CERN COURIER

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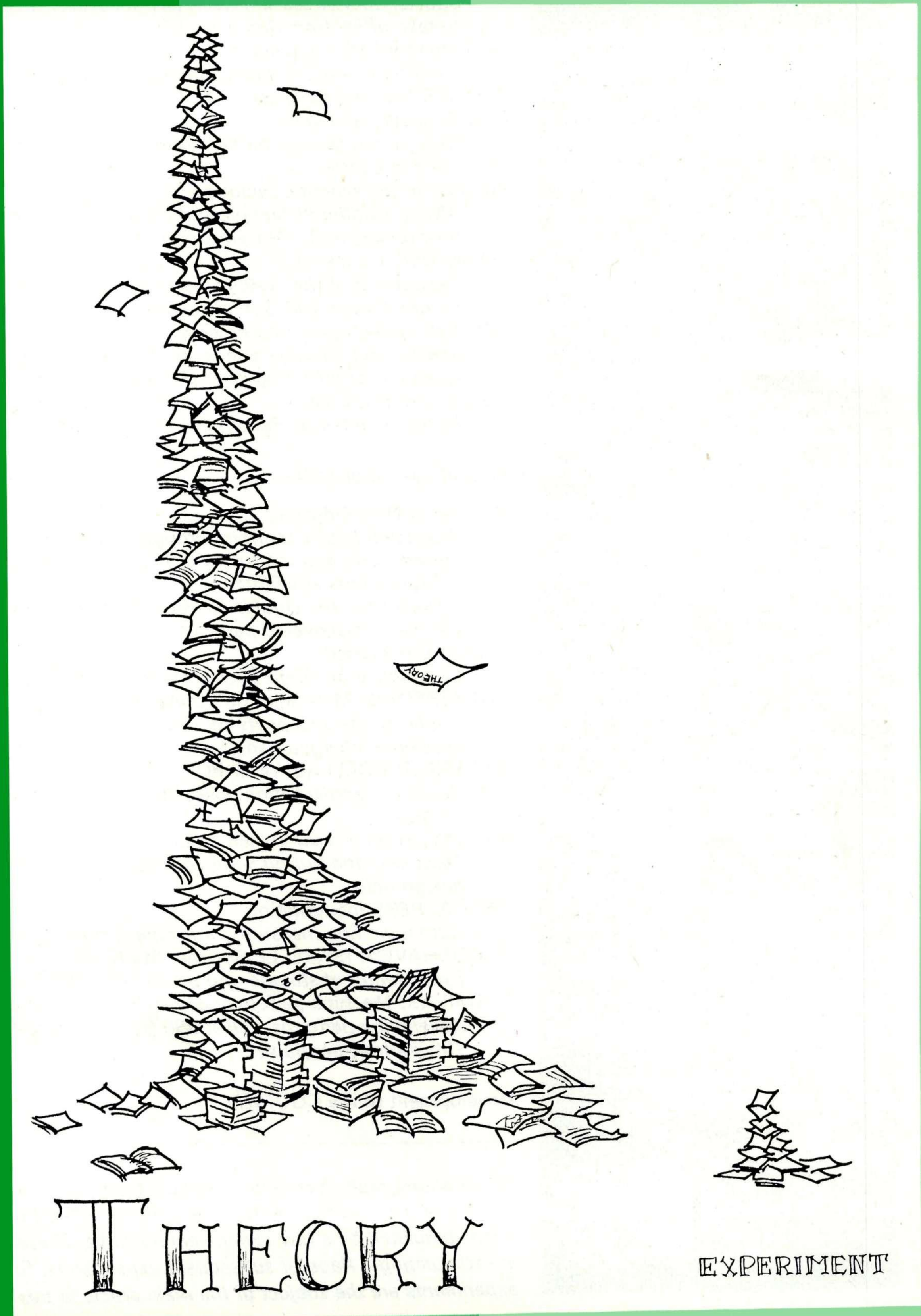

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, 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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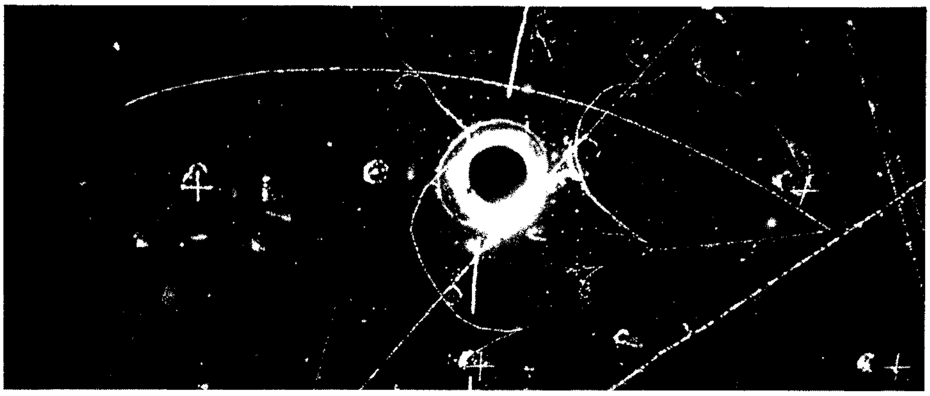
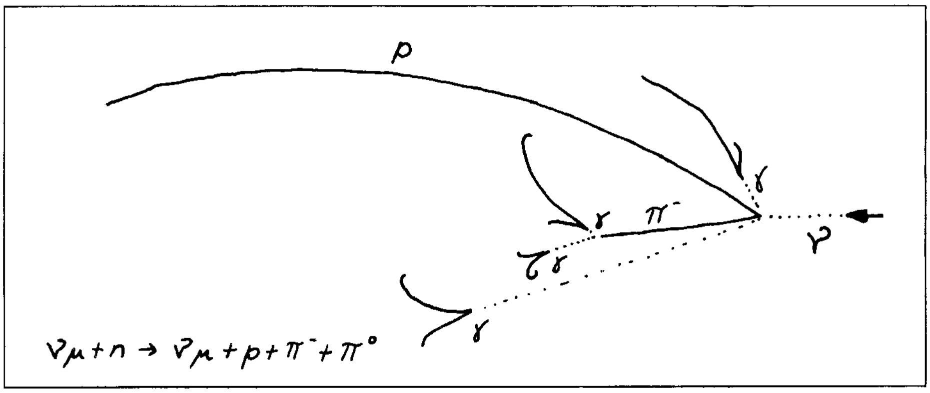
Cover photograph: A reflection of high energy physics at the present time (from an idea of J.D. Jackson at Berkeley) where a flood of theoretical ideas has been stimulated by a few experimental results. These ideas in their turn are stimulating a flood of subsequent experiments. Some of the ideas and experiments are the subject of the main article in this issue.

Charming

We have observed a very sharp peak in the number of theoretical papers attempting to make sense of the world of particles. They have been stimulated by the discoveries at the high energy accelerators in the past two years which have opened up completely new interpretations about the fundamental components of Nature and their behaviour. These interpretations in their turn have pointed in a multitude of directions, where experiments can look to give important further input so as to select those interpretations which are going along the right lines.

This article will touch on some of the main ideas which have emerged and report some of the experiments which are attempting to check them. It is hard to give a thorough review when so much is going on but we will try to get across some of the humming excitement which pervades high energy physics at the moment.





One of the events that started the ball rolling. A neutrino, coming from the right interacts with a neutron in the Gargamelle bubble chamber at CERN and does not give a charged muon emerging. It revealed the existence of 'neutral currents' in weak interactions. The fact that neutral currents do not seem to operate in other interactions, where they are expected, has promoted the idea that another particle property, called charm, is intervening.

The neutral current route to charm

Completely fresh insights in particle physics came in 1973. They added significantly to the picture of how Nature behaves rather than just further decorating the existing one.

On the experimental side, things began with the discovery at CERN of the existence of neutral currents in weak interactions. We have covered this topic many times before (see for example May 1974, page 165). In essence, it means that when particles interact by the weak force, the leptons involved (particles which do not feel the strong force) need not change the sign of their electric charge. Thus a neutrino interacting with a proton can remain as a neutrally charged neutrino and not convert (as it more usually does) to a negatively charged lepton. The interpretation of what is happening in such a neutral current interaction is that a neutral particle (called the neutral intermediate boson or Z°) passes between the neutrino and the proton communicating the weak force from one to the other. With the more common charged currents, the communicator is a charged particle (charged intermediate boson or $W^{\pm}$).

On the theoretical side, this tied in nicely with theories about the weak interaction which were then maturing. These theories tried to extend to the weak force the basic ideas which work so brilliantly in understanding the electromagnetic force. (Those interested in absorbing this in more detail could try the May issue of last year.) They weld the weak and electromagnetic interactions together as being different manifestations of the same phenomena. This is in itself philosophically satisfying since the separation of Nature's behaviour under the headings of four separate forces (adding the strong force and gravity) was never a happy situation. In addition, the theories required the existence of neutral currents (and/or heavy leptons) which added to the joy of the experimental discovery of neutral currents.

But the discovery of neutral currents opened Pandora's box in another direction which has led to the present furore. If the weak force can manifest itself via neutral currents, then other neutral current interactions besides the neutrino ones should be seen. A particular example, is the decay of the neutral kaon into two muons. This has been carefully looked for but not seen at the rate expected for the direct decay (it has only been seen at a much lower rate which corresponds to the kaon going to two gammas with muons then coming from the gammas). What is stopping this decay?

When our existing knowledge tells us that something can happen and it does not happen, we invent a mechanism which would stop it. This has worked well in the past. For example to explain why the kaon is such a stable particle and to explain why it is produced in some interactions but not others (which previously looked equally good), we say that the kaon has an additional property, called strangeness. The very name indicates how out of the ordinary the property appeared when it was proposed. Strangeness either completely prevents (in the strong interactions where the kaon is produced) or considerably inhibits (in the weak interactions where the kaon decays) the particle being involved in some interactions.

This idea is so crucial to what follows that we will come at it in another frivolous way. Supposing the animals in our everyday world interacted as particles do — transforming and breaking up from one configuration to another in an ever changing pattern. Watching these antics from afar, intelligent beings might make observations such as we make for particles. They might remark that interactions occur such as a dog with a camel producing a cat and a horse, or a mouse and a cow, etc.... but never two cats and a horse, or a hydra. Intelligent beings could deduce from this that heads were always conserved in the interactions — if two heads go into the mix, only animals totalling the same number of heads could emerge.

They might then be puzzled as to why it was not possible to produce a cat and a man, or a centipede and a horse since both interactions would conserve the 'headiness' property. They might then postulate another property, 'legginess', which also has to be conserved. Thus

dog + camel → cat + horse

can work since the postulated number of legs adds up the same at both ends of the interaction but

dog + camel → cat + man

does not. Even though the heads come out right, the legs do not and the interaction cannot go.

Returning to our kaons — a pion interacting with a proton cannot produce a kaon since neither of them have this property of strangeness. The only way a kaon can come out of the interaction is for another particle, such as the sigma, carrying the opposite strangeness property to be produced at the same time (called 'associated production'). In expressing these properties mathematically we say that the positive kaon has strangeness quantum number + 1 and the sigma has strangeness quantum number −1.

When the kaon breaks up under the influence of the weak interaction, the strangeness property can be lost (not conserved) but it is a struggle to get shut of strangeness and because of this the kaon takes over a million times longer to decay than equivalent particles.

For the decay into two muons which should happen, since we now know neutral currents exist, perhaps there is yet another property which inhibits decays. The postulated property has been given the name 'charm'.

By introducing the property of charm, S.L. Glashow, J. Iliopoulos and L. Maiani were able to deduce that weak interactions mediated by neutral currents and involving a change of strangeness (such as the two muon decay of the kaon) cannot occur. This is the simplest way out of the difficulties though not the only one that has been thought of.

Proliferation of quarks

Let us suppose that charm is for real. What does it do to our picture of the particles?

We had a convincing picture of the hadrons (all those particles like the proton, the kaon, etc.... which feel the strong force) as being built out of three components, given the name quarks. Both the 'spectroscopy' of the particles — the way in which the relationships of their properties fitted orderly patterns — and the observations of how they scattered projectile particles, indicated clearly that there are constituents in the hadrons (see October issue 1974, page 331).

None of these constituents has been seen in isolation at the energies with which hadrons have so far been investigated but this does not perturb the theoreticians who have concocted models of the hadrons which 'confine' the quarks getting them to cling together so firmly.

The three types of quark we will call Q_p (proton-like with electric charge $+{}^{2}/_{3}$), Q_n (neutron-like, charge $-{}^{1}/_{3}$) and Q_λ (strange or lambda-like, charge $-{}^{1}/_{3}$ and strangeness). By shuffling them together in different ways all the known hadrons can be assembled. Thus a proton can be built up from two Q_p quarks plus a Q_n quark; a neutron from two Q_n quarks plus a Q_p quark a lambda from a Q_p a Q_n and a Q_λ quark, a positive kaon from a Q_p quark plus a Q_λ antiquark and so on.

This works beautifully and doing mathematics on the basis of such quarks gives remarkable agreement with many experimental measurements on particle behaviour.

Complications begin when considering the quantum states or energy states in which quarks can exist. It is a deep seated principle (Pauli exclusion principle, named after W. Pauli its proposer) that you cannot have two identical particles in the same state. (This all started with the atom — if we describe two orbiting electrons as being in exactly the same state, we are just describing a single electron twice.) Thus the two Q_p quarks in the proton must have something different about them. Searching for a name for this property, we come up with 'colour' and the hypothesis is

Our present picture of the basic (?) constituents from which all the hadrons (all the particles which feel the strong force) are built up. Baryons have constituents such that the total baryon number is equal to 1 — for example, the proton is made up of Q_p Q_p Q_n which gives its single positive charge with no strangeness and no charm. Mesons have constituents such that the total baryon number is equal to 0 — for example, the negative kaon is made of Q_λ $\bar{Q}_p$ ($\bar{Q}_p$ being the antiparticle of Q_p with all the properties of opposite sign) which gives its single negative charge, strangeness and no charm.

The quark constituents of the hadrons	Some of their major properties				Each exits in three "coloured" forms
	Charge	Baryon Number	Strangeness	Charm	
Q_p - proton like	2/3	1/3	0	0	Q_p(red) Q_p(white) Q_p(blue)
Q_n - neutron like	-1/3	1/3	0	0	Q_n(red) Q_n(white) Q_n(blue)
Q_λ - lambda like or strange quark	-1/3	1/3	1	0	Q_λ(red) Q_λ(white) Q_λ(blue)
Q_c - charmed quark	2/3	1/3	0	1	Q_c(red) Q_c(white) Q_c(blue)

that each quark exists in three coloured forms (say red, white and blue). These words have only been dreamed up to indicate a difference in property — in no way do they mean that quarks are actually tinted and that particle interactions are psychedilic happenings).

Now, the proton can be made of Q_p (red), Q_p (white) and Q_n (blue) without violating the exclusion principle. Our familiar particles are those for which colour is averaged out but it is not impossible that colour is behind some of the mysteries of the newly discovered particles that we will discuss shortly. However, the colour interpretation is not the one we are leaning on here so we will leave it aside.

Now we bring in the additional property of charm by increasing the number of quarks. Adding a charmed quark, Q_c, to our list, leaves all our spectroscopy information untouched and also the scattering information untouched since we say that Q_c is not a component of the well-known particles. This is a good start because the previous quark picture was working well and it would hurt to abandon it.

We should mention that the idea of an additional type of quark is not new. Ten years ago, it was put forward by several theoreticians, though for very different reasons (such as an attempt to construct the known particles from quarks with integral charges rather than charges which are a multiple of 1/3 of the charge on the electron).

The introduction of Q_c makes it possible to build still more particles and these particles will show distinctive behaviour.

The significance of the new particle discoveries

Let us go back to what experiments have unearthed to see why the spotlight now shines even more strongly on charm.

The dramatic discoveries (see December issue 1974) at the Brookhaven double spectrometer and the Stanford electron-positron storage ring, SPEAR, were initially a complete mystery. Particles were found with three times the mass of the proton and yet remarkably stable. It is now the favourite theory that the 3.1 GeV particle is built of a charmed quark and a charmed antiquark (Q_c $\bar{Q}_c$). The combination is sometimes called 'charmonium'.

(M.B. Einharn and C. Quigg of the FermiLab had a bit of fun by selecting the word 'panda' rather than charm for the new property — 'We chose this name because of the panda's well-known shyness and tendency to stay among his own kind. The great mass of the giant panda has also influenced our thinking.' This enables them to call the 3.1 GeV particle 'pandamonium' which is a fair reflection of its impact on the world of high energy physics.)

A similar case involving the strange quarks is already well documented. The phi meson is surprisingly heavy and surprisingly stable compared with its relatives the omega and rho mesons. The phi is built up of Q_λ and $\bar{Q}_\lambda$. (There is incidentally, no deep understanding of how quark and antiquark can live together without annihilating one another but such systems are not unfamiliar — back in atomic physics the electron and positron were known to live orbiting one another for a short time in the positronium system.) With a mass of 1 GeV it has difficulty breaking up into two kaons (mass about 0.5 GeV) and yet this is the way it likes to decay in order not to loose the property of strangeness carried by its two component quarks. It does not like to go to pions which carry no strange quarks. Hence its stability. Note that the phi itself does not show strangeness — the quark and antiquark cancel strangeness out and the phi is said to have 'hidden strangeness'; only when it splits to the two kaons does the strangeness become apparent.

In the same way it is suggested that the new particles, at 3.1 GeV and 3.7 GeV, have 'hidden charm'. The 3.1 GeV is (Q_c $\bar{Q}_c$) and the 3.7 GeV is (Q_c $\bar{Q}_c$) plus some other quarks. It seems that the charmed quark is significantly heavier than the others and that the particles built out of Q_c will be heavy. Thus the charmed mesons into which the 3.1 GeV might decay (carrying charm in evidence rather than hidden — like the kaons from the phi carrying strangeness) are probably too heavy for the decay to be possible. This would explain the great stability of the 3.1 GeV particle. It has been seen going into lepton pairs but it is not fond of this decay since it has to do away with charm (just as the phi is reluctant to go to pions and do away with strangeness) and hence hangs around a long time before breaking into leptons.

Here we can get a first stab at the mass of a charmed particle. Neither the 3.1 GeV nor the 3.7 GeV (which goes to 3.1 GeV plus pions) decays readily into two charmed mesons usually called D particles. Thus the D must be greater than ½(3.7) GeV in mass. However, at the Stanford SPEAR storage ring a more blurred peak has been found around 4.1 GeV indicating a particle of much less stability. This is possibly another variant of (Q_c $\bar{Q}_c$) plus other quarks but this time having enough mass to decay into two charmed mesons. We can therefore pitch the D particle mass at below ½(4.1) GeV, that is around 2 GeV.

Coming at the D mass by theoretical calculation also lands us in the 2 GeV ball park. Knowing that particles exist at 3.1 GeV and 3.7 GeV makes it possible to calculate others just as it was possible in the 'old' particle spectroscopy tables to predict other masses when some were known.

Layman's guide to finding charmed particles

How are we going to identify particles with charm? First of all, the existence of a new quark will mean the existence of new particles which will not fit into the particle classification schemes that we have so successfully built up on the basis of three quarks. There are two possible groups of particles — charmed mesons like the Ds where Q_c is joined to another antiquark or $\bar{Q}_c$ is joined to a quark, and charmed baryons, where Q_c replaces one of the more familiar quarks in the known baryon configurations. We would see them via unusual features when such mesons or baryons decay.

i) In the decay, which goes by the weak interaction, charm need not be conserved (just as strangeness can, with an effort, be lost in weak interactions). This means that the charmed quark is converted to another type and the theory can write down equations for the probabilities that Q_c will convert to one or other of the familiar quarks. What emerges from this is that Q_c much prefers to change to Q_λ. This gives us an important signature. If charmed particles are being produced, we can expect to see strang particles around in unusually high numbers from their decays.

ii) Particle decays generally involve the production of leptons, so another signature of charmed particles could be the appearance of leptons in unusual ways from the charmed particle decays. For example, spotting leptons in association with a high number of strange particles could point to charmed parent particles. Spotting lepton pairs which do not have the characteristics of normal pair production could indicate that one or both has charmed parentage.

iii) In the particle decays where leptons are not involved, the violation of the normal rules governing such decays could again signal that a charme particle is present.

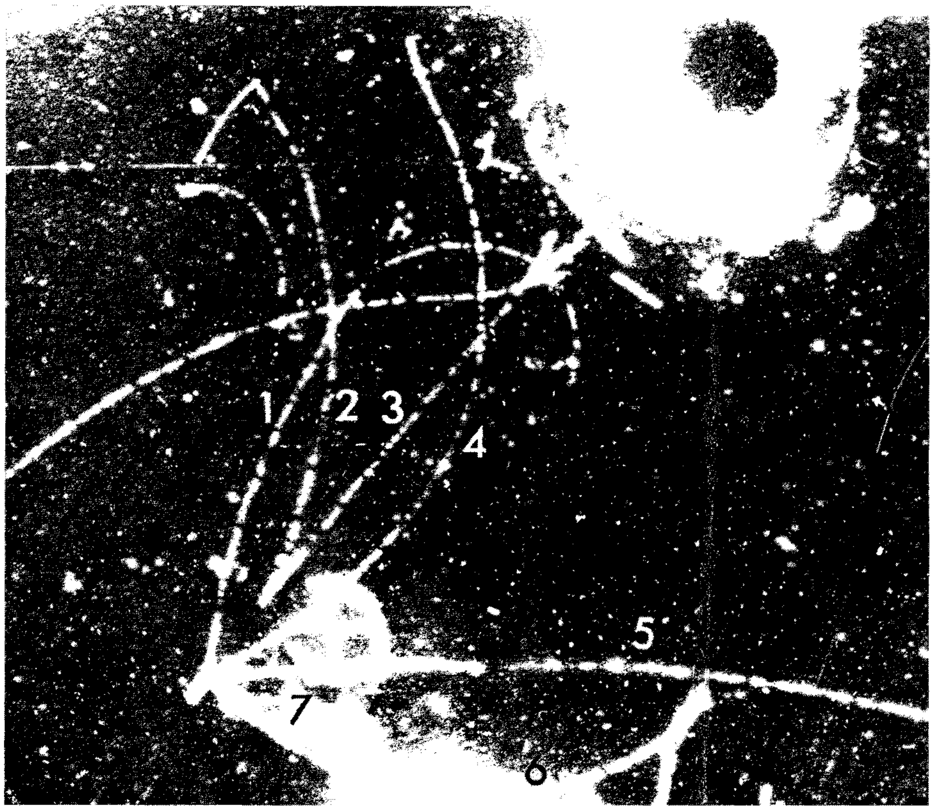
Experimental results so far

An important search using signature number (i) is going on at the SPEAR storage ring. If we believe that charmed D particles are being produced in the decay of the 'hidden charm' particle of mass around 4.1 GeV, then we can expect to see the number of strange particles emerging from the interactions at this energy to increase suddenly and markedly.

At the time of writing, no news on the measurement of the kaon to pion ratio when crossing 4 GeV has come from SPEAR. (SPEAR has been held up for some weeks due to a fire which caused damage in the West experimental region on 15 March. They hope

✱ SPEAR was in normal operation on 25 March and the West region on 8 April. The peak beam energy is now raised to 4 GeV.

Event in the CERN heavy liquid bubble chamber, Gargamelle, which is a candidate for a charmed particle. A neutrino (coming in from the left) in interaction with a nucleon seems to have yielded, 1 – a positron, 2 and 3 from decay of a neutral kaon, 4 – negative pion, 5 – positive pion or proton, 6 – muon, 7 – positive pion or proton. If this assignment is correct, the event has a good signature for charm — two leptons are seen emerging from a neutrino interaction together with a strange particle.



to be back in action well before the end of April.) ✱ The double spectrometer at Brookhaven is also looking for kaons but, again, no news up to now. The latest results from the DORIS storage rings at DESY are reported separately later in this issue.

Several searches are under way at the CERN Intersecting Storage Rings using signature number (ii). At the SR the extremely high energies of the proton-proton collisions should yield many charmed particles but the profusion of hadrons being produced is likely to drown any signature which is purely hadronic.

The very low background for leptons around the storage rings, however, makes this a promising route. Since we are dealing with strong interactions, we expect that the charmed particles from the proton-proton collisions would appear in associated production (as described for strange particles above) — in other words, a particle carrying positive charm will be produced together with one carrying negative charm. These could be spotted via leptons, for example if one harmed particle decayed with an electron and the other with a muon, or if leptons were seen in events with high production rates for strange particles. No news at the time of writing.

At the CERN Gargamelle bubble chamber a neutrino event is under scrutiny as being a strong candidate for the production of a charmed particle. (Note that since we are dealing with a weak interaction, associated production is not necessary.) It has precisely the two lepton/one strange particle signature mentioned above. If the tracks have been correctly assigned, what is recorded is

ν_μ + nucleon → e^+ + K° + π^- + π^+ (or p) + π^+ (or p) + μ^-

This looks like the production of a charmed particle

ν_μ + nucleon → charmed particle + μ^- (+ pions)

and the subsequent decay of the charmed particle yielding K° + e^+ + ν_e (+ pions). The event was discussed at the Paris neutrino meeting on 18-20 March. The probability that it has been produced by other means (for example, an electron-type neutrino contaminating the muon-type neutrino beam and being the source of the positron) is regarded as below one in a hundred if the tracks are correctly assigned.

At the FermiLab, two experiments are seeing unusual effects in neutrino interactions yielding two muons. They are the FermiLab/Harvard/Pennsylvania/Wisconsin experiment of D. Cline, A.K. Mann and C. Rubbia and the Cal. Tech./FermiLab experiment of B. Barish. The first has over 30 and the second has 4 mysterious di-muon events. They are convinced that the muons are not originating one from the initial neutrino-nucleon interaction and the other from the decay of a pion or kaon. Things such as the rate at which they occur, the fact that they are always of opposite sign, etc.... seem to rule out this possibility.

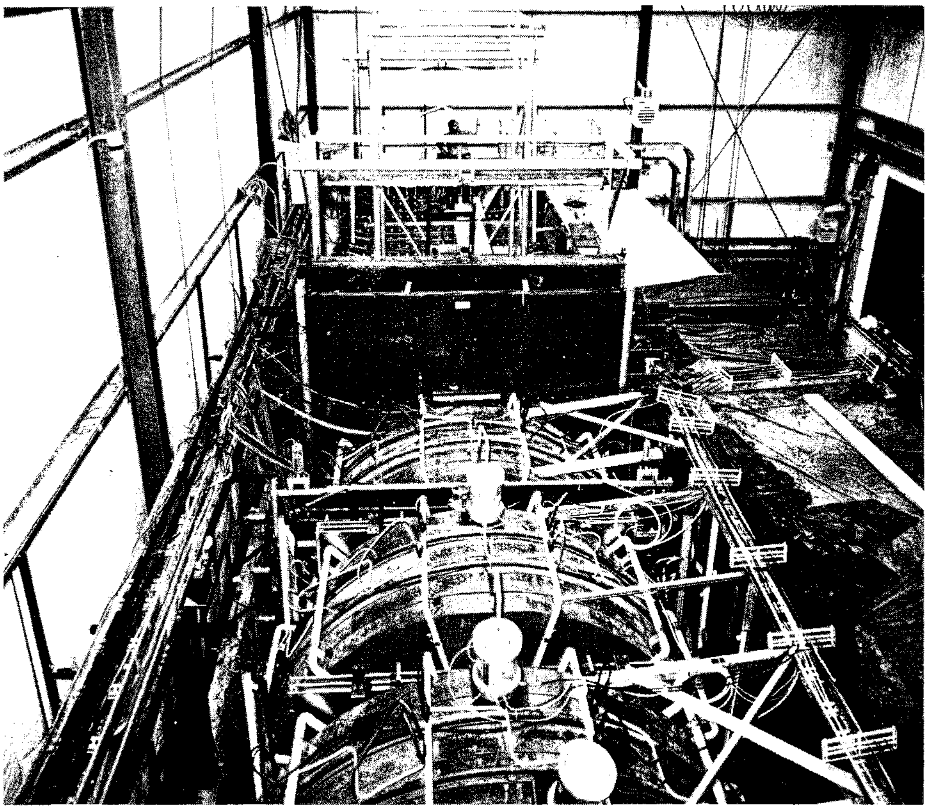
The combined muon masses show no peak (indicating that they are not, for example, from the decay of a particle like the 3.1 GeV) but are rather evenly distributed over a range of several GeV. There are also inexplicable features such as the fact that the negative muon is always of higher momentum than its positive counterpart in seeming violation of charge symmetry.

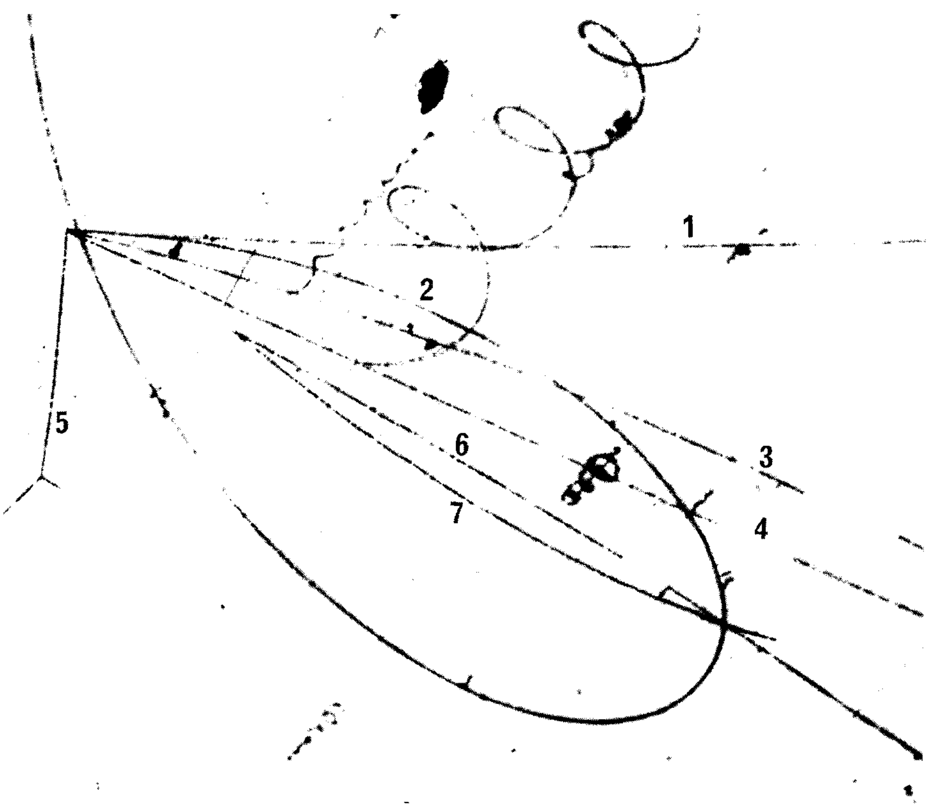
The favoured explanation is that new particles, given the name y (not 'Why') particles, are being produced in the energy range 2 to 4 GeV. They could be charmed baryons, produced together with a single muon in the initial neutrino-nucleon interaction, which then subsequently decay via the weak interaction yielding a second

Part of the huge detection system at the FermiLab where neutrino interactions yielding two muons are being seen. Some completely new interpretation seems needed to explain the origin of these muons. The detectors which can be seen are huge drift chambers (the large square plaques of 4 m side) and cylinders of magnetised iron which form the muon spectrometer.

(Photo FermiLab)

The picture from the 7 foot bubble chamber at Brookhaven which is put forward as being most probably the decay of a charmed particle produced in the interaction of an incoming neutrino with a proton. The tracks are assigned to the following particles 1 — negative pion, 2 — positive pion (its muon and electron subsequent decay is also seen in the chamber), 3 — positive pion, 4 — muon, 5 — positive pion, 6 and 7 from decay of a neutral lambda. Some of the reasoning behind the claim that a charm particle is the origin of these tracks is given in the article.





muon. Details of these di-muon events have been published in Physics Review Letters.

Signature number (iii) is being looked for particularly in bubble chambers where detailed information on the particles emerging from an interaction is often more readily available. A strong candidate for a charmed particle event, which is being published in Physics Review Letters, has bee put forward by the group of N.P. Samios at Brookhaven and more Gargamelle pictures are also under study.

The Brookhaven team have been chewing on the event shown in the photograph, recorded in a neutrino experiment with the 7 foot bubble chamber, for about nine months and are now convinced that, to high probability, they know the identity of the particles which gave the tracks. The event is:

$$\nu + p \rightarrow \mu^- + \Lambda^\circ + \pi^+ + \pi^+ + \pi^+ + \pi^-$$

Such an event cannot be explained under the normal conservation laws of particle interactions. In particular, it violates the rule which says that the strongly interacting particles wi' change their total strangeness by the same amount as they change their total charge (the $\Delta S = \Delta Q$ rule). In the event, the strangeness has changed by -1, the proton ($S = 0$) has gone to a lambda ($S = -1$). The charge has changed by $+1$, the proton ($Q = +1$) has gone to the lambda and four pions (total charge $Q = +2$).

The proposed explanation is that a charmed baryon was produced

$$\nu + p \rightarrow \mu^- + \text{charmed baryon}$$

and that it was the charmed baryon decay which gave the lambda and pions. The mass of the baryon can be calculated by measurements on the tracks as about 2.4 GeV. If we do sums on feeding a charmed quark into a baryon, since the new particles have given us a good estimate of what to use as the charmed quark mass,

CERN News

we arrive at about 2.4 GeV for a charmed baryon.

The interpretation therefore looks tantalisingly right. What is surprising is that the event has been found in the examination of a few hundred photographs. Gargamelle would then expect a good handful of such hadronic decays in the number of photographs examined. However statistics are difficult with a single event. As the authors themselves say, 'the validity of the above conjectures can only be verified by the accumulation of additional such events'.

Pastures new

We have concentrated on the 'charm' interpretation of the present excitement in high energy physics. This could be wrong — the amount of experimental evidence is still flimsy — but it does hang together in a convincing way.

V. Weisskopf is fond of a Columbus story — 'The accelerator physicists and engineers are the ones who built the boat. The experimental physicists are the ones who set sail and discovered America. The theoreticians are the ones who stayed in Madrid and predicted the boat would land in India.'

At the moment, the theoreticians are predicting quite a number of countries where the boat will land. The only thing that we can be absolutely sure of is that it has sailed beyond all the continents we have explored up to now and is bound to come ashore in a completely new land.

Directors General appointed

At a special session on 21 March, presided over by P. Levaux, the Council of the European Organization for Nuclear Research appointed J.B. Adams and L. Van Hove as Directors General of the Organization for a period of five years beginning 1 January 1976. Dr. Adams will be responsible for the administration of CERN, for the operation of the equipment and services and for the construction of buildings and major equipment. Professor Van Hove will be responsible for the research activities of the Organization.

When the Council approved the construction of the 400 GeV proton synchrotron in 1971, it set up a second Laboratory. The two Laboratories were to be unified when the accelerator was completed. The SPS is due to be commissioned during 1976 and Council has decided that the Laboratories should be unified from January of that year when the present D.G. of Laboratory I, Professor W. Jentschke will have completed his five year term.

John Adams joined CERN in its earliest days and, after leading the team which built the 28 GeV proton synchrotron, became Director General in 1960 before returning to England. He came back to CERN as Director of the 300 GeV Accelerator Project at the beginning of 1969 and became Director General of Laboratory II in 1971. Léon Van Hove came to CERN in 1961 as Head of the Theoretical Physics Division and has since taken a leading role in the scientific life of the Organization, twice serving as Director of the Theoretical Physics Department (in 1966-68 and in 1972-74). He was also President of the Scientific Directorate of the Max Planck Institute of Physics and Astrophysics in Munich during 1971-74.

Line up of Directors General at the Council Session on 21 March. On the left is W. Jentschke, present Director General of CERN Laboratory I. Centre and right, respectively, are J.B. Adams and L. Van Hove who are appointed to lead the combined Laboratories as from 1 January 1976.

CERN 261.3.75

The innocent looking stacks of magnets in the large Assembly Hall awaiting their installation in the SPS tunnel. Something was happening to the coil insulation while magnets sat in the stack and chemical detective work was needed to pin the problem down.

Acid time for SPS magnets

All large-scale projects run into problems of one kind or another. High energy physics Laboratories, in general, take pride not because they do not meet problems during their big projects but because they tackle them successfully. In the building of the 400 GeV proton synchrotron, which is by far the largest project that CERN has faced, a number of unexpected difficulties have already arisen and been overcome. At the present time, the team are wrestling with such things as tidying up the radio-frequency accelerating system and achieving good quality components for experimental area beam-lines and transformers for the magnet power supplies.

Most conspicuous of the accelerator components are the bending magnets of the synchrotron ring. Since there are many hundreds of them, any difficulties tend to be looked at with a magnification of at least 10^2. This explains the worry at the end of January when, routine insulation tests on magnets installed in the tunnel, prior to attaching the busbars, revealed four of them passing current with a 2 kV applied voltage. Returning to the store of magnets waiting in the large Assembly Hall added thirty-six others which were breaking down. All these magnets were of the MBA type.

What was disturbing was that the magnet coils had already successfully undergone a series of insulation tests — a 10 kV test under water at the manufacturers, a 7 kV test after assembly of the magnet at CERN. How could insulation deteriorate while the magnets were left quietly in a stack? How likely were the rest of the coils to be affected? Also, it didn't take long memories to recall the hard time during the commissioning of the 400 GeV machine at the FermiLab due to previously successfully tested magnets breaking down after installation.

CERN 163.5.74

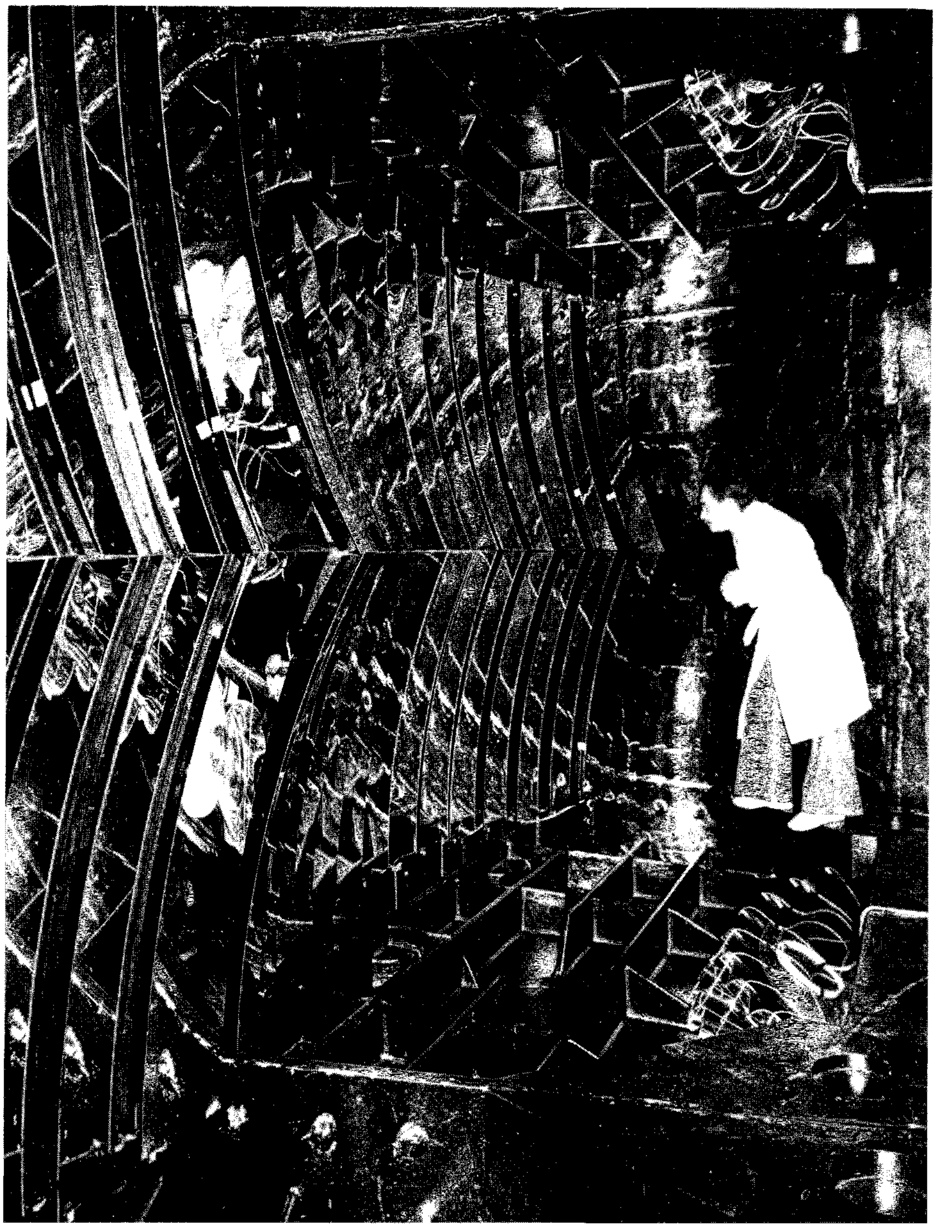
The CERN magnet specialists went into a huddle to try to understand the cause. They naturally thought predominantly of the physics and engineering aspects of the problem. The answer proved to be more chemistrv and finding this out was a fascinatin little saga in itself.

On opening up the faulty magnets, it was found that breakdown, in virtually all cases, was occurring on the underside of the coil near the manifold end where the copper conductor emerges and is brazed. In this area, white spots were visible in the resin. The first, seemingly aimless, clue came when R. Billinge, Leader of the Magnet Group, rubbed one of these spots and licked his finger remarking that it tasted acid. It was learned that the manifold had been cleaned, after brazing, with a solution containing phosphoric acid.

One of the first questions to R. Sheldon and G. Stapleton, two chemists from the Rutherford Laboratory wh arrived to carry out some experiments on the coil insulation, was therefore, 'What effect could phosphoric acid have?' Their unhesitating answer was 'None at all'. However, among the many tests they lined up, they included some with phosphoric acid.

They ran into a long series of surprises. It was found that a sample of the insulation from the coil, washed in acid and dried was a dead short when voltage was applied. Glass cloth, such as is used in the insulation, dipped in acid, washed thoroughly in water and dried, became over a million times more conducting. (Incidentally, mica was affected the same way but mica — traditionally used in CERN insulation systems — could not be used in the SPS bending magnets since the mechanical stresses are too high.)

Elliptical mirrors of the large Cherenkov counter used in association with the Omega spectrometer. These mirrors reflect the Cherenkov light onto four sets of parabolic light collectors (sets are visible above and below the white coated gentleman). The counter, which was built at Saclay, has been working in the CERN West Hall for two years and will also be involved in the first experiments with the 400 GeV proton synchrotron. Meanwhile, it is the essential component of the triggering system in an experiment looking for charmed particles such as are discussed in our opening article.



CERN 73.2.75

Making up resin used in the insulation and contaminating it with phosphoric acid led to the same sort of white spots as were seen on the faulty coils. These white spot regions cracked much more easily under strain than uncontaminated resin.

Having seen these devastating effects, the next step was to look for acid on the coils. A faulty magnet was opened and the breakdown area was located using a high voltage probe. Rubbing over the coil with a piece of litmus paper showed no reaction until the defective area was touched. The litmus paper then turned red indicating the presence of acid. A swab from this region was checked with Nessleriser reagents and showed that the acid was phosphoric. This was confirmed by M.P. Murray using the X-ray fluorescence technique at the Battelle Institute in Geneva where the chemistry section was very co-operative in the course of the tests.

It remained to show that the effects could occur with time, explaining how coils could pass voltage tests and then breakdown later. Parts of a good section of coil were exposed to different concentrations of the acid. After four weeks some parts were already breaking down, indicating that even cured resin systems were vulnerable with time.

A solution used on some of the FermiLab magnets contained sulphuric acid — a close chemical relative of phosphoric acid. Similar tests to those above using sulphuric produced the same results. However, there is no hard evidence that this was a cause of magnet failure. It is believed that water leaks at butt joints was the major source of the trouble on the USA machine.

The detailed information on the effects of these acids on magnet insulation systems is certainly not well known in accelerator Laboratories. It seems that the heavy electrical industries, such as transformer manufacturers, stay clear of phosphoric and sulphuric but, as far as can be uncovered, without really understanding why they are to be avoided. The experience of the SPS magnets make the reasons abundantly clear.

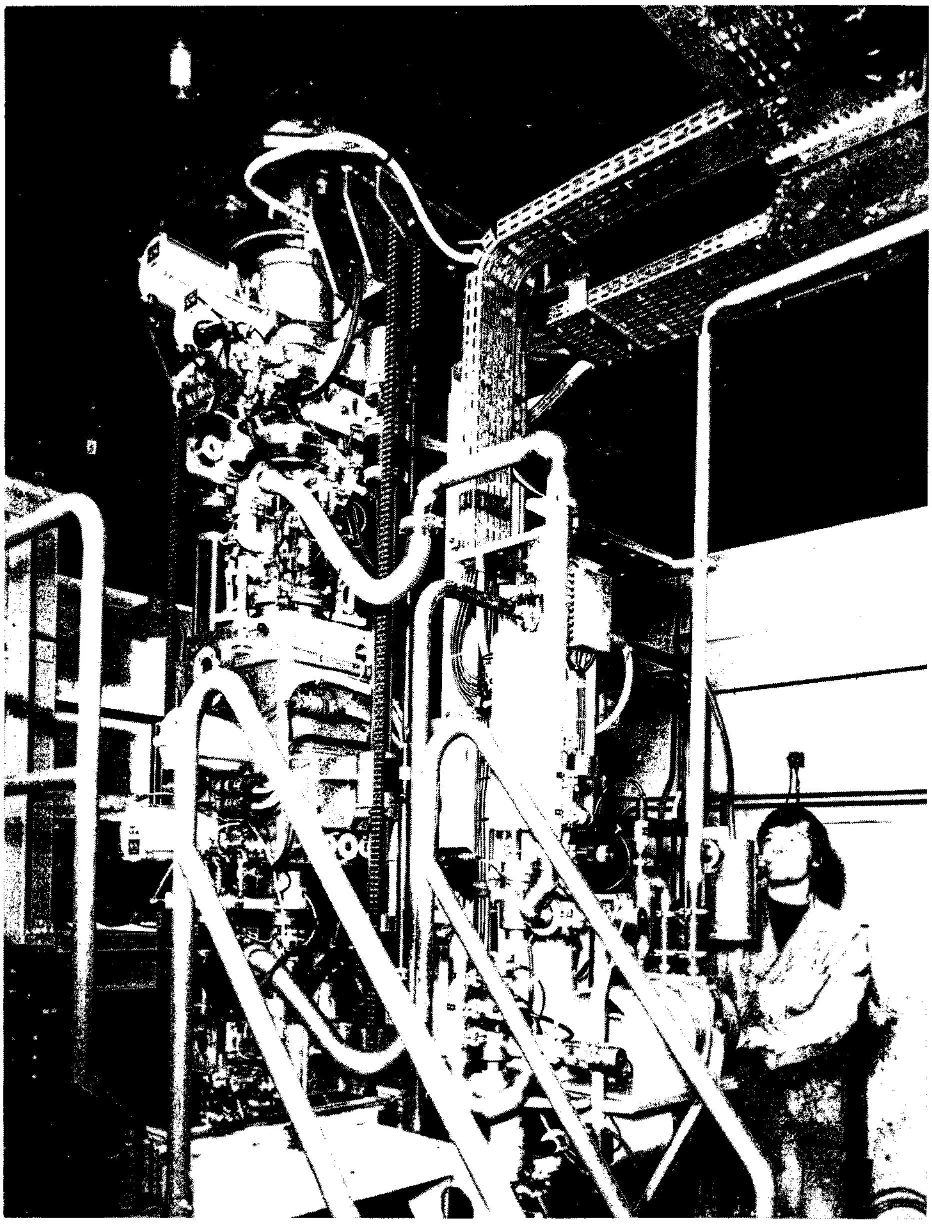
The phenomenon has been found in time. The faulty coils are being remade at the manufacturers and the other magnets already at CERN, on which the cleaning fluid could have been used, are being opened so as to neutralize the acid and wrap the coils with two layers of insulating kapton. The magnet assembly line is back in action working even harder. Use of the cleaning fluid has obviously been stopped and, to make assurance doubly sure, all coils from now on will be kapton wrapped. By keeping the pressure on, it will still be possible to meet the machine construction schedule.

Meanwhile an installed half sextant of the ring, including 30 MBA bending magnets and 32 MBB bending magnets, has had a good life test in the machine tunnel. At the time of writing, they have clocked up 80 000 pulses with peak fields corresponding to proton energies of 400 GeV and have given no trouble. Regular 4 kV insulation tests show a monotonously high resistance to ground.

ESO: discovery of a comet

A new comet has just been identified by the European Southern Observatory (ESO) on a photographic plate exposed on 15 October last year with the ESO Schmidt telescope at La Silla, Chile. This comet, which has been christened WKI from the initial letters of the names of its three successive astronomers (R.M. West, L. Kouhoutek

First sighting of a new comet, baptized WKI, by the ESO Schmidt telescope in Chile. The film, taken during the 'Quick Blue Survey' was processed in the Sky Atlas Laboratory at CERN.



The unit which raises the ion source into the central region of the 600 MeV synchro-cyclotron. The photograph shows the underside of the magnet yoke and the equipment which makes it possible to introduce and remove the source and to make adjustments and component changes without breaking the machine vacuum.

CERN 393.2.75

and N. Ikemura) is the first to be discovered by ESO and the first to be found at the Sky Atlas Laboratory installed at CERN.

Comets are of special interest because, as they are probably the remains of the outside fringe of the original gas-cloud of the solar system, they provide evidence in the composition of the cloud which contracted to form the sun and the planets. Comets are a kind of contaminated snowball, consisting essentially of ice and various impurities like minerals. They become visible when they pass close to the sun which heats them and produces a halo of incandescent gas (the head) blown by the solar wind (the tail).

Orbit calculations have shown that the trajectory of WKI was considerably deflected in March 1972 by the planet Jupiter, which it brushed past at a distance of 1.5 million km. Its new orbit, close to the sun, makes it all the more interesting since it will pass by the Earth and the sun every six years. It will be possible to study it in detail from 1981.

Progress at the synchro-cyclotron

Despite the difficulties which arose at the start of operation of the improved 600 MeV synchro-cyclotron at the beginning of the year, its commissioning programme and the first physics experiments were successfully completed. The Isolde group is already preparing to publish the first results obtained with the new isotope separator installation.

Vacuum leaks which developed in the ion source supply and in the rotary capacitor have been repaired and the equipment is now more reliable.

Operation has continued with an internal beam of deliberately limited

1. Diagram of the CERN machines imposed on the spherical earth. With the large dimensions of the accelerators (the SPS has a diameter of 2.2 km, for example) the sphericity cannot be ignored. Going from the plane of the 28 GeV PS to the plane of the 400 GeV SPS there is an angle of 0.23 mrad.

2. To ensure that the median planes of each of the SPS quadrupoles all lie in the same plane, the sphericity of the earth has to be taken into account. The tolerence in the vertical direction is 0.1 mrad and in the horizontal direction (the plane of the orbiting particles) is 0.17 mrad.

intensity in order to prevent over-activation of machine components until everything is thoroughly under control. Nevertheless, SC-2 is already giving better extracted proton beams than those of the SC-1. The extraction efficiency has been raised from 50 to 70 % by modifying the focusing electrodes surrounding the source.

The machine was shut down at Easter for permanent repairs to the Dee, in which leaks had been temporarily plugged (see February issue, page 32). This will take two months after which the internal beam intensity will be gradually increased up to its design value of 10 μA.

Survey work for the SPS

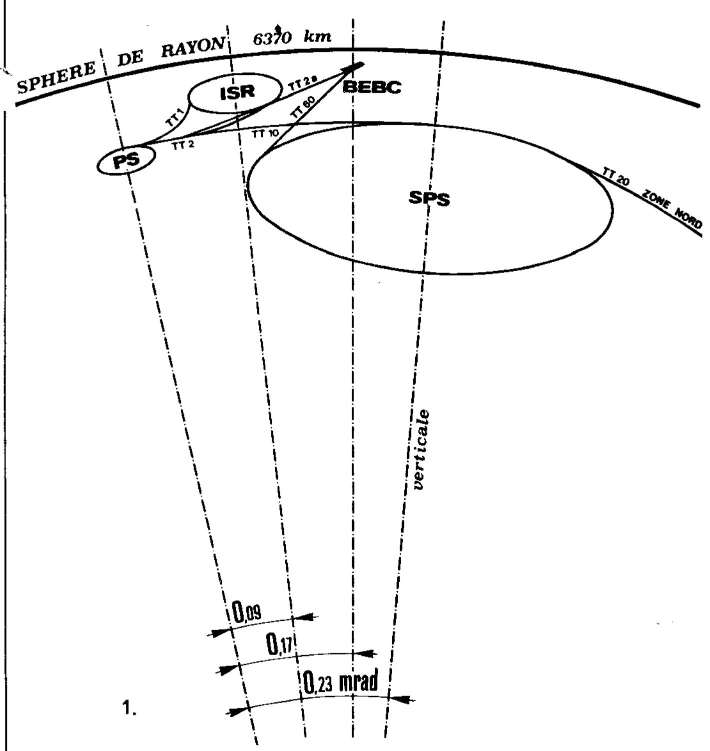
From the point of view of survey work there are two fundamental problems for the builder of a particle accelerator. He must ensure that the foundation for the magnet structure which guides the particles is stable and he must then position the magnets with great precision on this stable foundation.

The geological studies of the site for the CERN 400 GeV proton synchrotron showed that the rock was similar to that on the site of the 25 GeV PS and ISR so the stability of the foundation was assured. The problem of accurately positioning the 1000 bending and focusing magnets spread around a tunnel 7 km long (2.2 km in diameter) and some 40 m underground was the challenge to the geodesist.

The accuracy with which magnets must be positioned can be appreciated by considering that the protons, travelling in a vacuum chamber whose transverse dimensions never exceed 150 mm, orbit the machine more than 72 000 times, travelling slightly more than 500 000 km (around the world 12 ½ times) in less than 3 s.

A consequence of the need for this precision is that, in all the operations described below, allowance has to be made for the curvature of the earth. A plane cut through a sphere gives a circle but the synchrotron is not quite circular. It has six curved segments with a radius of 947 m separated by six 250 m straight sections. In these straights, the deviation from the mean plane is 2.3 mm, which is not negligible. Moreover, as the SPS is constructed horizontal to within a few tenths of a millimetre, its plane is not parallel to that of the 25 GeV PS but at an angle of 0.23 mrad to it.

The curvature of the earth, leads to a deviation between the perpendiculars to the machine's horizontal plane and the verticals in the access shafts. Depending on their depth, corrections may amount to 12 mm in the outward direction in the plane of the machine.



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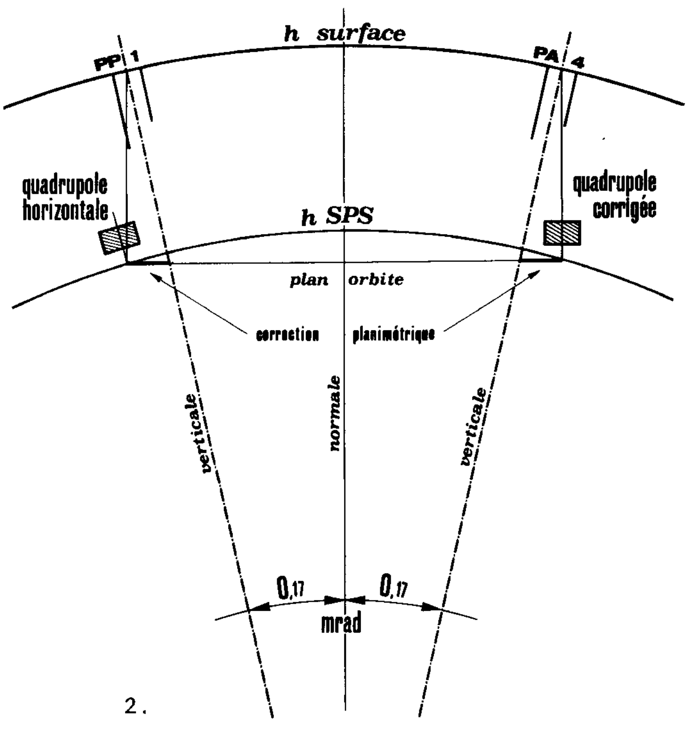

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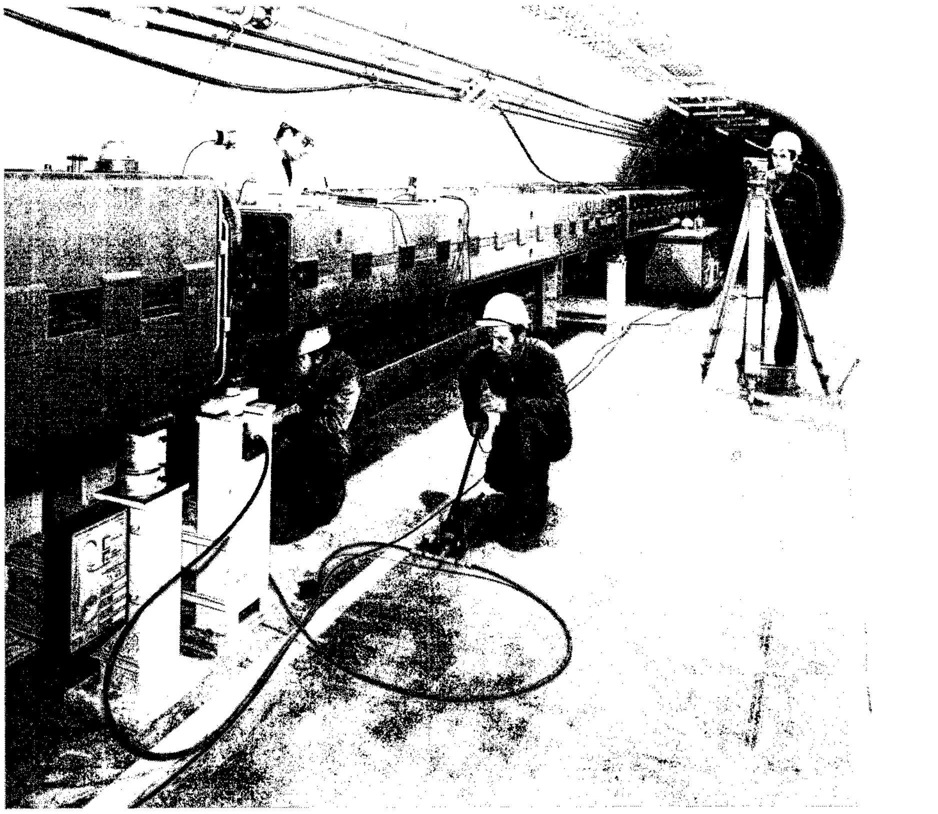


Alignment of a bending magnet in the tunnel of the 400 GeV proton synchrotron. The feet on which the magnet sits are being positioned vertically using jacks. A previously aligned quadrupole is on the left.

CERN 160.11.74

A correction also has to be made to the transverse tilt of the focusing quadrupoles so that their median planes coincide. Tolerances of 0.1 mrad are required and the deviation between the verticals and the orbit's horizontal plane is 0.17 mrad.

The first stage in the building of the SPS was the boring of the tunnel. The work began by establishing a geodetic network (external triangulation-trilateration). The network of the PS was used as the starting point since it is to be the injector to the SPS. The quality of underground geodesy depends on the accuracy of the surface network. All traverses made in the main tunnel must close on geodetic points once they have been transferred down to the level of the accelerator. From these external measurements, six points spaced at equal intervals around the 6911 m circumference were determined with 2 mm accuracy in relation to the origin of the co-ordinates: six vertical shafts were then sunk at these points connecting the surface and underground networks.

The underground traverse was carried out from these access shafts. Errors in angular measurement are cumulative, so a system based on an absolute reference — the axis of rotation of the earth — was chosen. A gyroscopic theodolite was used to measure the bearings of the traverse. Pillars were built every 32 m and the geographical North was determined at each one, avoiding cumulative errors. This traverse ensured that the laser beam used to guide the boring machine was pointing in the correct direction.

The boring machine emerged at the six access shafts with the following deviations from the desired position — 23 mm at shaft 2, 19 mm at 3, 14 mm at 4, 10 mm at shaft 5, 26.4 mm at 6 and 1.5 mm at 1. These results were substantially better than those assured during the study. Once the tunnel had been completed, the gyroscopic traverse was calculated round the whole circumference, without taking into account the surface network. Starting from shaft 1 and returning 7 km around to the same point, the closure vector was only 70 mm.

There remains the task of correctly positioning the accelerator components. Maximum accuracy is needed for the quadrupoles located every 32 m in the magnet lattice and the metrology system is therefore adapted to the periodicity of the quadrupoles. To avoid error accumulation, the geometry of the SPS reference figure was broken down into 32 m sections.

The choice of instruments to achieve the required measurement accuracy was important. Electromagnetic distance-measuring instruments are designed to give maximum precision over much greater distances and for distances upto 50 m, only invar wire has provided the necessary accuracy and reliability. Invar wires used in an instrument developed at CERN, called the Distinvar, still provide the only industrial method of obtaining a relative precision of one part in a million in the range of distances encountered in accelerator construction. The reference figure is a chain of 216 braced quadrilaterals measured with the Distinvar: two brackets are positioned opposite each quadrupole — one on the outer wall and one on the inner wall.

Magnets have to be installed as each sextant of the tunnel is fitted out. Consequently, the first magnets were positioned before the whole system of quadrilaterals could be adjusted. In order to ensure the consistency of each sequence of adjacent quadrilaterals, measurements are brought down from the surface. Each sextant can then be given its precise shape so that magnets can be installed as soon as the measurements are finished in the sextant. With these methods, the rms value of the radial deviation of three successive quadrupoles will be less than 0.1 mm. On the other hand, the distance between two diametrically opposed points will not be known to better than ± 1.8 mm.

When all the magnets are in the tunnel, the whole system can be adjusted to ensure that no cumulative errors have crept in and that the magnets are positioned within the prescribed limits. The least squares method will be used again for this exercise and the resulting matrix is as vast as that of the geodetic network for the whole of France. This raises a problem. Despite its large capacity, the CERN computer centre cannot tackle (in one go) this impressive series of equations consisting as it does of 864 unknowns and 1728 equations. The calculations have had to be adjusted to match the abilities of the computers!

The Split Field Magnet at intersection I-4 of the Intersecting Storage Rings almost submerged in a sea of additional detectors which have been installed around it. The Bologna/CERN group is using this array in carrying out a systematic search for new particles.

The Brookhaven/Rome group are using this detection system in intersection I-1. In the foreground on the right is one of two hodoscopes, incorporating lead glass, which detects particles emerging at small angles to the beam directions.

ISR start-up with new experiments

The Intersecting Storage Rings have come back into action on schedule after the long shutdown at the beginning of the year. On 4 March, the proton synchrotron, which had been started up a fortnight earlier (see March issue, page 68), injected beams into each of the two rings.

Two minor incidents occurred. A current of 23 A was rapidly obtained in Ring II, but Ring I reached only 14 A due to a vacuum breakdown near intersection I-7. This was quickly repaired and on 8 March a current of 20 A was accumulated in ring I increasing to 24 A by 10 March. At that time, the luminosity was 8.1×10^{30} $cm^{-2}s^{-1}$. In addition, it was found that there was a restriction in the radial aperture somewhere in the vacuum chamber of the same ring. This was tracked down to an area around intersection I-3 and remedied. The luminosity soon climbed to 1.2×10^{31} $cm^{-2}s^{-1}$.

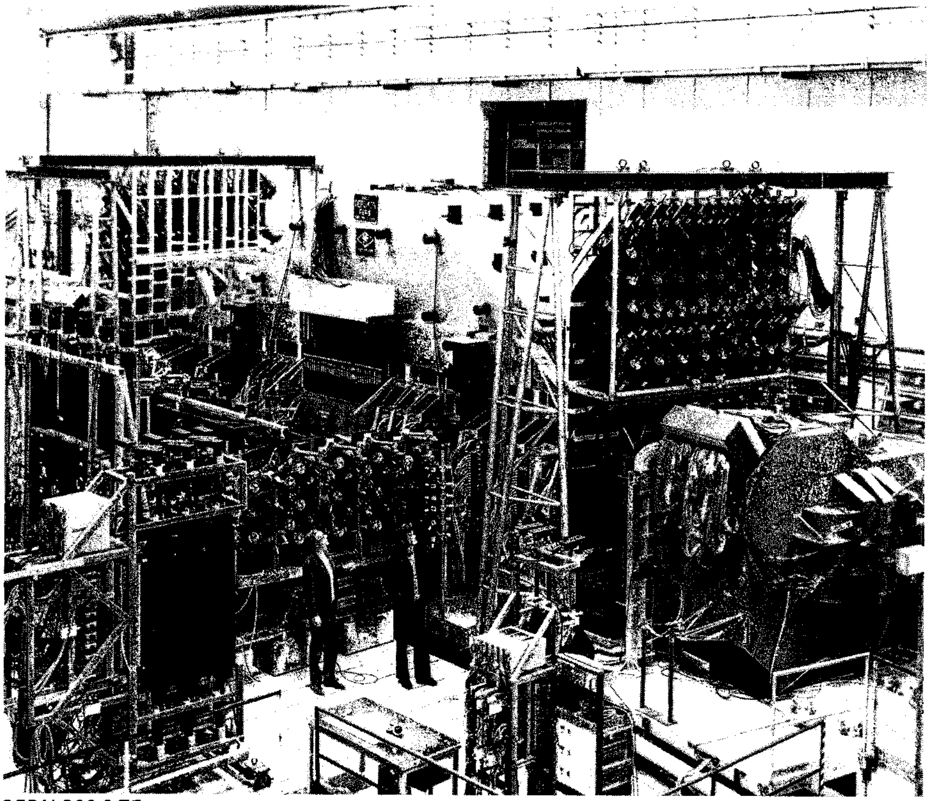
The experimental programme at the ISR for the coming months has been considerably influenced by the new particle discoveries and their possible implications in terms of particle properties such as charm. This is discussed in the opening article of this issue. The experiments can be grouped under two headings:

– search for charmed particles;

– the continuation of the studies of proton-proton collisions with a centre of mass energy higher than obtainable at any other machine in the world.

Search for charmed particles

At intersection I-2, the CERN/Holland/Lancaster/Manchester team and the Daresbury / Liverpool / Rutherford / Scandinavia team have linked



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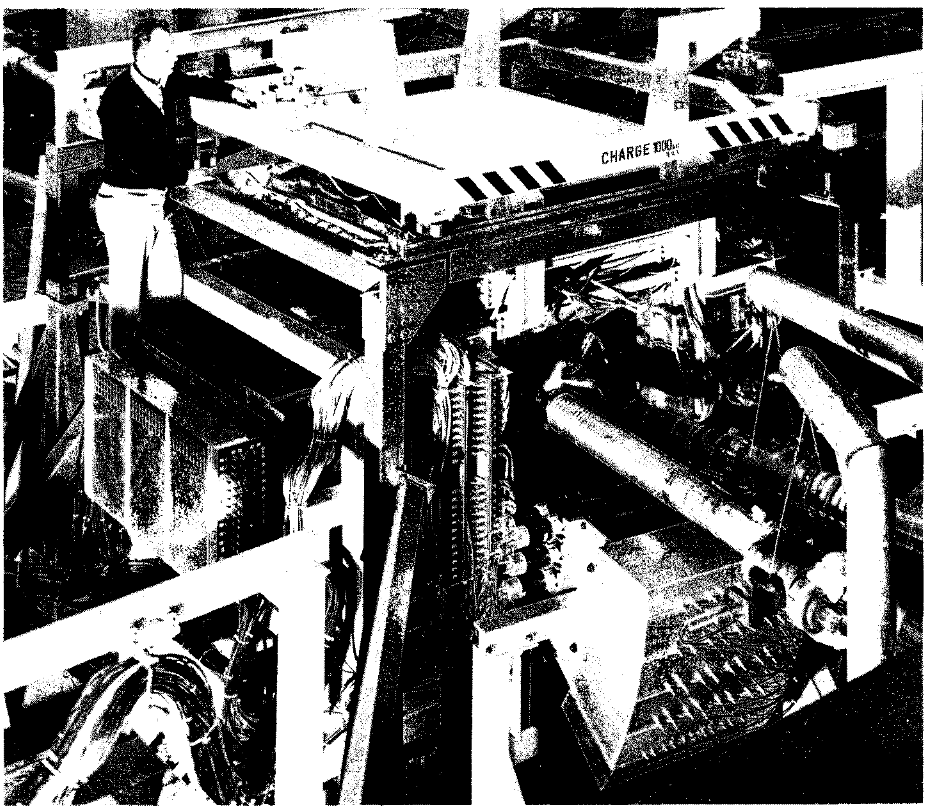

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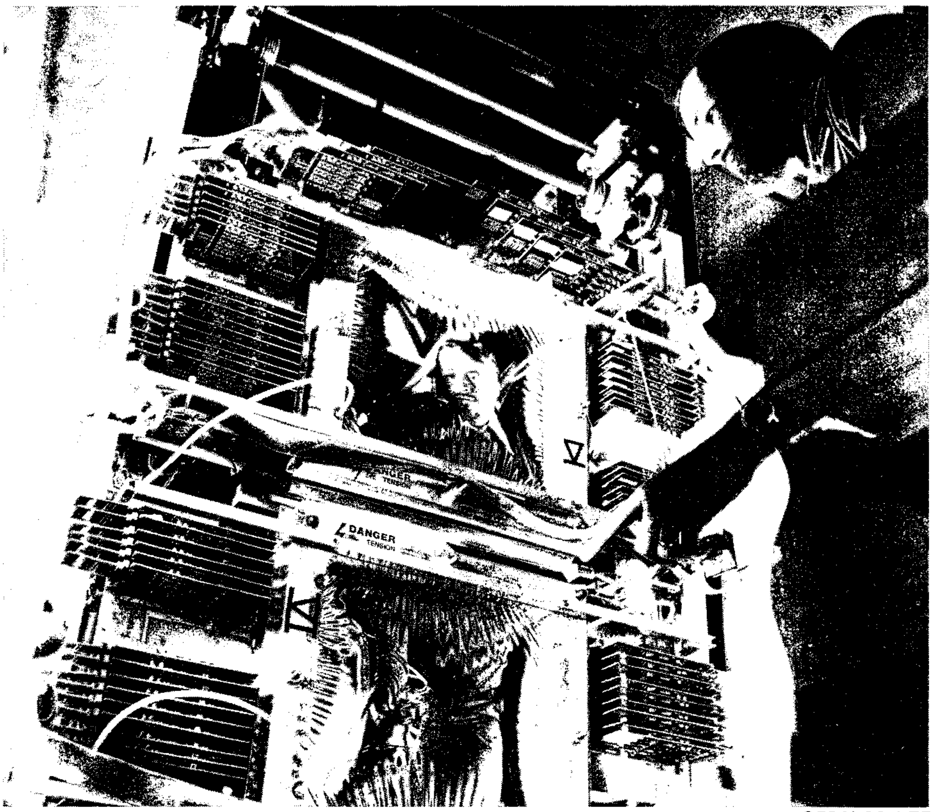
Two of the six multiwire proportional chambers, covered with aluminized mylar, which form part of the spectrometer used in experiment R 803 at the Intersecting Storage Rings. This experiment measured the pion, kaon and proton inclusive particle spectra at very low transverse momenta for the complete range of ISR energies. It was carried out by a collaboration of groups from Scandinavia, UK and USA.

One of the septum magnets to be used in ejecting protons from the 400 GeV synchrotron. These septa will be installed in straight section 6, at the junction with tunnel TT60, to point protons towards the West Hall and in straight section 2, at the junction with tunnel TT20, to point protons towards the North Area. This magnet has a copper septum and two of them form a single unit in a vacuum tank. Nine of these (four with 4 mm thick and five with 16 mm thick septa) will be installed behind four electrostatic septa. Beam deflected by the electrostatic units passes inside the rectangular aperture, 2 cm high, visible at the left-hand end of the magnet.



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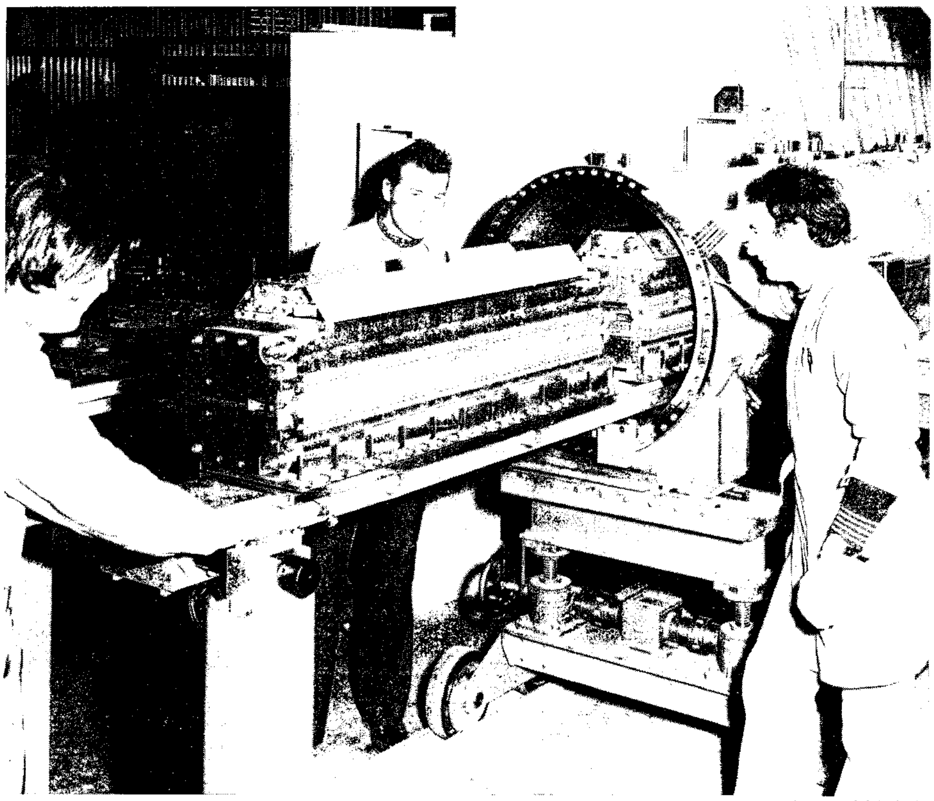

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their large angle and small angle spectrometers to study pair production. They will look for pion, kaon and proton-antiproton pairs and see if the combined masses show peaks corresponding to parent particles which could carry charm.

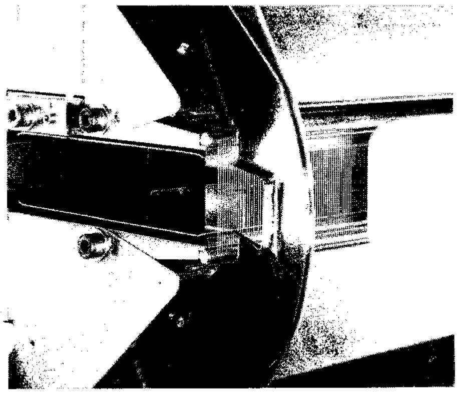
At I-6, a CERN/Harvard/Munich/Northwestern/Riverside team are hoping to see the associated production of charmed particles by spotting two emerging leptons. An electron and a muon (as explained in the opening article) is a possible signature of the decay of a charmed and anticharmed particle each producing a different lepton. Their detection system can also see the simultaneous production of an electron and a strange particle.

At I-7, a CERN/Saclay team is installing detectors to study in more detail the unexpectedly high rate of production of electrons emerging at right angles to the beam directions. Some can originate from known vector mesons such as the rho, omega and phi or from the new particles at 3.1 and 3.7 GeV but their contributions are too small to explain the number being seen. Perhaps they are from charmed particles. Data taking will start in May looking initially for the new particles via their electron-positron decay. Later the charmed particle search proper will begin using a lepton trigger and looking for a strange particle produced at the same time.

At I-8, a Brookhaven/CERN/Syracuse/Yale team are detecting electrons and photons produced at wide angles to the beam directions. (They are, incidentally using new types of detector — a transition radiation detector, with hundreds of lithium foils, for distinguishing between pions and electrons, and a liquid argon calorimeter to measure the energy of electrons and photons.) Again lepton information can be used to help pin down charmed particles.

Right: An SPS electrostatic septum in its vacuum tank; it consists of 2000 tungsten wires aligned vertically 1.5 mm apart over a height of 55 mm. The circulating beam will pass inside the anode, i.e. to the right of the array of wires. The deflected beam will be sent between the wires of the septum and the cathode, which will be fitted on its left.

Below: Detail of an electrostatic septum showing some of the tungsten wires (0.12 mm in diameter) with, on the left, the channel through which the circulating beam passes. The cathode, made of an anodised aluminium alloy is in place.



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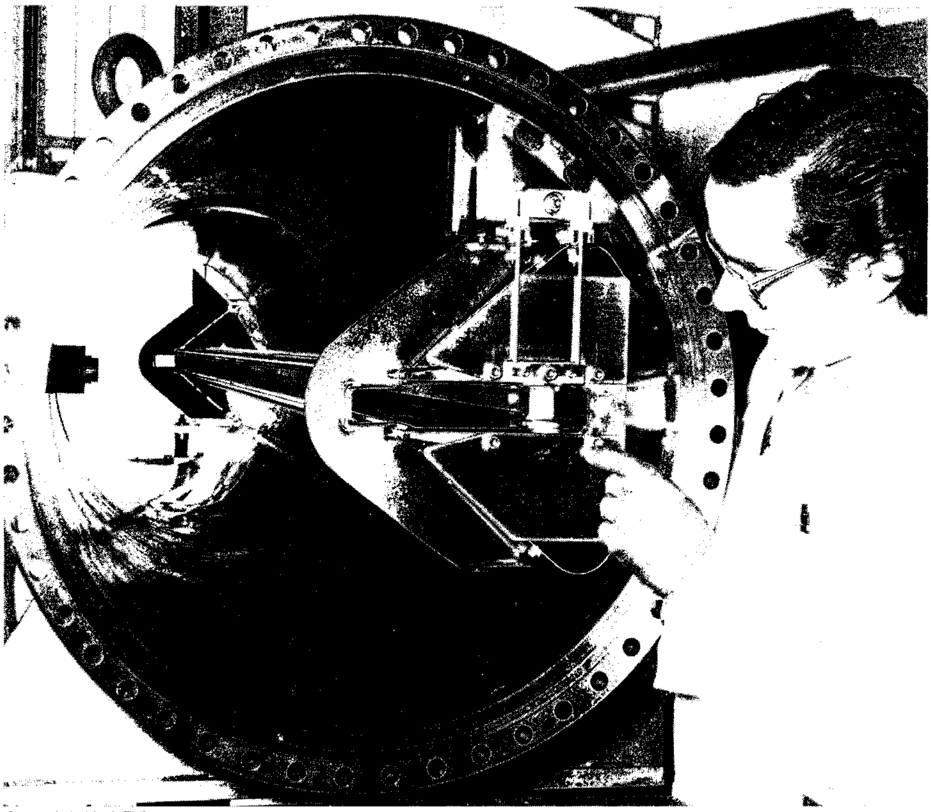

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Proton-proton interaction studies

In I-1, a Brookhaven/Rome team are looking at high multiplicity events (proton-proton interactions yielding many particles). With a detection system surrounding the interaction and capable of recording charged particles as well as photons, they can do thorough correlation studies and can also measure the energy of the photons. For example, two lead glass hodoscopes close along the beam directions are used to correlate particles emerging at a very small angle with those emerging at wide angles. They will also look for anomalies in gamma ray production which might result from the annihilation of the elusive magnetic monopole with its antiparticle.

At I-3, a Bologna/FermiLab group is also attempting to spot magnetic monopoles using plastic foils around the intersection. Monopoles could leave ionized tracks in the plastic which would then be made visible by chemical treatment.

At I-4, a Bologna/CERN group is using the large Split Field Magnet detection system plus additional detectors in a systematic search for heavy particles (2 to 30 GeV) with fractional or multiple charge. Among other things this is another hunt for the quark. The detectors will give information on the ionization produced by a charged particle and on the time of flight.

In I-8, a CERN/Rome group are continuing the study of elastic scattering of protons at very small angles, using counters manoeuvred to within 10 mm of the orbiting protons. They aim to extend the data up to the highest energies available at the ISR (31.4 GeV per beam).

Honours for physicists

The French Physical Society has recently awarded four prizes:

– the Grand Prix Jean Ricard to P. Musset for his contribution to the discovery of neutral currents. This prize is the reward for work since 1964, first of all with the construction team for the large heavy liquid bubble chamber Gargamelle and subsequently for the study and development of the methods of analysis. While this prize rewards the efforts of one man, he would be the first to stress that the demonstration of neutral currents is the result of the work put in by all in the Aachen / Brussels / CERN / Ecole Polytechnique / Milan / Orsay / University College London collaboration who took part in the experiments;

– the Robin Prize to L. Michel, whose work is well-known. Examples include contributions to the application of group theory to elementary particle physics and to the development of the theory of weak interactions, with special reference to the analysis of the decay of muons;

– the Foucault Prize to M. Borghini for his work on polarised targets, which has resulted in the manufacture of many targets used in physics experiments;

– the Joliot-Curie Prize to J.-P. Vialle also for research into neutral currents during the neutrino experiments with the Gargamelle bubble chamber.

Around the Laboratories

Meeting at New Orleans

Beginning in 1967, several informal meetings have been held by small groups of prominent high energy physicists from the Eastern and Western European countries, and from the USA to discuss the future of high energy physics and questions of international collaboration. The meetings began with the participation of Western and Eastern European physicists as a part of the CERN-Dubna and CERN-Serpukhov collaborations and were extended to include USA physicists. The first four meetings were held in Western Europe and in the USSR and the fifth took place at New Orleans, USA, from 4 to 7 March. It was entitled 'International Topical Seminar on Perspectives in High Energy Physics' and was attended by about forty-five Laboratory Directors and senior scientists from Western and Eastern Europe, Japan, the USSR and the USA.

In the first part of the seminar, M. Gell-Mann summarized the present state of the theory of the fundamental structure of matter. The exciting discoveries made with high energy accelerators in the last decade have significantly advanced the understanding of the basic laws governing the behaviour of matter. However, the unexpected phenomena which have been seen, present many unsolved problems. At the seminar, a discussion of the recent discoveries of new particles concluded that it is more likely than ever that a further extension of the energy frontier on a broad front — electron and proton storage rings and fixed target accelerators — will yield valuable and needed information.

The second part of the seminar was devoted to the ideas and plans regarding new high energy facilities in the different parts of the Soviet Union, the countries collaborating at Dubna, Western Europe, Japan and the USA. Many projects were discussed, most of which are not yet officially approved for construction. They span a wide range of possibilities, including fixed target accelerators and colliding beam devices with electron, proton and ion beams up to the TeV range. The presentations showed the technical feasibility of extending the energy frontier on a broad front.

The third part of the seminar was devoted to international collaboration in high energy physics. Accounts were given of the present state of such collaboration between the Dubna Member States and the Soviet Union on the one hand and the United States or Western Europe on the other. In particular, experiments by mixed groups from different regions at the most advanced accelerators (Serpukhov, CERN, FermiLab) were reported for which instrumentation was brought from one region to the other.

The discussion which followed was directed towards improving and strengthening this inter-regional collaboration at existing and at future facilities. The possibilities of increased collaboration in the planning and design of new facilities were considered. One of the measures proposed was the repetition of the seminar every two years in order to provide full information on the development of new ideas and projects and in order to review, improve and expand inter-regional collaboration.

It was recognized that the realization of many important regional projects will be of tremendous importance for the progress of science, especially if the new facilities are exploited in active collaboration between the different regions. It was also felt that developments in high energy physics are likely, eventually, to require the construction of accelerator facilities beyond the size and scope of the present regional proposals. Ideas on extending inter-regional co-operation to prepare for this situation were discussed.

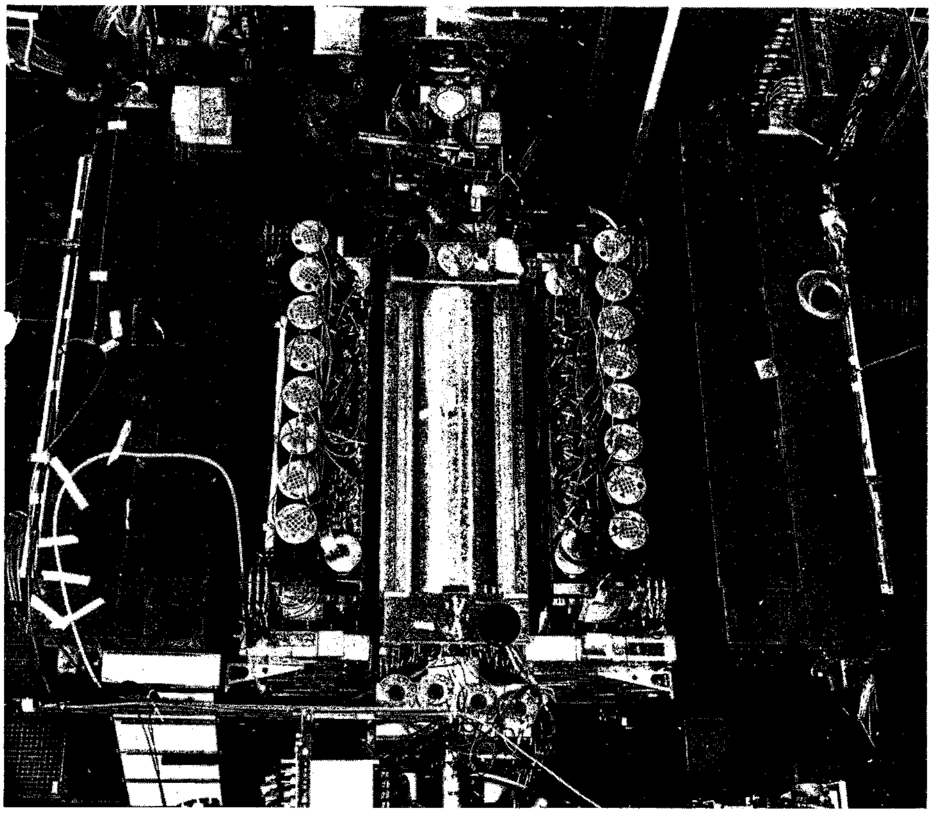
DESY Experiments at DORIS

Since November of last year th electron-positron Double Storage Ring, DORIS, has been running most the time at energies of about 2 × 1.5 and 2 × 1.85 GeV. These energies correspond to the masses (3.1, 3.7 GeV) of the two new particles. At the two intersection regions in the rings, the detectors PLUTO and DASP and an experimental set-up of a DESY/Heidelberg team have been looking at the emerging particles. (For a description of PLUTO and DASP see December 1974, page 426). This is a summary of the additional information on the new particles that has been gathered.

The magnetic detector PLUTO was scheduled for its test run in October 1974 and about three quarters of i' chambers and electronics were ready at that time but the discovery of the new particles interrupted the systematic tests. With the help of the selective trigger of PLUTO, the first determination of the position of the particles on the DORIS energy scale was performed. There was a delay of some days in finding the 3.1 GeV particle caused by a mass discrepancy of some 10 MeV between the SPEAR measurement at Stanford and that indicated by DORIS. Some weeks later, Stanford adjusted their value downwards (as reported in the February issue). After this first success with PLUTO, three months were devoted to collecting data with ten million triggers and to gaining experience in the operation of the detection system. No difficulty was found in running the magnet together

The DESY/Heidelberg experiment installed in the southern intersection region of the DORIS electron-positron storage rings. The cylinder in the centre contains drift chambers and scintillation hodoscopes. On both sides of it, rows of sodium iodide and lead glass counters for energy determination and iron walls for muon filtering are visible. The positron beam is entering from the top of the photograph.

(Photo DESY)



with the stored beams. According to schedule, PLUTO was taken out of the area in February and work is now being carried out to improve the detector and its data handling system.

At the northern intersection region the double arm spectrometer, DASP, has been looking for the decays of the new particles. Its nonmagnetic inner detector has a high detection efficiency and good angular resolution for gamma rays of more than 100 MeV. It was therefore used to study neutral decays. No peak was found in $e^+ e^- \rightarrow \gamma\gamma$ at 3.1 GeV which supports the spin J = 1 assignment to the particle. Upper limits for the decay into two gammas, gamma and neutral pion, η_c and gamma can be derived from the data (reported in Physics Letters). η_c is a hypothetical heavy particle of mass greater than 2.6 GeV decaying into two gammas. Several events have been observed which are consistent with the decay.

The decays of the new particles into muon and hadron pairs have been investigated with the two magnetic arms of DASP. Covering a solid angle of 0.9 steradian they offer good momentum and time-of-flight resolution and good particle separation. Electrons and muons are separated from each other and from hadrons by shower and range counters. Pions and kaons can be separated up to 1.7 GeV/c, kaons and protons up to 3 GeV/c. The angular distribution of muon pairs at 3.1 GeV is consistent with a J = 1 particle. There is no significant forward-backward asymmetry and no pion pairs were found at 3.1 GeV. This is strong evidence for isospin I = 0. Also, no kaon pairs were seen but the decay into proton and antiproton has been observed.

Inclusive particle distributions were measured by triggering on a charged particle in one of the magnetic arms in coincidence with a charged particle or photon in the inner detector. The kaon/pion and proton/pion ratios are rising with increasing momentum.

The cascade decay of the 3.7 GeV resonance was studied by looking at muon pairs with an invariant mass of 3.1 GeV/c^2. In about half of the cases the muons were accompanied by two charged pions. Also events with two neutral pions and events with charged tracks and/or photons have been observed which cannot be classified as $\pi^+ \pi^-$ or $\pi^0 \pi^0$.

At 4.1 GeV some data has been taken and is awaiting analysis. In the near future the DASP team will concentrate on details of the 3.7 GeV particle. The inner detector will be completed in order to get a better photon efficiency at low energies.

The experiment of the DESY/Heidelberg group replaced PLUTO at the southern intersection point. Their apparatus aims to identify charged particles, to measure energies of positrons, electrons and gammas and to separate hadrons from leptons. To detect charged particles, an inner detector consisting of cylindrical drift chambers and scintillation hodoscopes is installed around the crossing point of the circulating beams covering about 85 % of 4π. The energy measurements are performed with sodium iodide and lead glass counters surrounding the inner detector. In addition, drift chambers are installed behind 60 cm of iron to identify muons. Data has been taken at total energies of 3.1 and 4.1 GeV and the group hopes soon to get information on inclusive gamma and neutral pion spectra and will look for gamma transitions.

Gordon Conference

A conference on 'High Energy Hadronic Interactions' will be held at Meriden, New Hampshire, USA from

18-22 August. It will be of the 'Gordon' type and has nine subjects — A theoretical introduction (H. Harari), An experimental overview (G. Giacomelli), The new particles (G. Goldhaber), Diffractive phenomena — experimental (M. Derrick), Diffractive phenomena — theoretical (M. Jacob), Single particle distributions (H. Sens), Correlations among produced particles (C. Quigg), Phenomena at large transverse momentum (L. Di Lella), A look forward (S. Wojcicki). Further information may be obtained from J. Lach at the FermiLab.

RUTHERFORD More light on accelerators

The possibility of using the light from high power lasers to accelerate charged particles was recently put forward by K. Mizuno, S. Ono and O. Shimoe (see Nature 17 January, page 184). With the high electromagnetic fields available with modern lasers, the tantalizing figure of 1 GeV/m was quoted as a potential rate of acceleration, leading to speculation on book-shelf accelerators being just around the corner. At the Rutherford Laboratory, the well-known accelerator theoretician J.D. Lawson has taken a look at this problem (Rutherford Lab. lecture notes RL-75-043) and, unhappily, he concludes that things are not quite so bright as they might first appear.

The idea seems to have been considered first by another Japanese physicist, K. Shimoda in 1962 and has been taken up several times since. Basically, it attempts to use the inverse of the effect seen in an experiment by E.M. Purcell and S.J. Smith in 1953. They fired 300 keV electrons along the surface of a diffraction grating (at right angles to the grating lines) and observed that light was emerging at angles calculable from the usual grating formula. This must decelerate the electrons since they are giving off energy. If we can send light back at the grating in the right way, perhaps we can accelerate particles along its surface?

Lawson first considered using a plane light wave and worked from there to set up appropriate conditions for acceleration. Maxwell's equations obviously impose limitations and a plane wave cannot accelerate particles in its direction of motion because its electric field is perpendicular to that direction. Tilting the wave through an angle overcomes this obvious restriction but accentuates the problem that the wave would be travelling faster than the particle and therefore could not consistently make the particle feel the accelerating field. A dielectic medium would slow the wave down and the associated light wave at its surface could then have the desired properties — some electric field pointing in a direction to accelerate the particles and keeping pace with the particles.

Unfortunately, there is also an unwanted electric field at right angles to the good direction and the ratio of this to the useful field increases with the energy of the particles. Very high energies could be ruled out. Using a diffraction grating rather than a dielectric slab doesn't improve the situation, its effect can be analysed as a combination of plane waves and waves of the type described above.

Bringing two gratings or dielectric slabs very close together and accelerating particles between them would make it possible to escape from the impasse since their accelerating fields would add while, on the symmetry plane, the unwanted transverse fields would cancel out. Away from the symmetry plane the transverse fields increase rapidly and would push the particles sideways out of the beam. To keep the sideways effect smaller than the forward accelerating effect, the gratings or slabs would have to be very close together. (Similar conclusions were reached by A. Lohmann in an unpublished IBM note as long ago as 1962.)

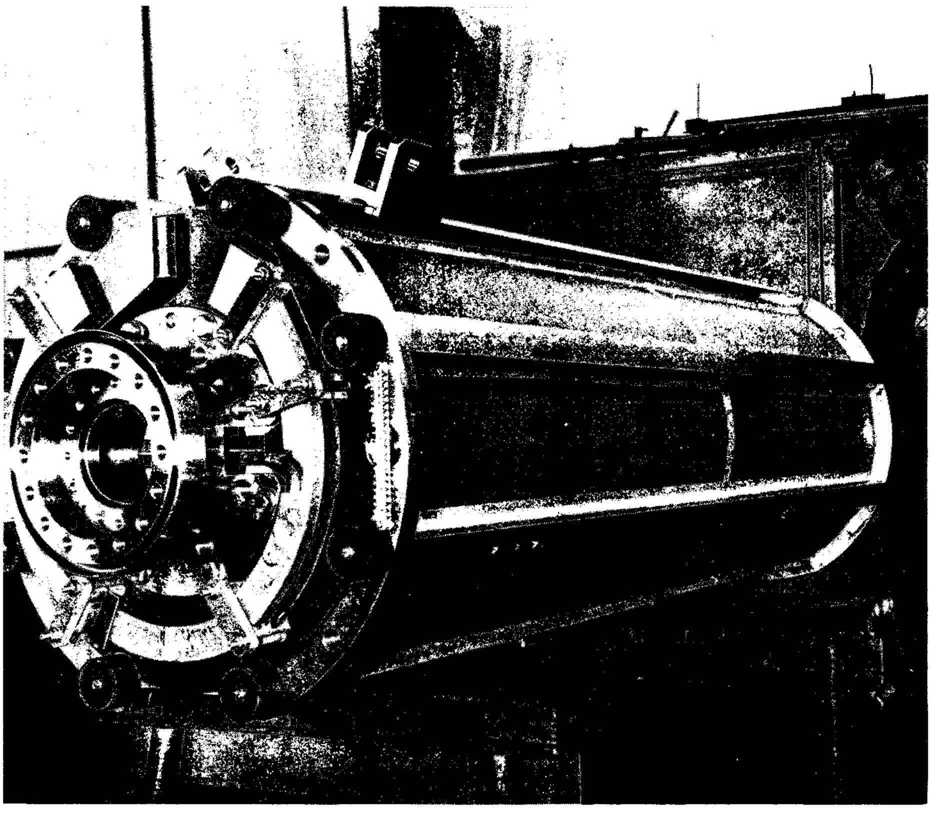
Lawson concludes that a miniature linac of tiny bore might be feasible with accelerating fields of about 200 MeV/m for pulses less than 1 μs long. With a high brightness electron microscope as source, it might yield a few nA of current.

'Non-synchronous' acceleration (where the charged particles get one sudden enormous boost in energy at a sharp laser focus rather than a consecutive series of energy nudges as laser light is applied along the length of a linac) might still be interesting but it is not clear how it could be used to make a useful accelerator. Nevertheless, the subject of particle acceleration using light is a very enticing one and worthy of serious attention.

WESTFIELD COLLEGE WES-POP

Stimulated by the success of AIX-POP, the science popularization exercise carried out during the particle physics Conference at Aix-en-Provence in 1973, Westfield College London took up the challenge of communicating the fascination of science in their own 'Carnival of Science — WES-POP'. The Carnival was initiated by E. Leader, who led the preparations with particular help from V. Bull, C. Cooke and M. Green.

A provocative publicity campaign preceded the Carnival day and the whole event was arranged to be light-hearted and yet to convey scientific principles. Participation of the visitors was encouraged with exhibits such as



The ALEC superconducting pulsed magnet before it was installed in a cryostat. The magnet has had its first tests at Saclay.

(Photo Saclay)

reaction timers, computer terminals, operable resonance systems, oscilloscopes, etc.... Spark chambers, light guides, lasers, holograms were inevitable attractions and communicated ideas on cosmic rays, light phenomena and so on. A link with the Rutherford Laboratory enabled the IBM 360 computer to play the Hampstead chess club. There was another link with a weather satellite. An exhibition of popular science books and a series of films rounded things off.

The Carnival was a great success with over 2000 people passing through, many of them enjoying themselves for hours. Anyone interested in mounting a similar exercise would do well to read an excellent report prepared by E. Leader.

SACLAY
Tests of new pulsed dipole

A pulsed superconducting magnet, known as ALEC, has reached its design field during tests at Saclay in March. ALEC is a prototype bending magnet such as could be used in a superconducting synchrotron having all the characteristics (with the exception of the length) suitable for a high energy machine. The peak central field is 5 T in an aperture 110 mm in diameter with a pulse repetition rate of 0.1 Hz (field rising at about 1 T/s).

The first tests were carried out using a temporary vertical cryostat where it was decided not to attempt to exceed the design field. The magnet trained and reached 5 T after 45 quenches. A life-test, pulsing up to 4.9 T at the design repetition rate, was carried out without problems for two hours. At no point did the superconducting coil go higher than 4.4 K in temperature (in agreement with the calculations) and the heat losses at 5 T and 0.1 Hz were about 400 J per cycle.

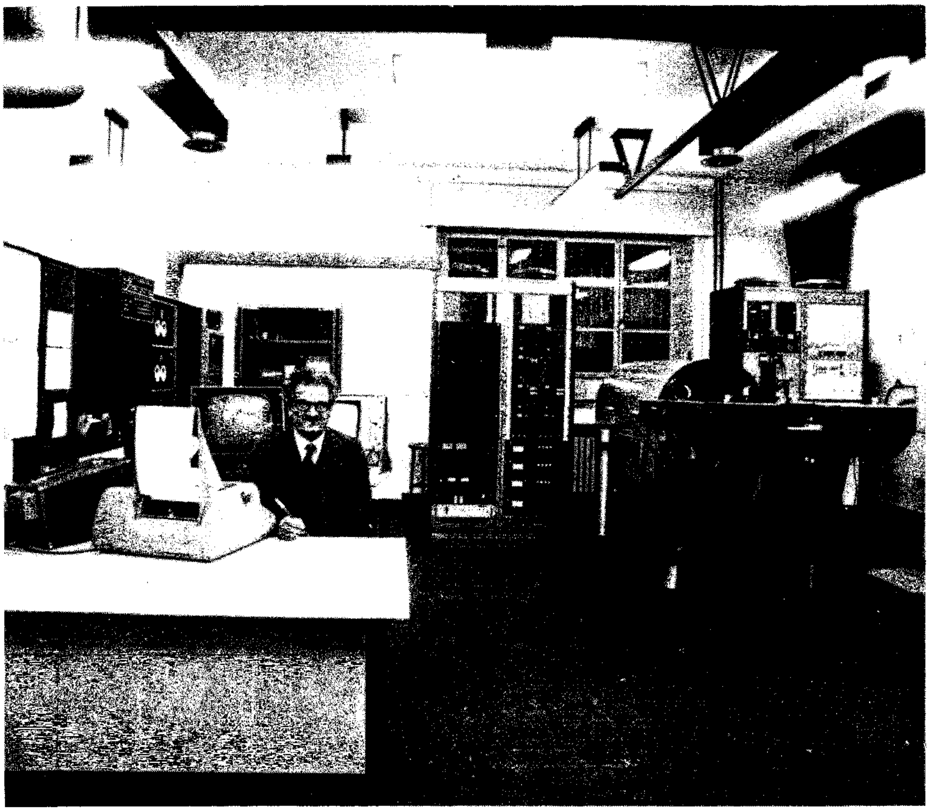
The ALEC programme is supported by the Délégation Générale à la Recherche Scientifique et Technique and carried out by the CEA Saclay Laboratory in collaboration with the CGE Group (Alsthom and Laboratoires de Marcoussis). The purpose of such a collaboration is to develop pulsed superconducting magnets in such a way that their manufacture can be taken over by industry.

The present magnet is the biggest of its type to be built and some of the design features are very different from those being adopted in other Laboratories. In particular, rather than attempting to constrain the superconducting coils to the maximum, they are held in a rather flexible configuration so that they can move under the influence of the electromagnetic forces. This flexibility eases the problem of the different thermal expansion coefficients of the materials used in the magnet construction which have to cool down to superconducting temperatures. Also it makes easy assembly possible — applying a small pressure to the coils they can be introduced into or removed from the iron magnet core.

The next step will be to feed the magnet into its horizontal cryostat and to test it again. This time a map of the magnetic field during the pulse cycle will be obtained.

PADUA
PEPR inauguration

The automatic film-measuring device PEPR, of the Italian Nuclear Physics Institute (INFN) was inaugurated at the Physics Institute of the University of Padua on 11 March in the presence of the staff and of the INFN Section and students. Members of other Italian



A general view of the Padua PEPR. On the left is the CRT system, in the centre is the modular digital controller and on the right is the computer and operator console.

(Photo INFN Padua)

groups and of the President of INFN, C. Villi, also participated.

The construction of PEPR started in 1971 and has been carried out in close collaboration with the Oxford Nuclear Physics Department where a PEPR was built some years ago (see August issue 1970, page 258). It was realized by the Padua 'strong interactions bubble chamber group' under M. Cresti, in collaboration with the INFN Section and the Physics Institute. The Directors of the Physics Institute, M. Baldo Ceolin and of the INFN Section, C. Ceolin spoke at the inauguration ceremony.

Many of the system's features have been designed to make PEPR capable of measuring film from large bubble chambers. The signal processor is almost completely digital and all the parameters of the system are controlled by software through a modular digital controller whose flexible structure allows for future modifications or expansions. PEPR is equipped with a hardware TV system, which has proved a very important tool both for hardware tests and in the production runs.

The cost has been kept low by building PEPR almost entirely in the laboratory and by connecting it to a computer of much smaller size than those used elsewhere in similar installations.

The system started production on a bubble chamber experiment in June 1974, producing 60 000 measurements of three prong events for which only the interaction vertex in one view had been predigitized. Recently a new type of measuring technique has been put into operation. The beam tracks are automatically found and followed by PEPR up to an interaction vertex, where the hardware TV system is used to ask the operator to record the topology of the events. In this way the total cross-section is measured at a rate of 150 to 200 events per hour. 20 000 events of this type have been measured.

The use of PEPR to measure pictures other than those from bubble chambers has also been studied. In particular, automatic measurement of the co-ordinates and magnitude of stars on astronomic plates and of the equal level curves on geographic maps have been shown to be feasible. This opens a new and very wide field of application.

BROOKHAVEN ISABELLE Summer Study

The 1975 ISABELLE Summer Study will be held at Brookhaven from 14-25 July. Its aim is to improve, reinforce or modify the concepts which have gone into the proposal for the construction of the 200 GeV proton storage rings, looking at the experimental physics as well as the machine design aspects.

The opening two days will be used to review the present status of the project and are open to all interested physicists. For the remainder of the time, participants will get their heads down on specific topics in working groups covering such things as Experimental insertions, Performance limitations, Stacking and acceleration, Electron-proton option....

Further information can be obtained from H. Hahn or G. Kalbfleisch at Brookhaven, A. Pevsner at Johns Hopkins or L. Sulak at Harvard.

FERMILAB Machine performance reaches new heights

The recent performance of the proton synchrotron at the Fermi National Accelerator Laboratory was reported by P.V. Livdahl in the opening paper of the 1975 Particle Accelerator Conference in Washington, 12-14 March. The accelerator now has 70 completed experiments under its belt and another 36 are under way. They involve physicists from 68 research centres in the USA and 43 from other countries.

For the month beginning 14 February the machine had a very successful run at 380 GeV rather than its usual peak energy of 300 GeV. Operation at the higher energy came on very smoothly in comparison to previous attempts and intensities of over 10^{13} protons per pulse were reliably available on a 15 s cycle with a 1 s flat top.

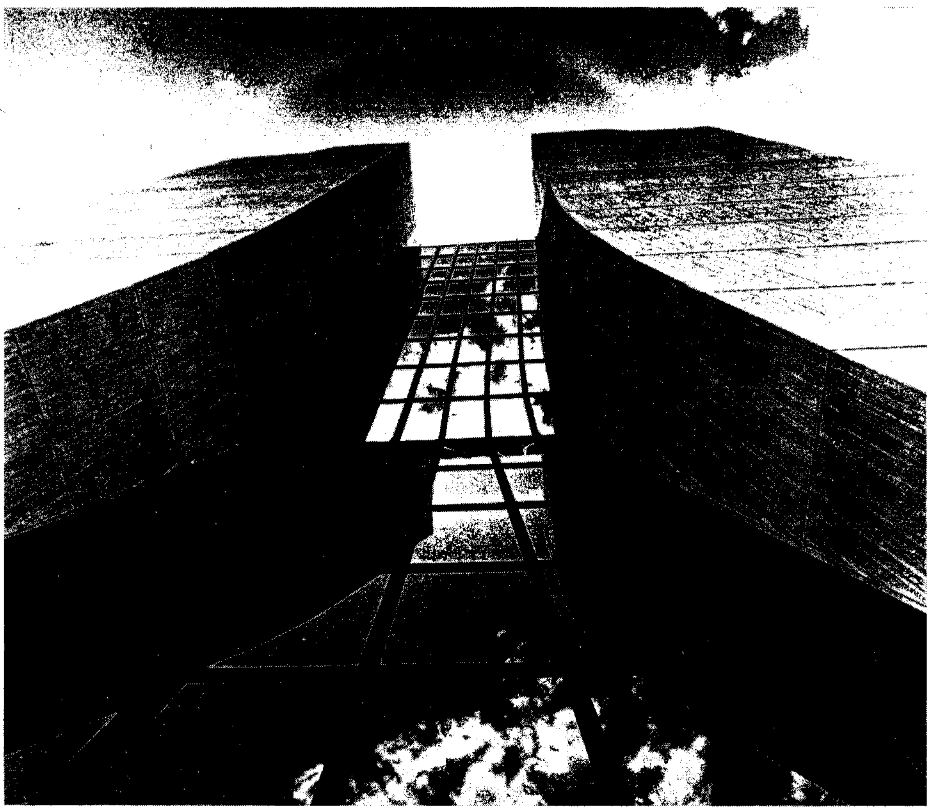
Improvements in the power supply program made a major contribution to the performance. The new program, controlled by on-line computer, generates new cycles for the magnet currents much more rapidly.

It learns from pulse to pulse to adapt currents to achieve a smooth field rise and after 20 pulses or less is ready with a new cycle. It can also switch in reserve regulating supplies if trouble develops in any of the supplies. Overall machine reliabilities are up to 70-75 % and magnet breakdown rates are down to about one per six weeks.

So as not to overstep the power rating of the feeder cables, the experiments which were to receive particles from the 380 GeV protons had to be carefully selected. The Proton Area, for a photoproduction experiment related to the new particles, and the Neutrino Area for neutrino and muon experiments and experiments in the 30 inch chamber received beam.

The problem of shunting power around is under attack with the project to build a superconducting transmission line (see September 1974 issue, page 289). Tests have been carried out on prototype sections and the first commercially built sections are now available. Superconducting pulsed magnets continue to improve in the development programme aimed at producing magnets capable of 4.5 T for use in an Energy Doubler/Saver with energy capability up to 1000 GeV. A prototype (75 cm long) achieved 4 T in January and a 3 m model operated at 2 T. A 6 m model is installed in a refrigeration loop to test cryogenic aspects of the proposed system. More refined models are under construction using better superconductor.

A move to still higher accelerator energies should not be far away. A new series capacitor is completed and a 500 GeV run awaits the recommissioning of a damaged transformer. On the intensity front a series of improvements in the 8 GeV booster and the main ring should continue the climb beyond the present peak of 1.5 × 10^{13} protons per pulse.



Always a delight to the eye — here is another view of the 'Hi-rise' at the FermiLab. This is taken up the front face of the building with clouds reflected in the huge windows and the sun sanctifying the construction with a halo.

(Photo FermiLab)

Development of the COURIER

One of the topics which found its way onto the agenda of the meeting at New Orleans (reported on page 118) was that of international communication in high energy physics. Under this heading, the COURIER was given an airing in unusually august company.

As readers are well aware, the COURIER has progressively evolved to include news of other Laboratories, in addition to CERN, and to report the major events in the field of high energy physics no matter where they occur. CERN proposed at the meeting that the COURIER could help further in international communication if this trend continues to develop. The proposal was enthusiastically received and to implement it, the Laboratories are ready to participate more actively in providing information for the journal. Also, to improve the dissemination of the information in the different regions, the distribution of the journal will be handled locally in several countries.

During the course of this year, it is hoped to establish all the mechanisms to bring this further development about smoothly. Their effect is likely to be seen progressively through to the end of the year and we hope to have all systems 'go' by the beginning of 1976.

We will, of course, do our best to ensure that manoeuvres at the editorial end of the journal do not disturb the calm at the readership end — other than to extend and improve the quality of the information.

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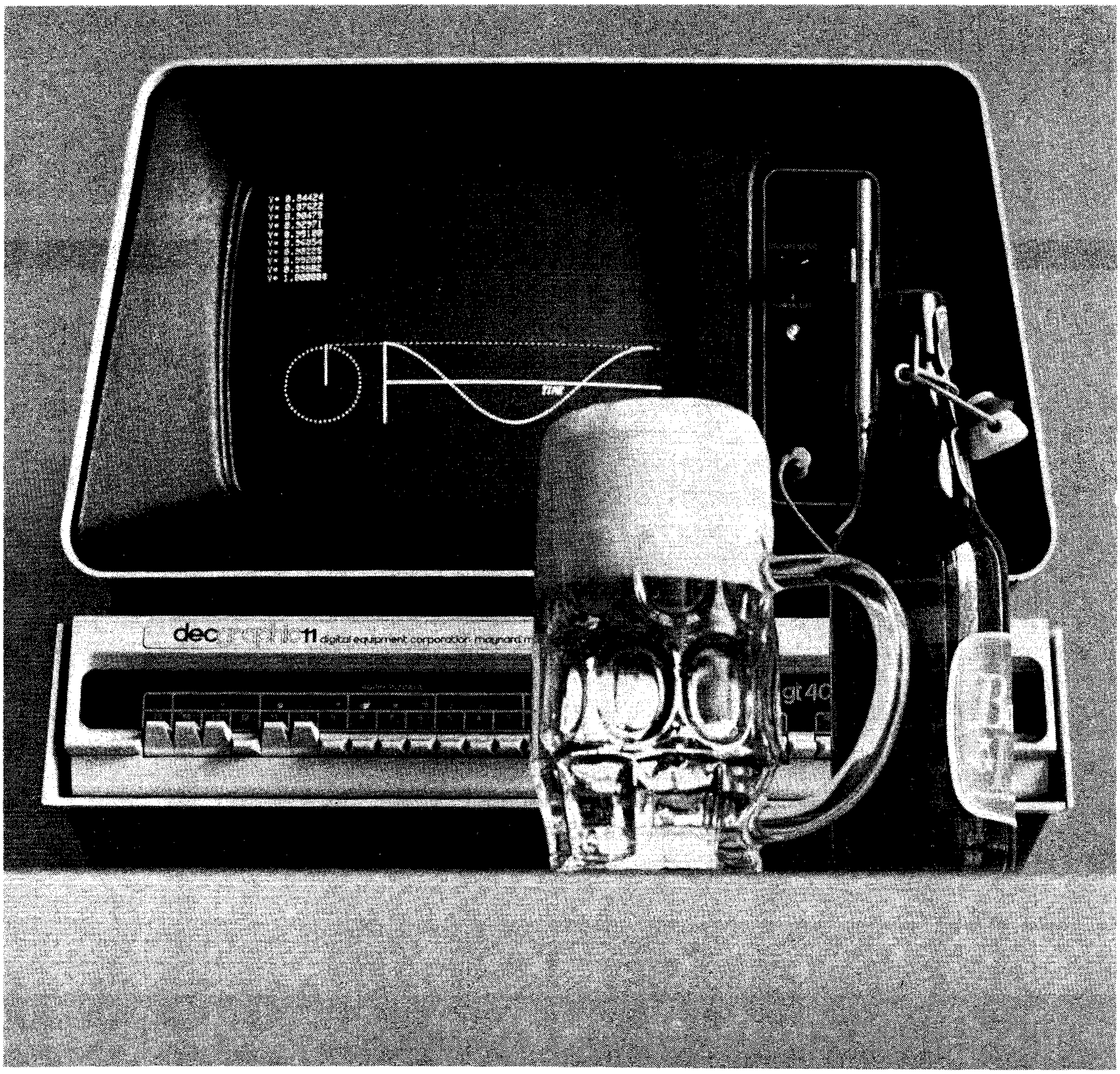

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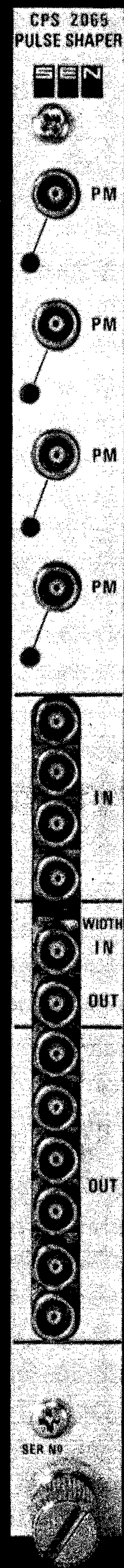

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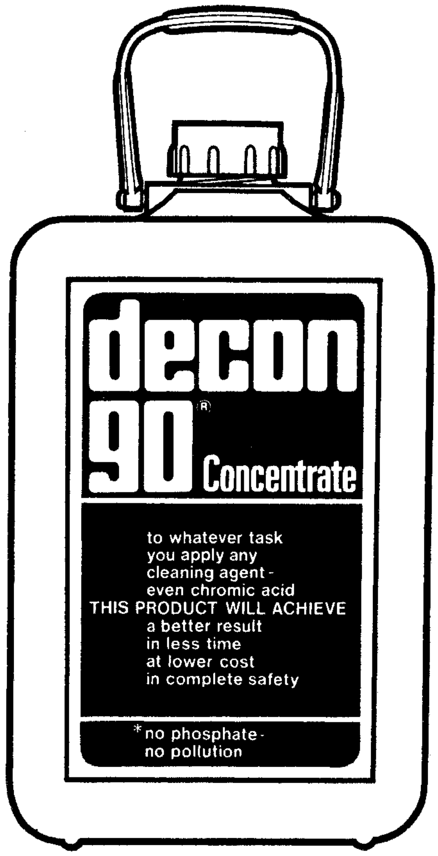

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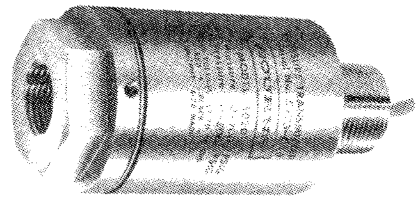

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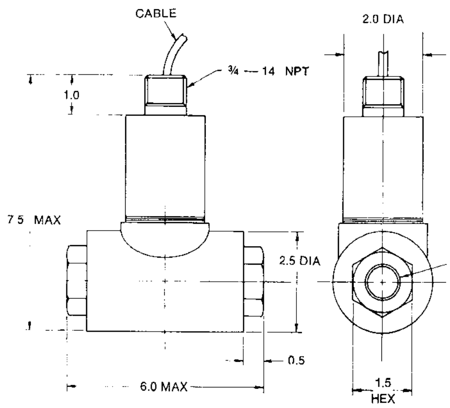

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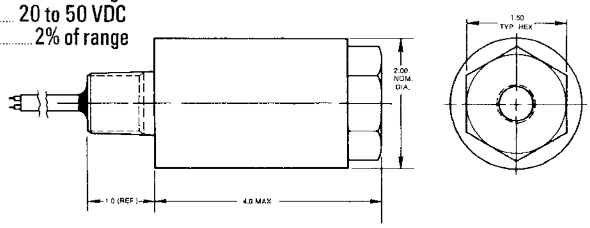

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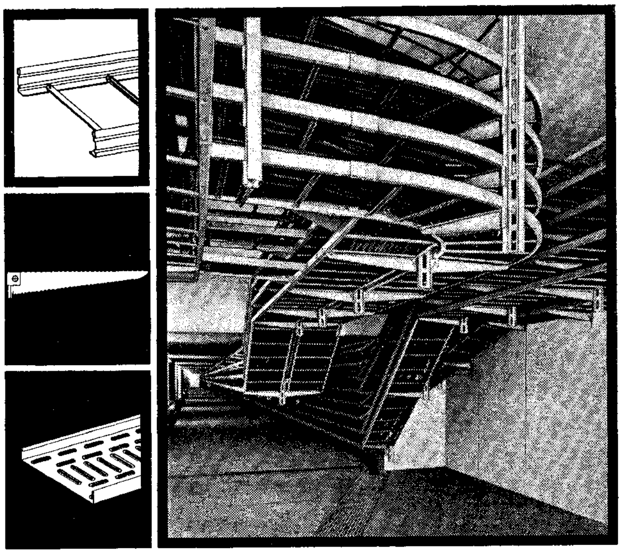

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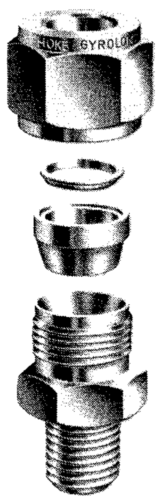

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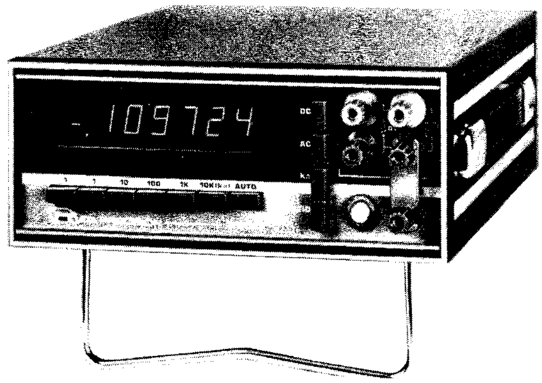

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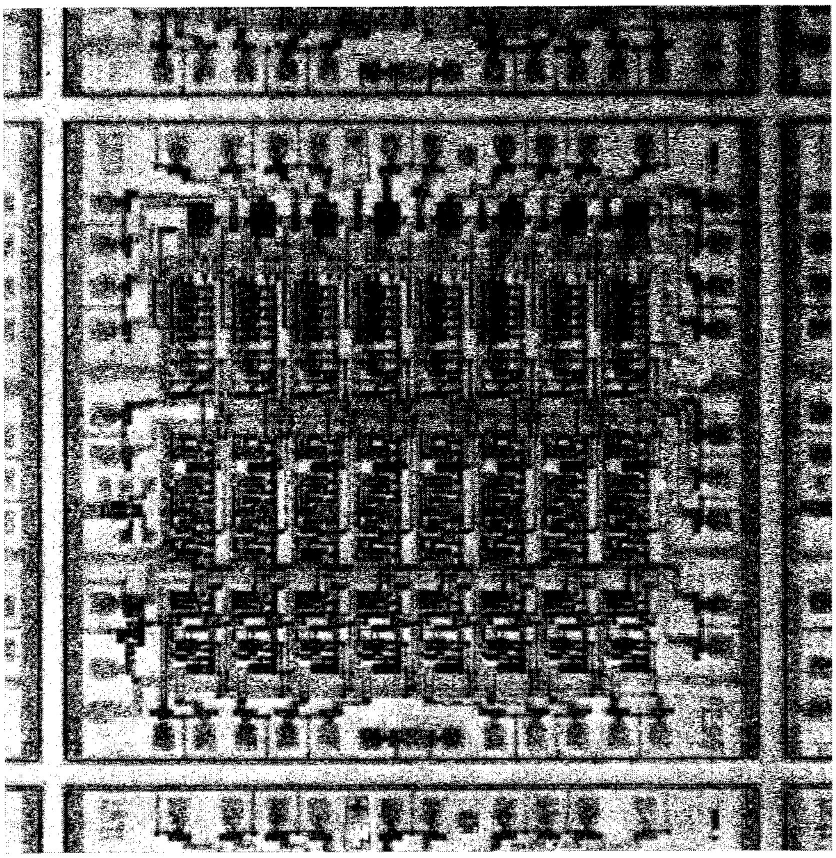

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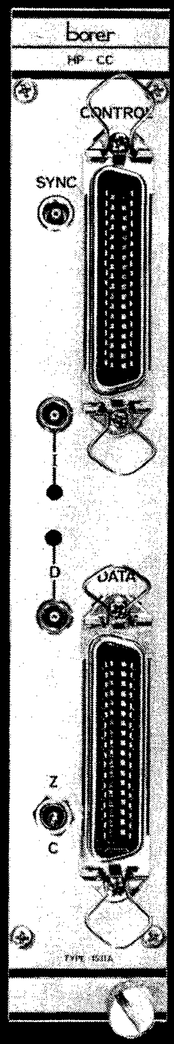

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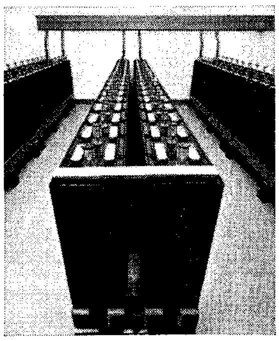

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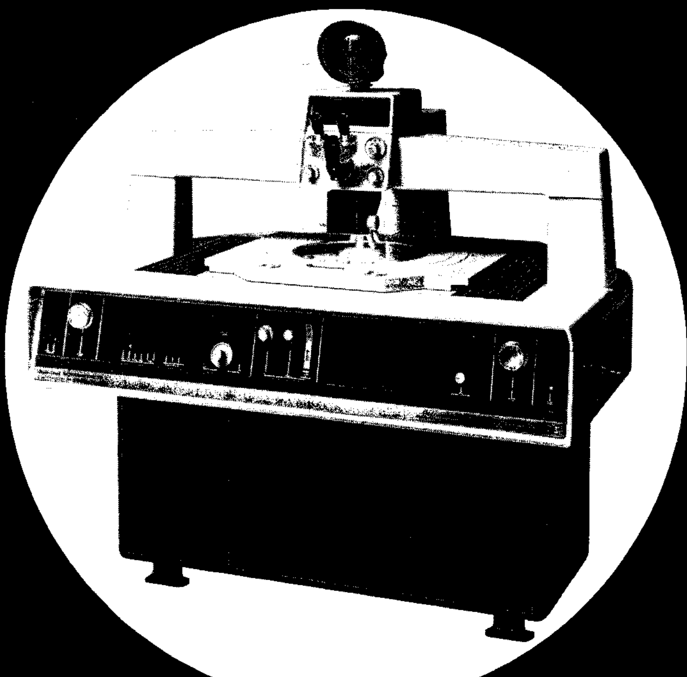

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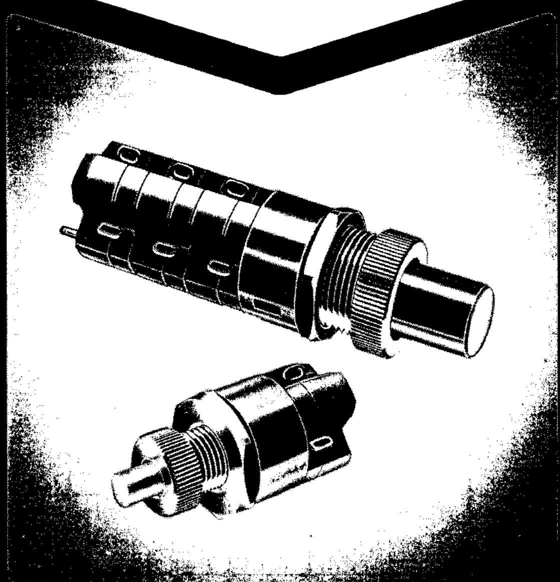

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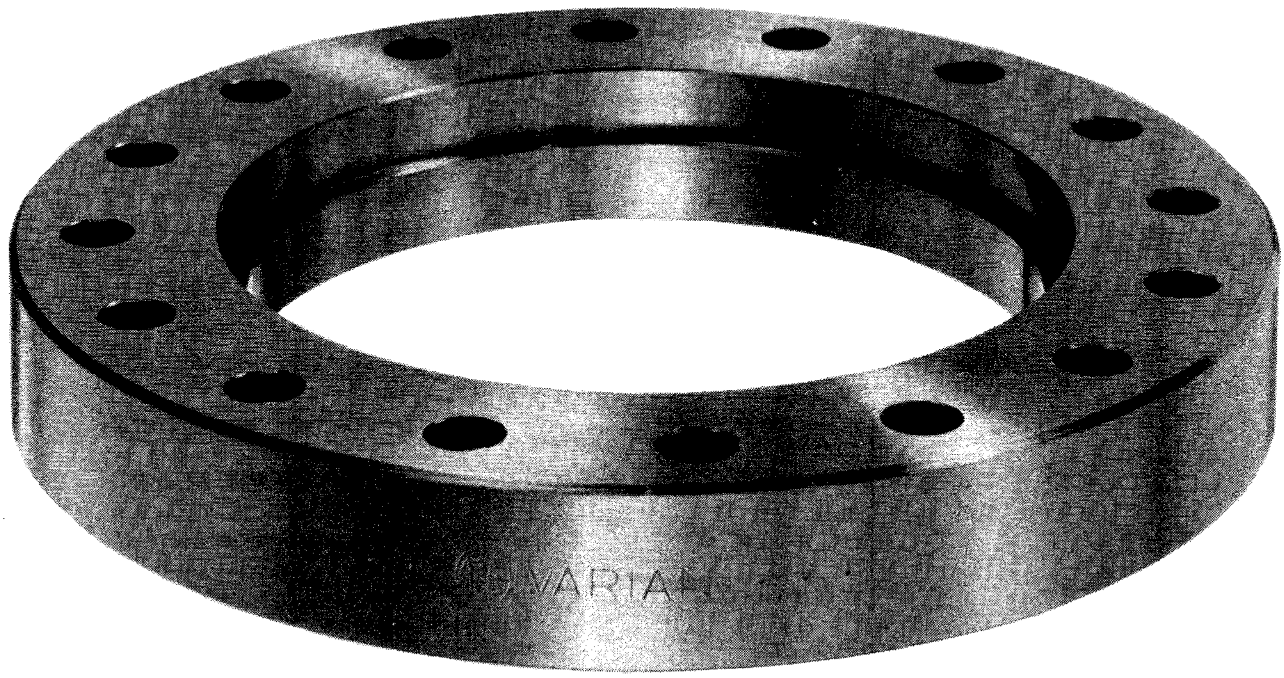

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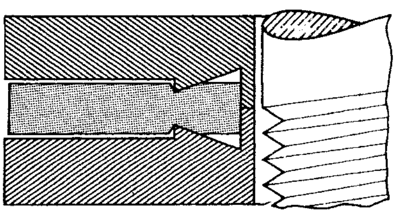

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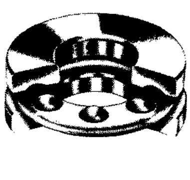

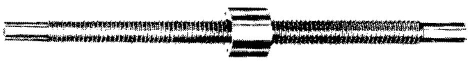

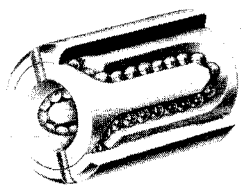

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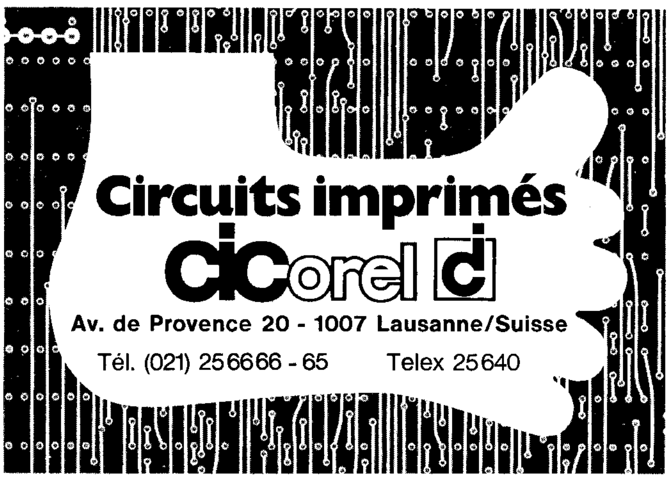

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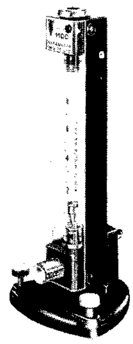

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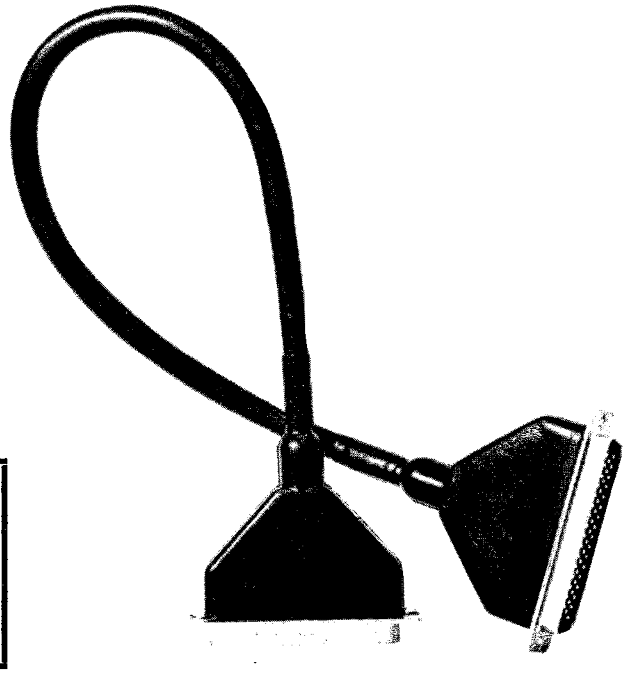

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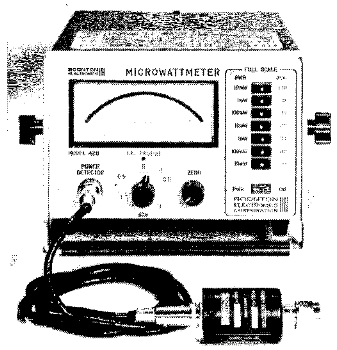

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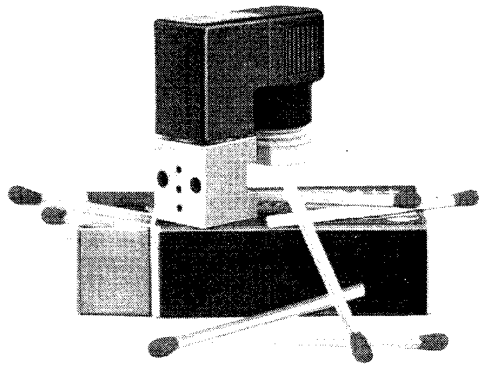

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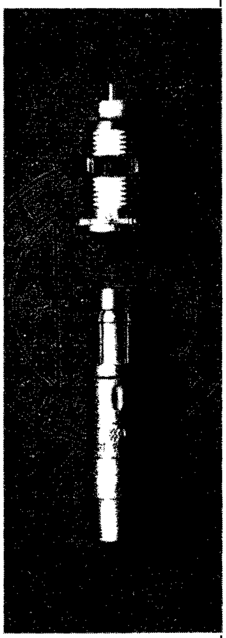

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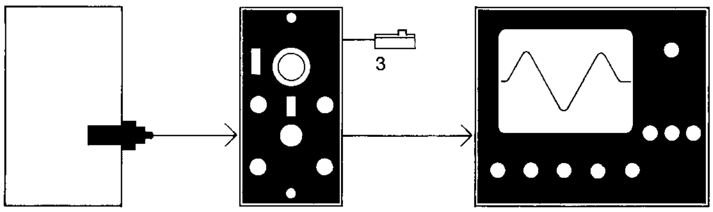

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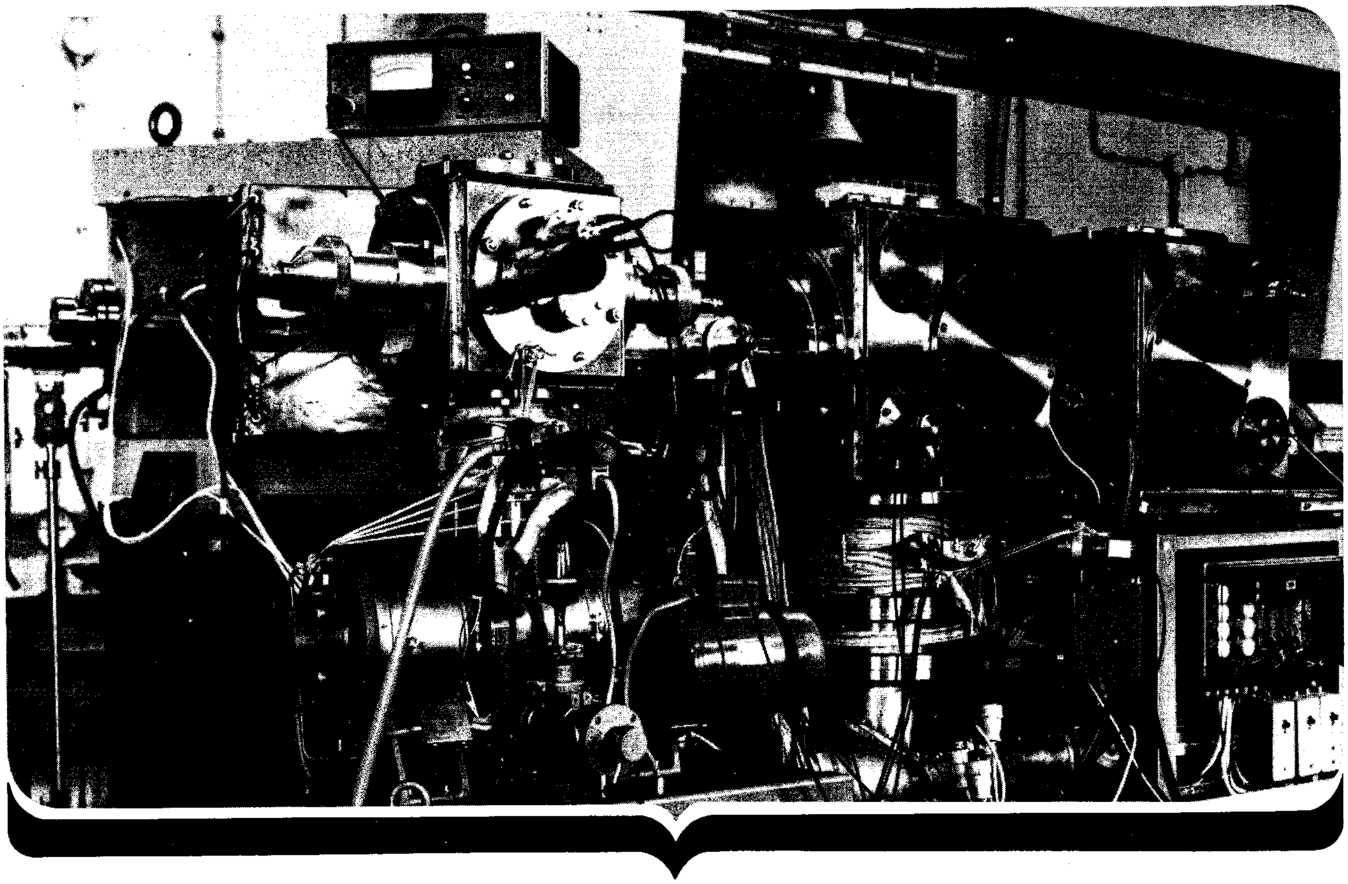

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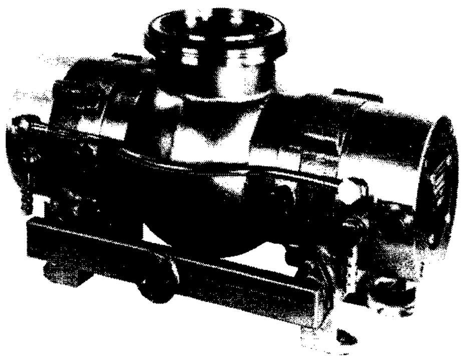

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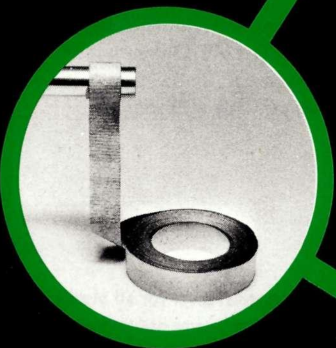

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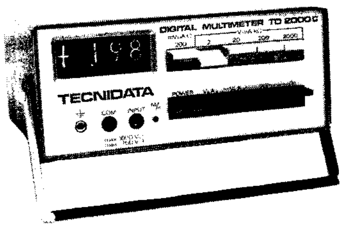

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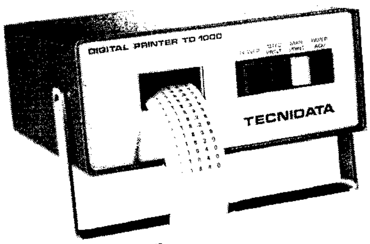

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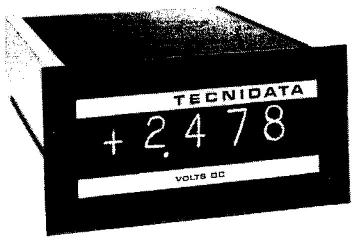

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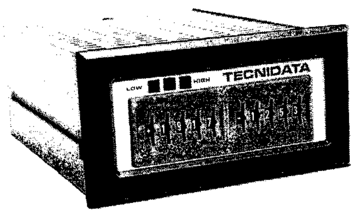

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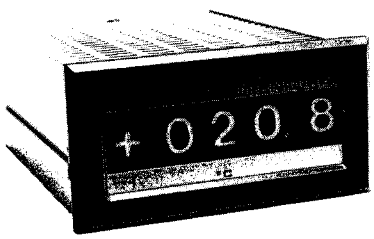

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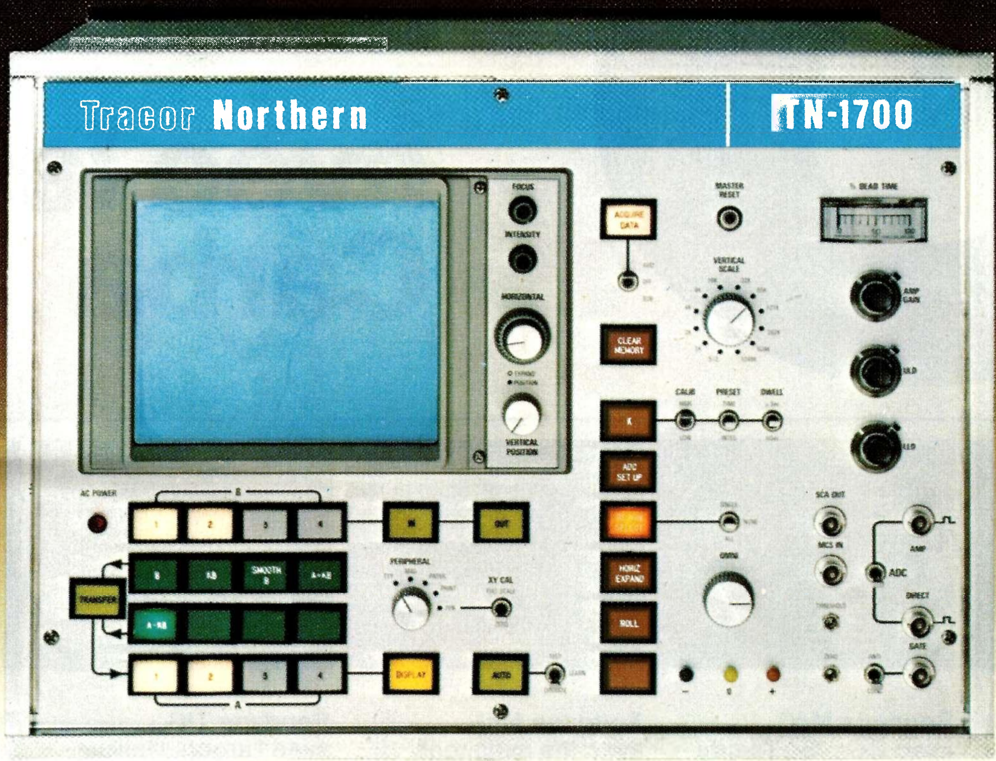

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- Parallel or Line Printer

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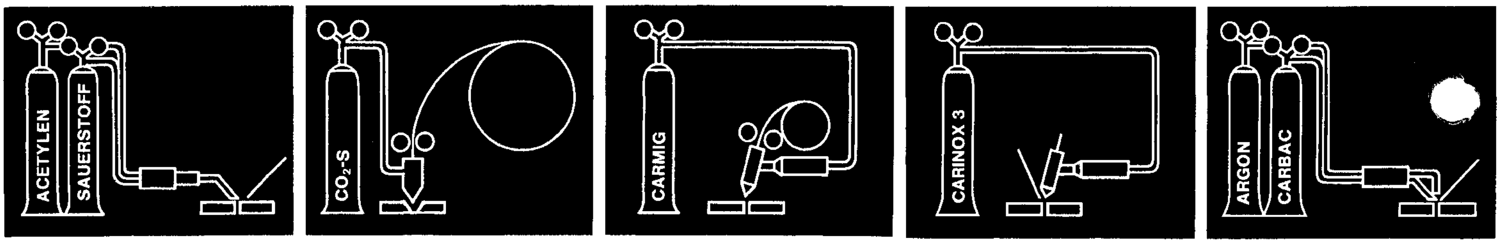
5 Procédés de soudage avec les gaz Carba



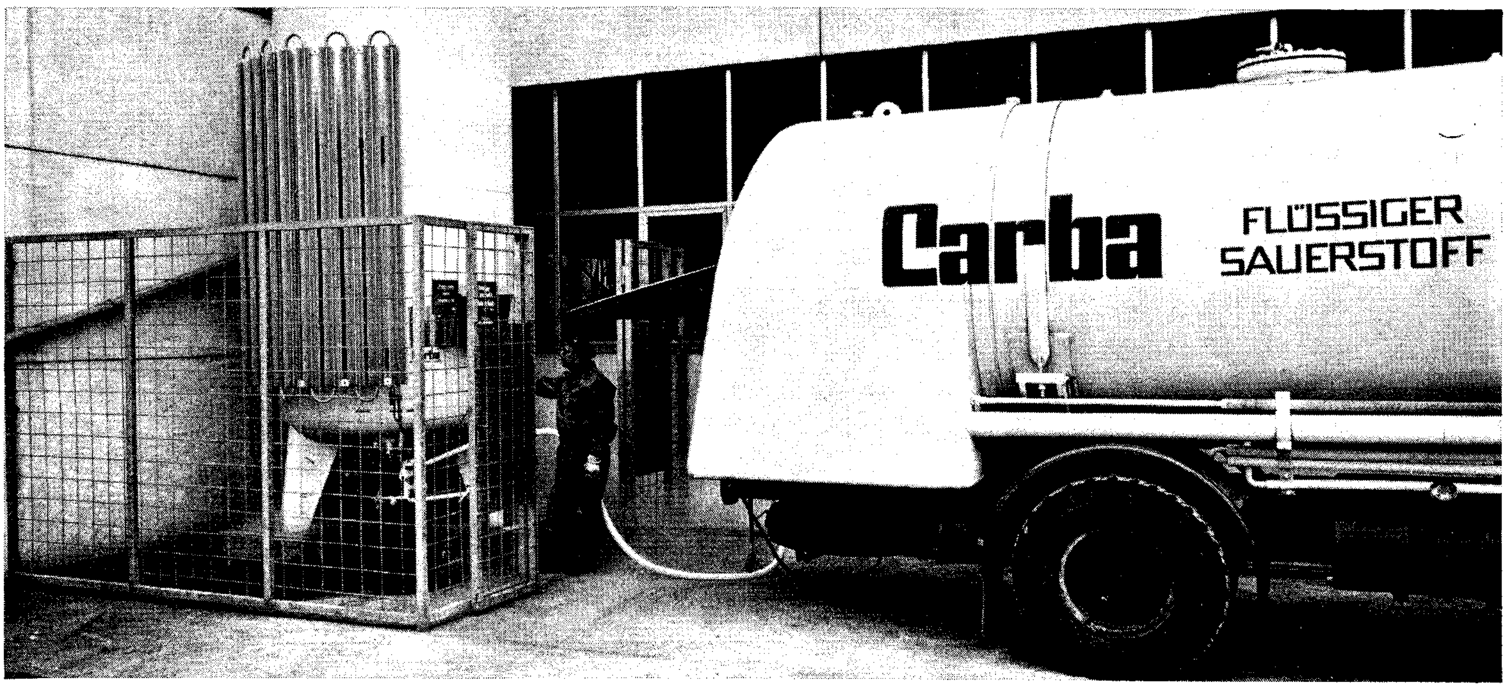
Techniques autogènes
avec l'acétylène-dissous et l'oxygène
soudage: tôles minces, tubes, métaux non ferreux
brasage, oxycoupage, chauffage, redressement, trempe, projection et décapage à la flamme.

Soudage MAG
avec CO_2 "S", l'acide carbonique de Carba avec pureté garantie
pour: les aciers de construction, les aciers chaudière, les tubes, les aciers à grain fin.

Soudage MIG
avec les mélanges Carba (Carmig, Carmox, Carinox 4, Carbac 30) l'argon et l'hélium
pour: les aciers faiblement et fortement alliés, l'aluminium, le cuivre et leurs alliages.

Soudage TIG
avec l'argon, l'hélium, Carinox 3 et Carbac
pour: l'aluminium et ses alliages, les aciers inoxydables de toutes compositions, les métaux cuivreux et à base de nickel, le titane et d'autres métaux spéciaux.

Techniques Plasma
Soudage, coupage, rechargement par projection
avec Carbac, l'argon et d'autres mélanges
pour tous les métaux



Carba

Berne Bâle Zurich Lausanne