Goitein. Several patients have been treated (in conjunction with X-ray or gamma-ray therapy) and, though no broad conclusions can be reached, it has at least been demonstrated that proton beams can be appropriately tailored for such use. Other clinical work has been done on eye tumours by I. Constable.

At the Rutherford Laboratory, a beam-line at the 7 GeV Nimrod proton synchrotron has been used in studies of the medical properties of negative pions. The beam normally operates with a flux of 3 rad per minute into a 10 cm^3 volume and it is expected that this will increase by a factor of five when higher Nimrod intensities become available with a new injector in action. It was intended to build a larger aperture beam-line to take the dose rates still higher but this project is in abeyance while the future of Nimrod is uncertain.

Several medical institutions are involved in the research, particularly from St. Bartholomew's Hospital London, Glasgow Institute of Radiotherapeutics, National Radiological Protection Board and Leeds University. They have studied the effects of pions on such things as cancer cultures, thymic weight loss in mice (where the results are not in line with a much higher RBE compared to X-rays), lens opacities in mice, frozen cancer cells, and chromosome aberations in human lymphocytes (in fractionation experiments).

Prototype work on multiwire proportional chambers for specific medical applications (see for example the June issue, page 185) has reached the stage where trials are starting at Leeds General Infirmary. MWPCs for X-ray detection, 2 cm gap with 2 mm wire spacing, have been built by a small group led by D.H. Reading. It has been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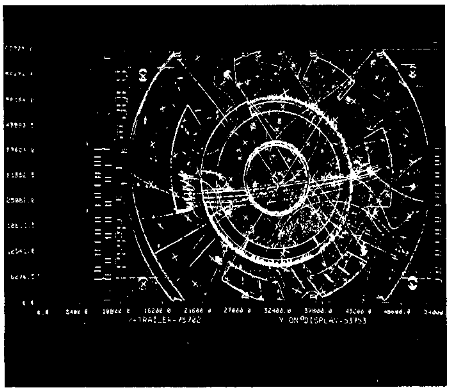
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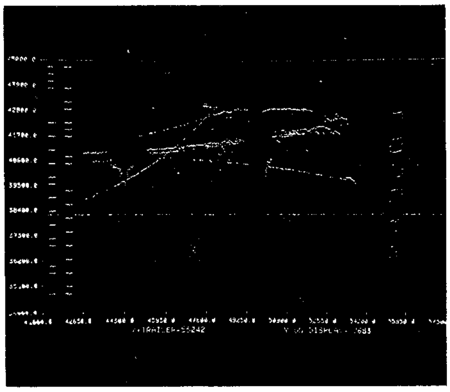
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decided to pick out a particular application following the trials and to optimise the chamber properties for that.

At the FermiLab, the first intense neutron beams into the cancer therapy facility on the linac of the 400 GeV proton synchrotron was announced on 15 August. The facility is to be used for experiments in cancer radiotherapy sponsored by the USA National Cancer Institute which has awarded a grant of $ 1 million to finance the research over the next three years. The American Cancer Society has also provided money to establish a Cancer Therapy Department at the FermiLab.

The proton beam is taken out of the linear accelerator after tank 3, emerging at an energy of 67 MeV. Neutrons are produced by bombarding a lithium target. Irradiations of 1 rad per second at 1 m from the target should be possible. (Incidentally, the rad has been replaced this year as the SI unit of absorbed dose by the Gray, Gy, the absorption of 1 joule per kilogram. What has been happening to units over the past few years is enough to make anything turn Gray.)

Work continues to optimize the beam quality and experiments will begin on bacteria, tissue culture systems and small animals to investigate the destructive ability of neutron beams on cancer cells and the effect on surrounding normal tissue.

GANIL authorised

At the beginning of September it was announced that construction of the heavy ion accelerator, GANIL, has been approved in France.

The project will be financed equally by the Commissariat à l'Energie Atomique (CEA) and by the Institut de Physique Nucléaire et de Physique des Particules (IN2P3). The total cost is 250 million French francs. The accelerator will be built at Caen, 200 km west of Paris near the Laboratoire de physique corpusculaire.

Construction is to start right away, in the context of the boost to the French economy, and 25 million francs have been allocated for 1975.

CERN ACADEMIC TRAINING PROGRAMME
(1975-1976)

This Programme is organized each year by the Academic Training Committee. Details may be obtained from the Training and Education Service, CERN, 1211 Geneva 23 (Tel. 022/ 41 98 11 Ext. 2844). The programme for each term will be published in the CERN COURIER (September, December and March issues).

1st Term (October to December 1975):
Survey of the CERN Research Programme

October 21 — 09 h 00	Introductory remarks by W. Jentschke
09 h 15	Electronic experiments by A. Astbury
11 h 00	Bubble chamber experiments by D.C. Colley
14 h 30	SC and Isolde programme by V. Soergel and P.G. Hansen
16 h 30	Theory by S. Fubini
October 22 — 09 h 00	The SPS by H.O. Wüster
10 h 30	SPS experimental programme by J.V. Allaby
14 h 30	ISR experiments by U. Amaldi

Lecture Series *

October 29, 30 & 31	The new particles (for non-physicists) by P. Sonderegger
November 4, 5 & 6	Electroproduction by P. Söding
November 11, 12 & 13	Corrosion and protection of metals by M. Brabers
November 18, 19 & 20	Multiparticle production by M. Le Bellac
November 25 & 27 December 2, 4 & 9	Accelerators by E.J.N. Wilson
November 26 & 28	Direct production of leptons in nucleon-nucleon collisions by L. Di Lella

* 11 h 00

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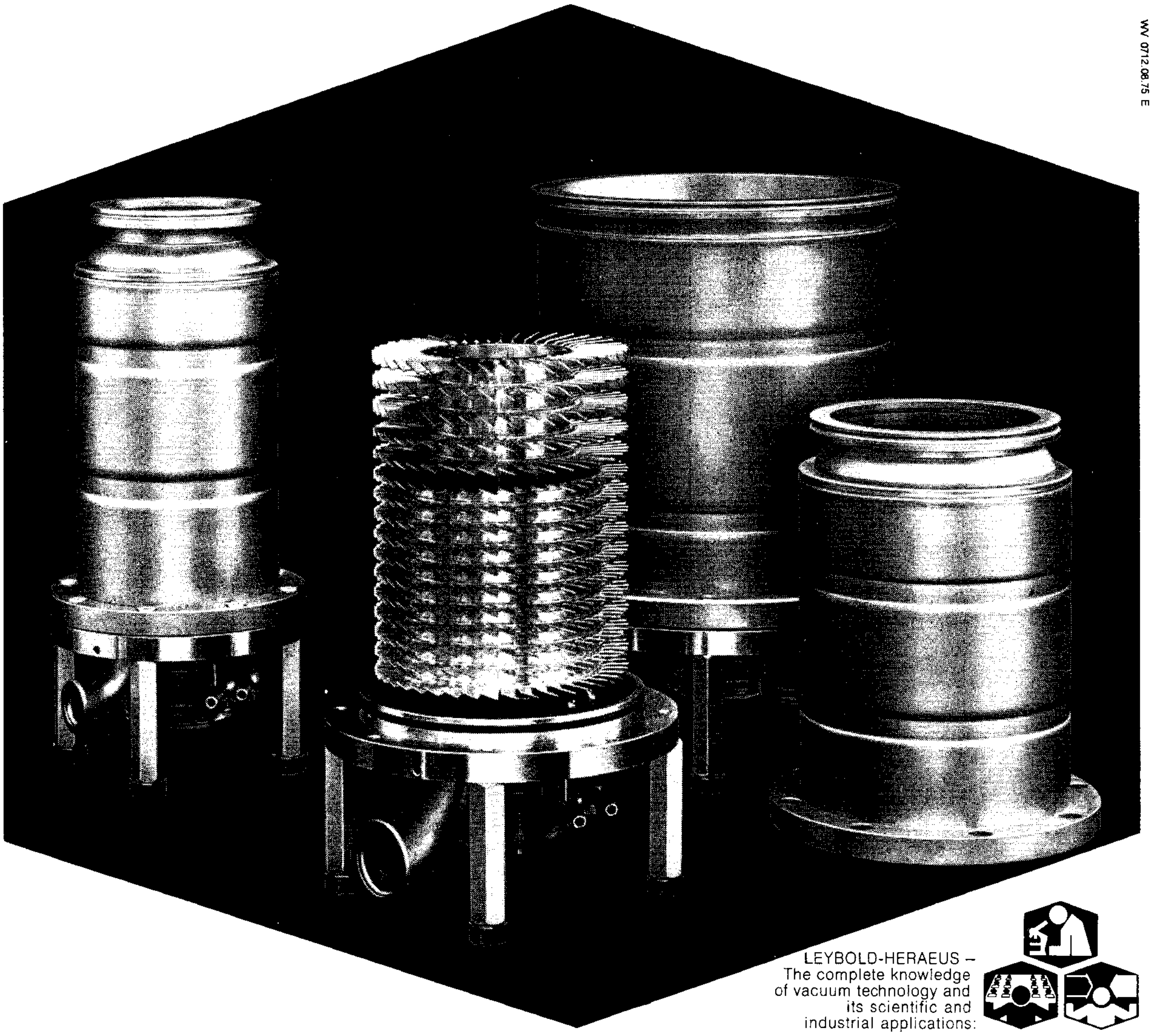

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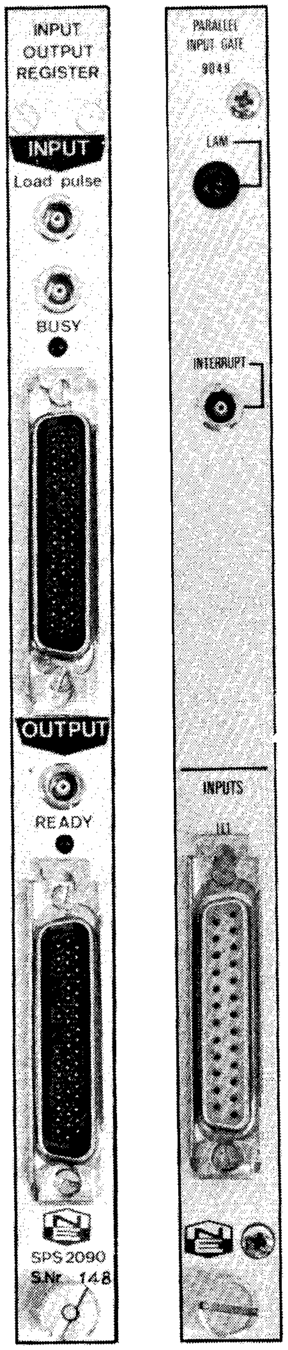

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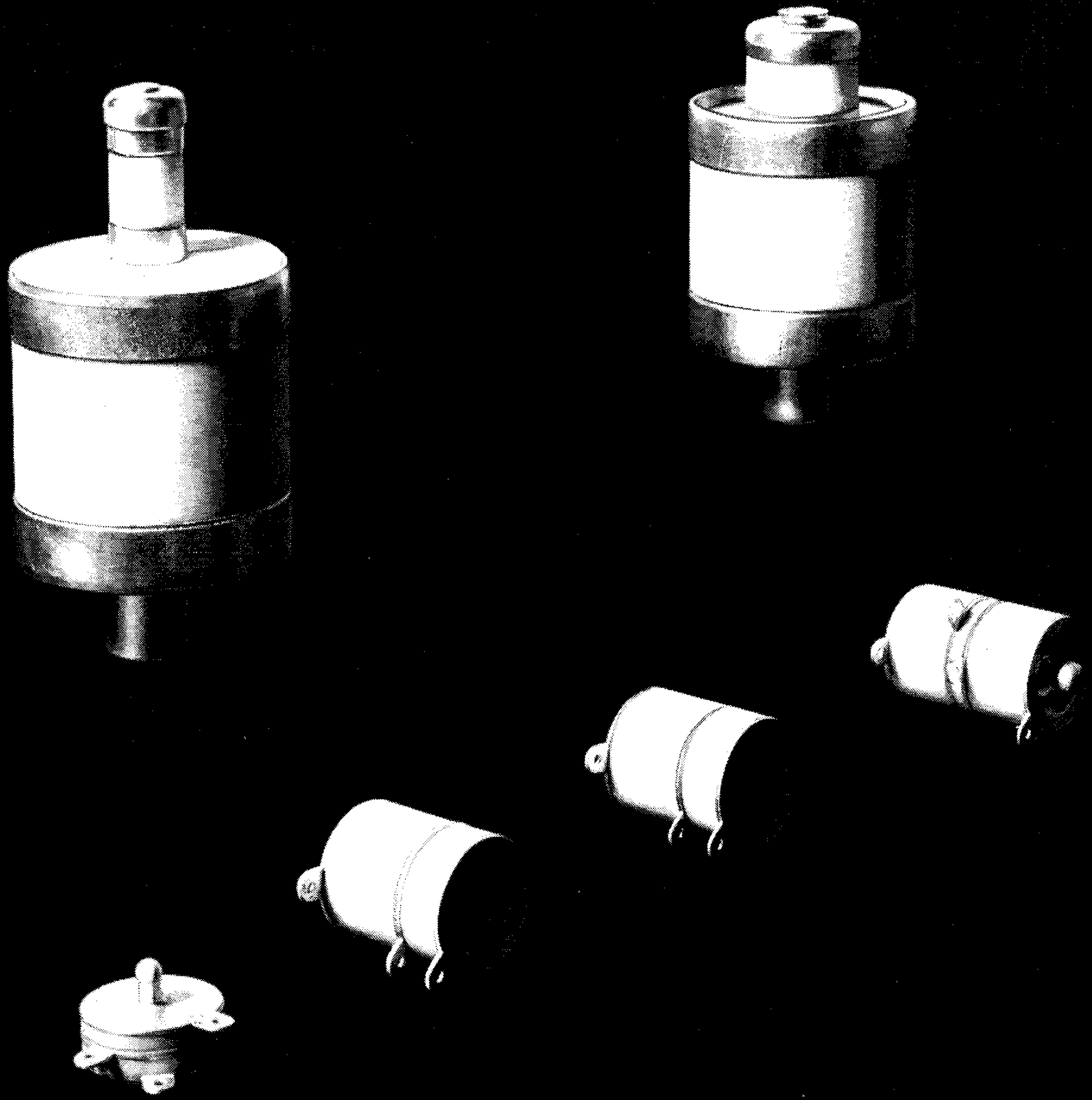

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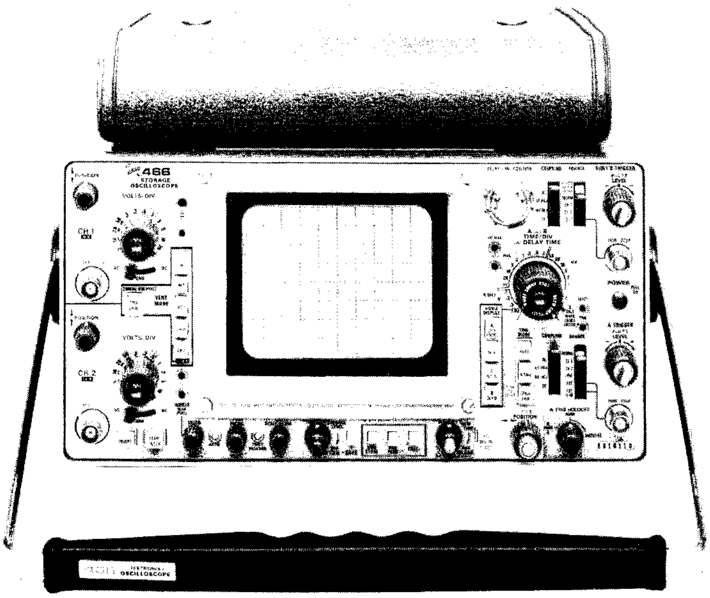

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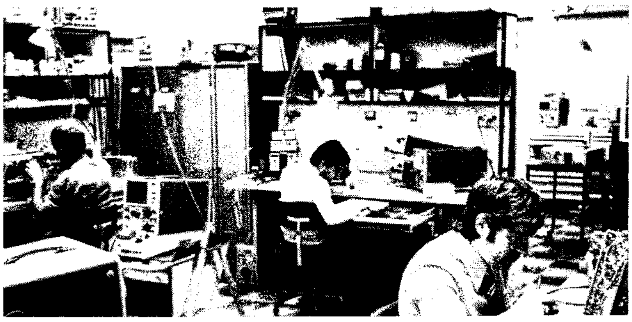

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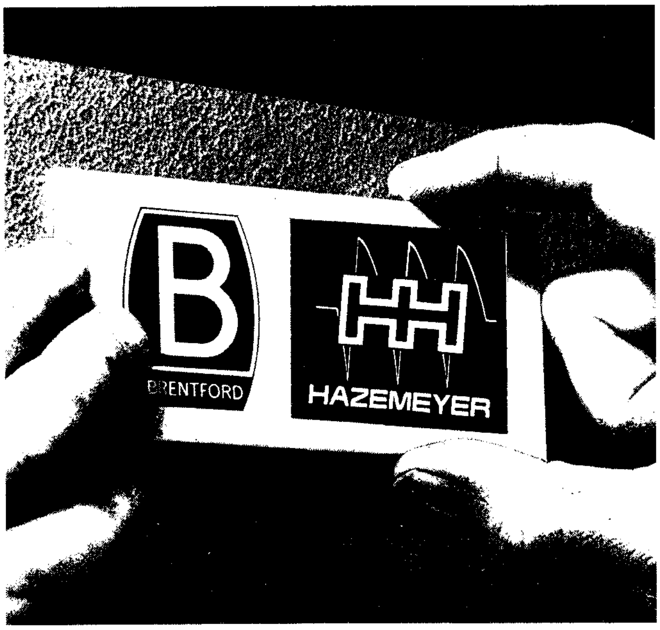

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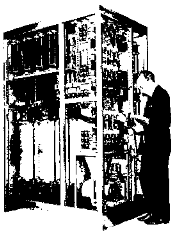

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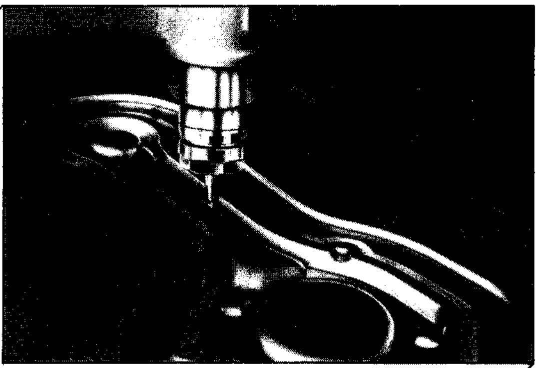

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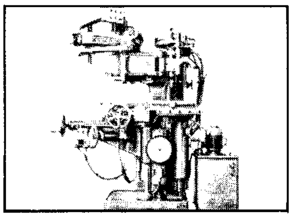

Que vous ayez à réaliser des moules, matrices ou outils similaires – que vous ayez à usiner des métaux, matières plastiques ou d'autres matières – que vous ayez à copier symétrique, à réduire ou à agrandir des pièces de petit ou de grand volume, en creux plat ou profond, aux formes raides ou tendres: les machines KF de Deckel, variables et adaptables à volonté, vous offrent tout le raffinement technique pour un usinage rentable.
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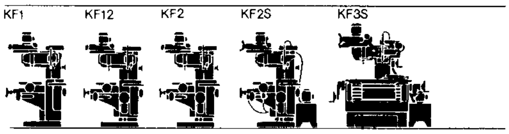

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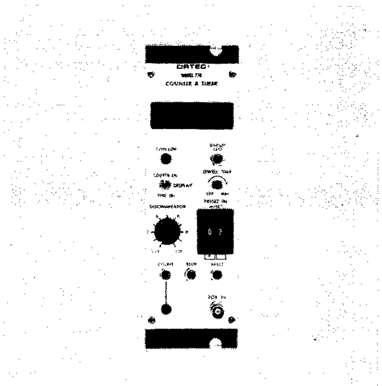
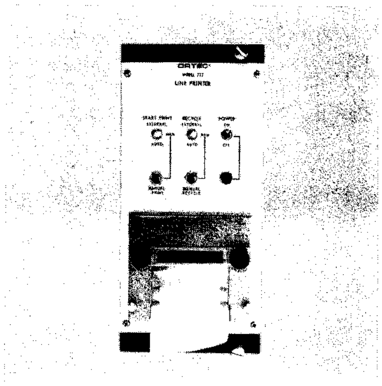
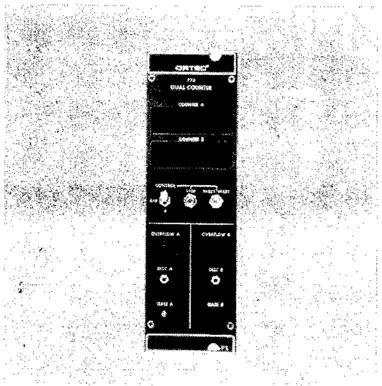


Simultaneous Timer & Counter operation, or as 2 counters.



Parallel Line Printer & printout controller. Prints 3 Lines/sec.



For dual and comparative counting. Print capability. + or — inputs.

NUCLEX Basel Oct. 7 — 11, 1975. Hall 6, Stand 233

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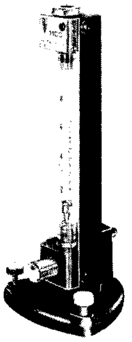

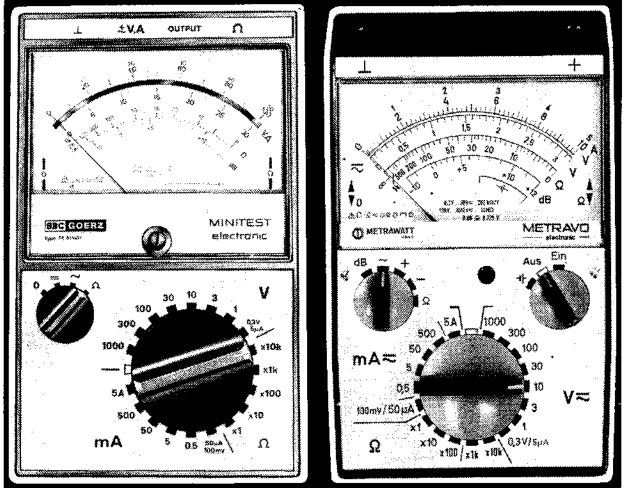
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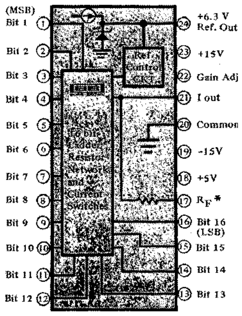

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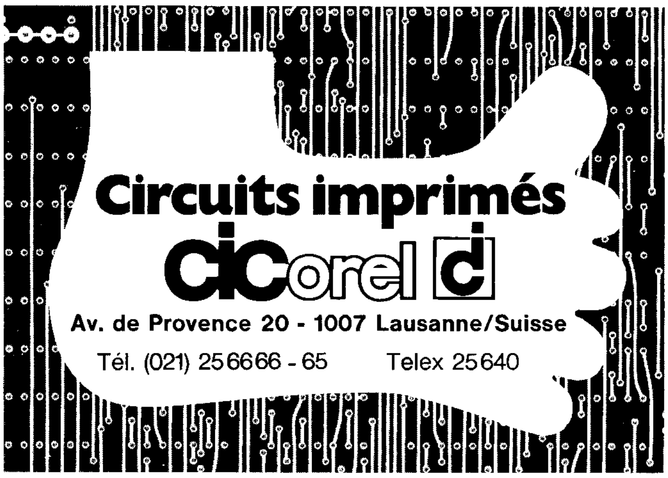

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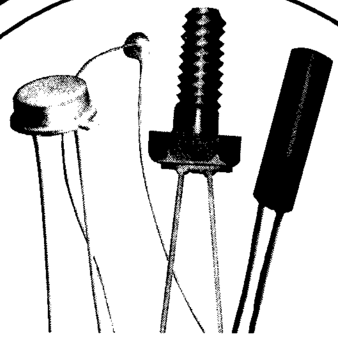

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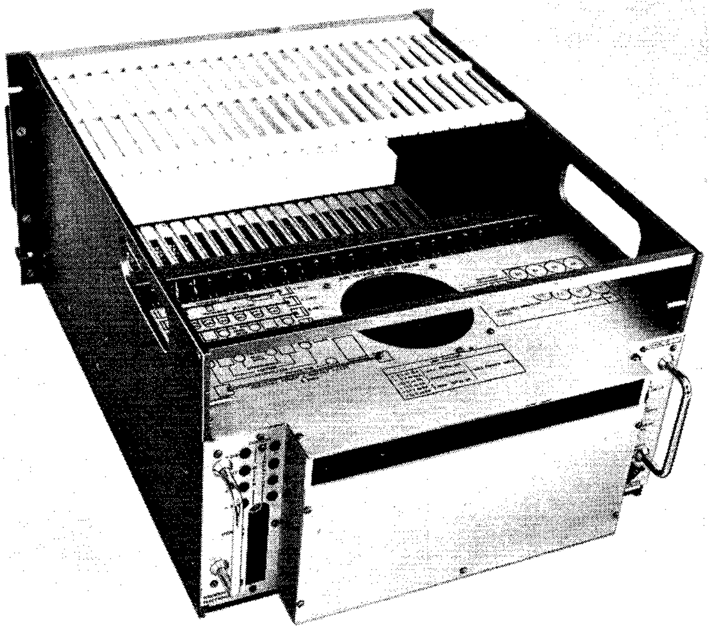

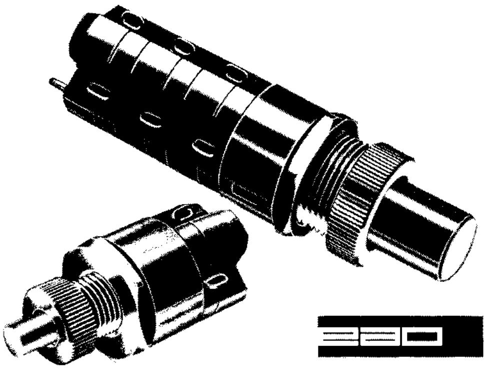

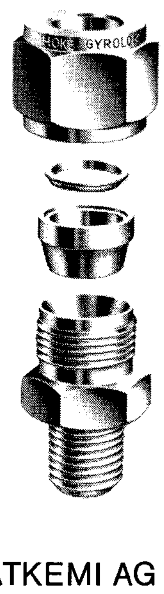
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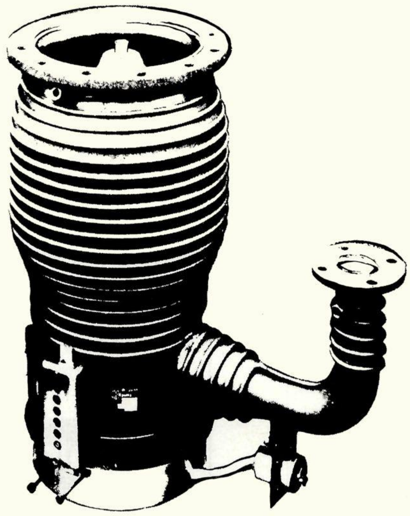

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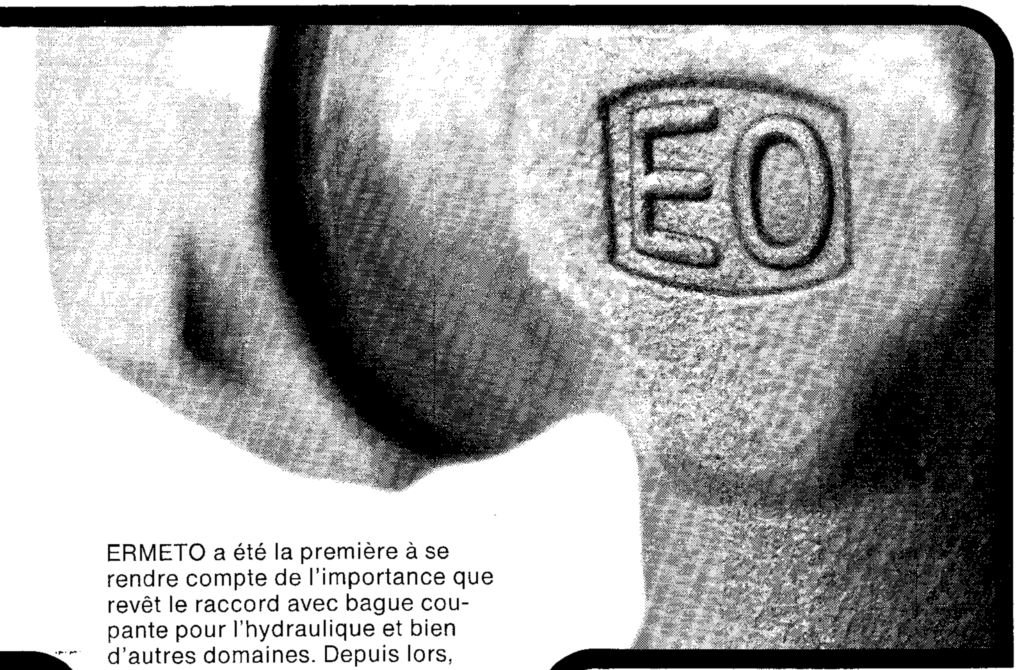
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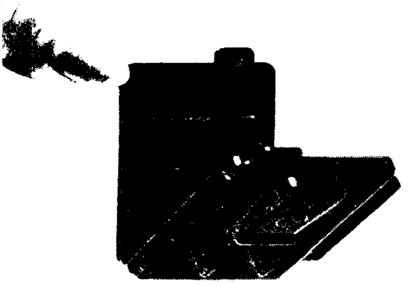

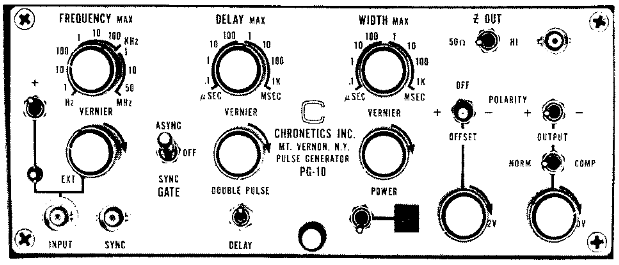
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100 10 1 Hz
1 10 50 MHz
VERNIER
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SYNC
ASYNC
OFF
SYNC GATE
DELAY MAX
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.1 1 10
μSEC MSEC
VERNIER
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DELAY
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.1 1 10
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Z OUT
50Ω HI
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OFFSET
2V
POLARITY
+ −
OUTPUT
NORM COMP
5V

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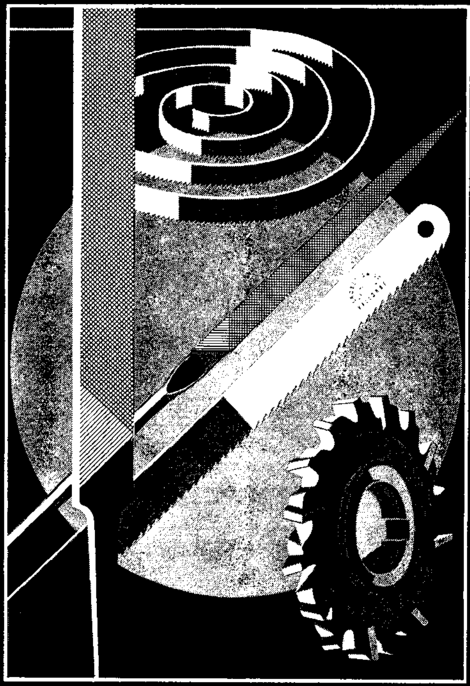

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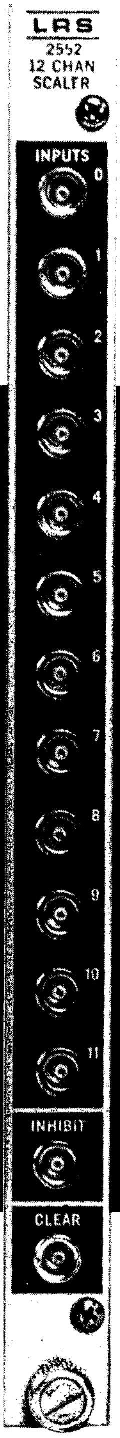

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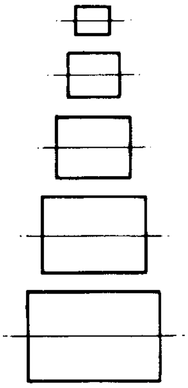
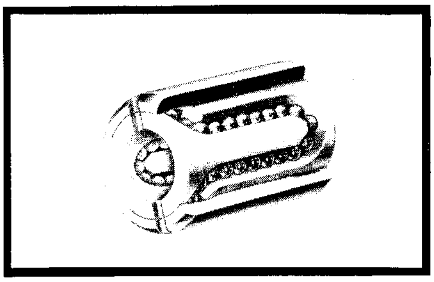
The Model 2552 features:

LRS

Kugellager für Längsbewegungen

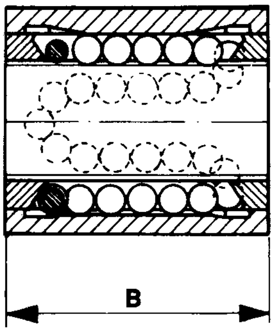
Wirkliche Grössen

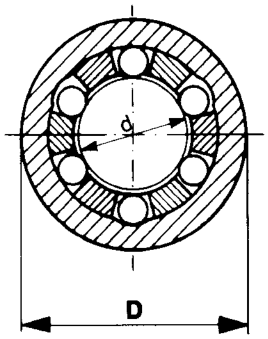




Hauptmerkmale

- Hohe Genauigkeit
- Exakte Führung
- Gute Funktionssicherheit
- Weicher Lauf
- Kleine Reibung
- Unbegrenzter Weg
- Hohe Belastbarkeit
- Rostbeständig und gehärtet





Zulässiger Pressitz: 1 bis 3 µm

Masse in mm, Toleranzen in µm

Bezeichnung	Kugellager Tol. d $^{+8}_{0}$	Welle Tol. d $^{0}_{-6}$	D Tol. $^{0}_{-10}$	B	Kugel ∅	Statische Tragzahl Co in Kp
L 204	2	2	4	5	0,60	0,8
L 306	3	3	6	7	0,794	1,4
L 408	4	4	8	10	1,15	2,9
L 510	5	5	10	14	1,588	7,4
L 612	6	6	12	18	1,588	11,4

Roulements Miniatures Bienne

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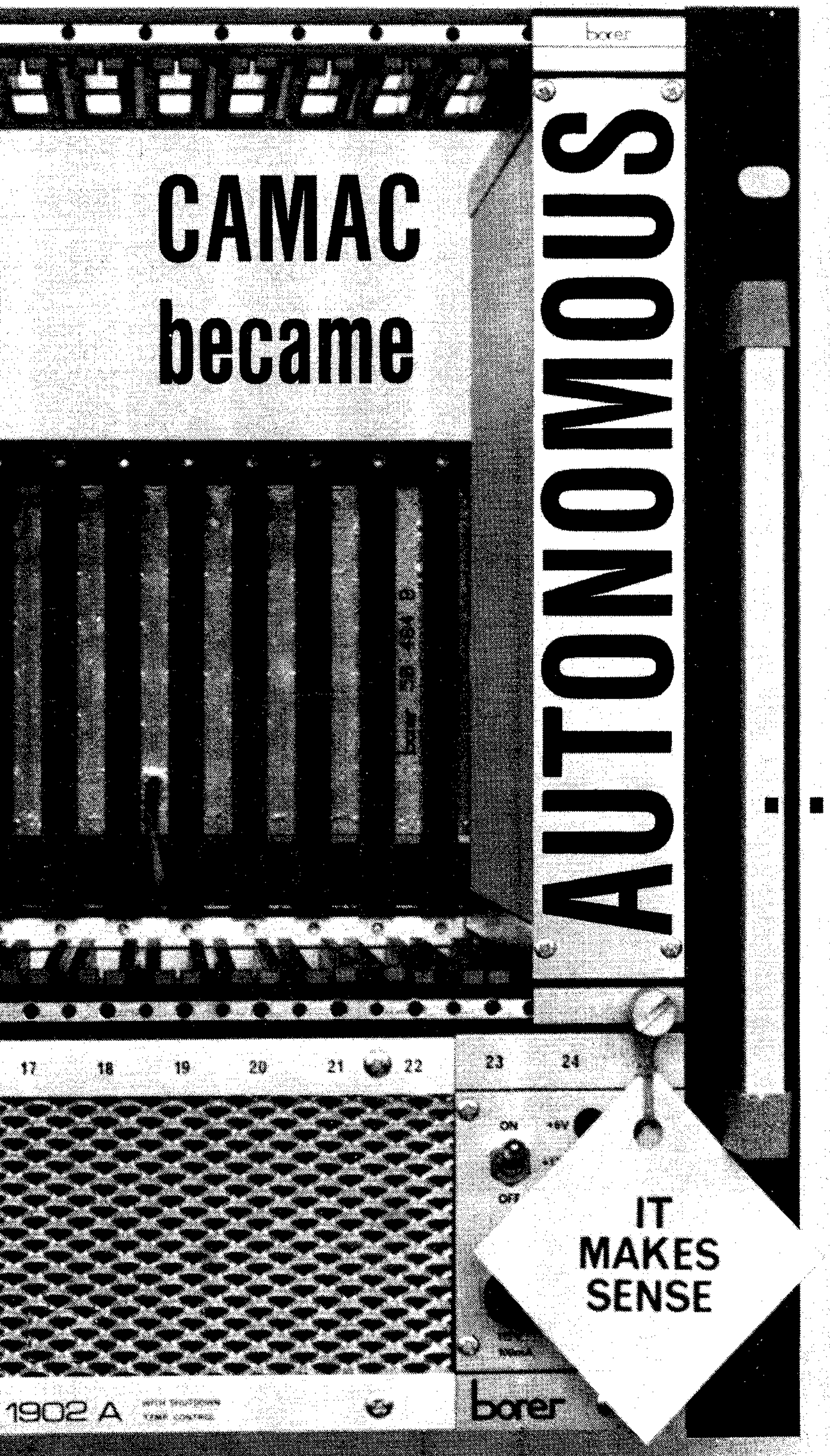
KEM – 2 weitere Informationen



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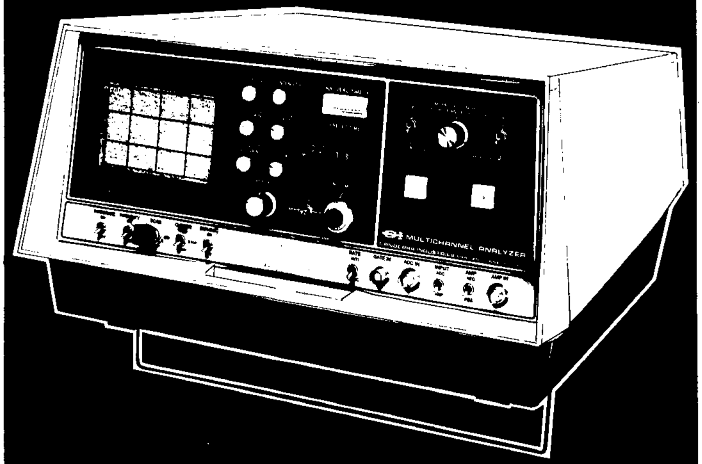

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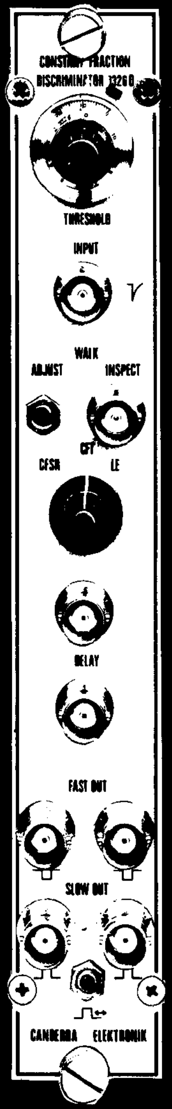
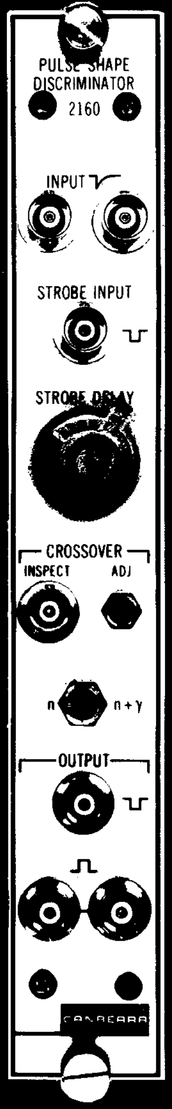
NEW NIM MODULES



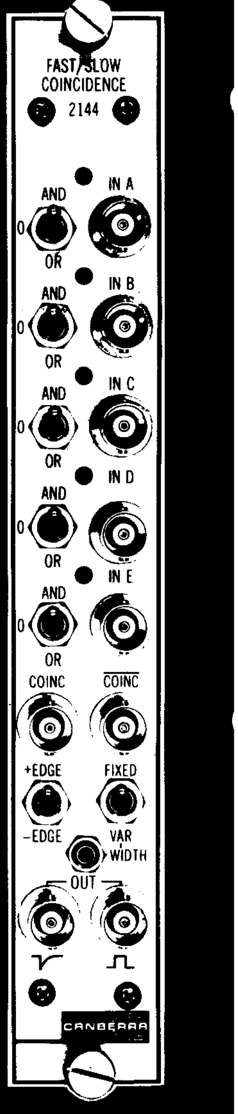
1326 D

The high countrate Constant-fraction-Discriminator DC coupled



2160 D

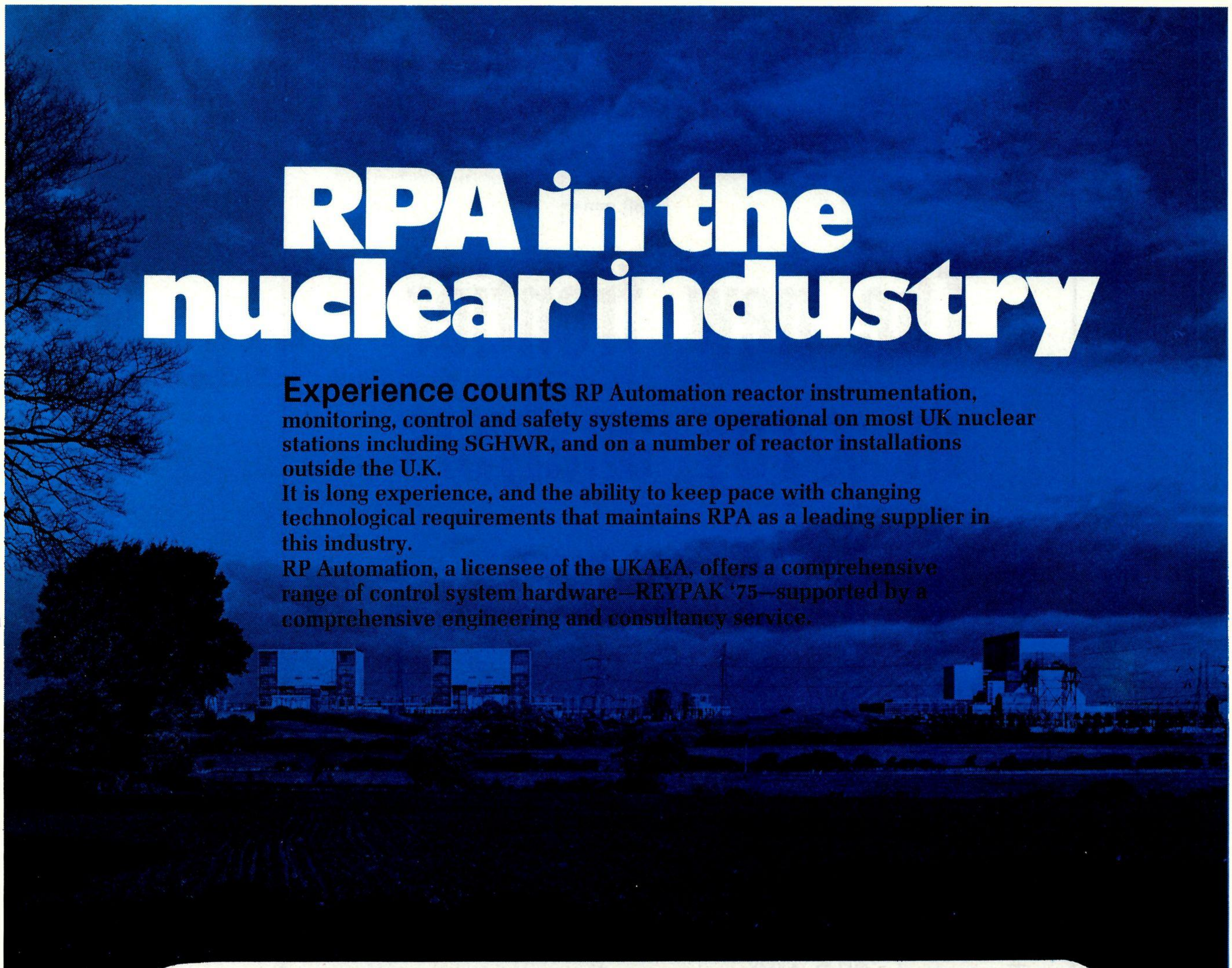
The pulse-shape-Discriminator DC coupled



2144 D

The Coincidence that mixes fast- and slow NIM logic DC coupled

Designed and manufactured in Munich, Germany



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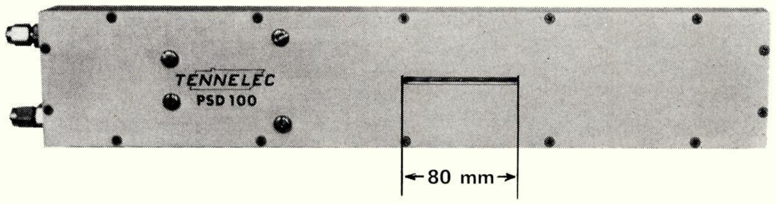
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