CERN COURIER

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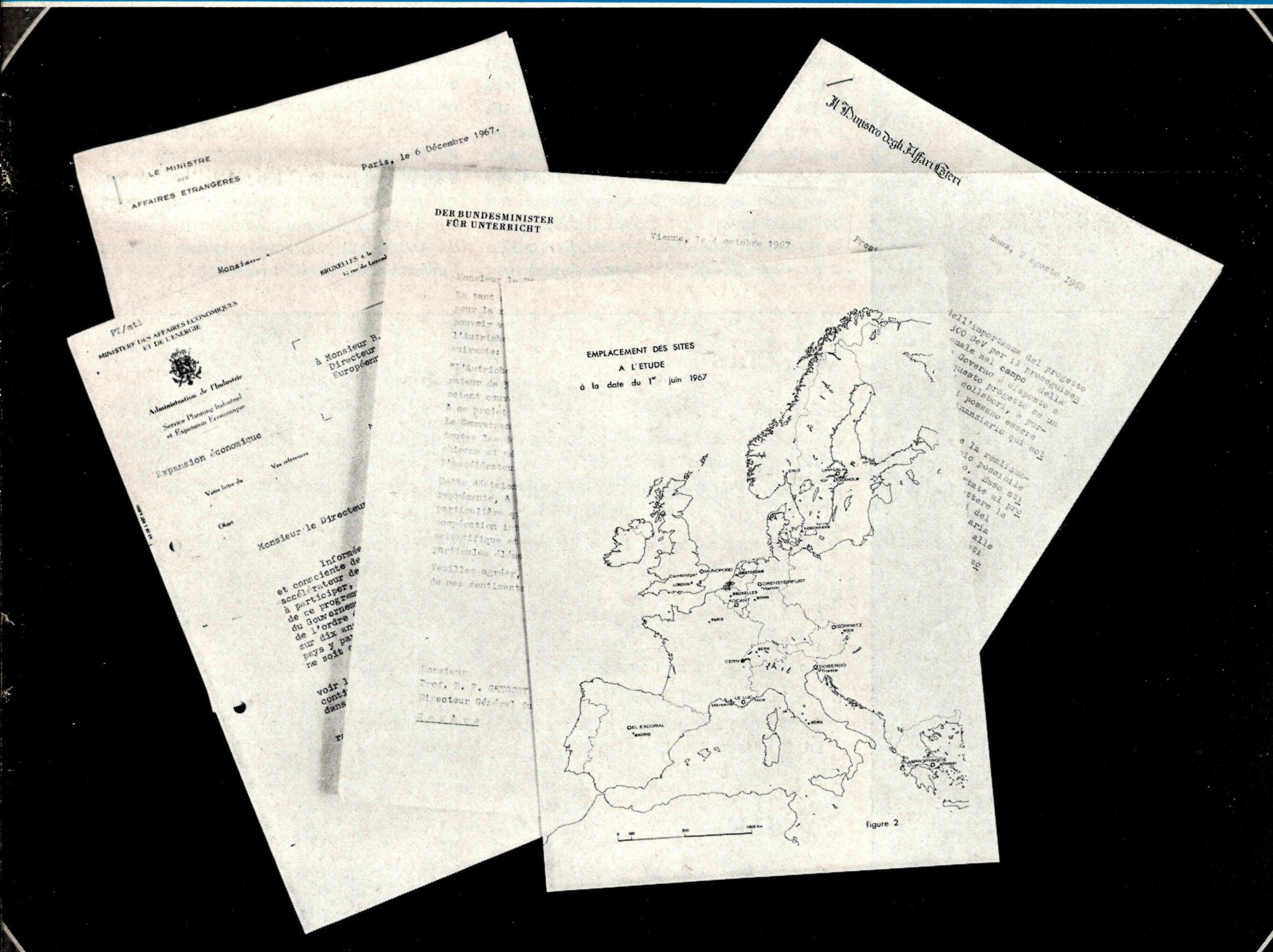
European Organization for Nuclear Research



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. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 700 physicists outside CERN are provided with their research material in this way.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2600 people and, in addition, there are over 400 Fellows and Visiting Scientists.

Thirteen European countries participate in the work of CERN, contributing to the cost of the basic programme, 197,5 million Swiss francs in 1968, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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CERN News

Letter of Intent from Italy

On 13 August, Ambassador G. Smoquina, Head of the Italian permanent mission to the international Organizations in Geneva, brought to CERN a letter of intent announcing the willingness of his government to participate in the 300 GeV project. Italy thus becomes the fourth European country to declare itself in favour of the project, joining Austria, Belgium and France.

The announcement from Italy is doubly welcome — for itself, and as an indication that other Member States retain confidence in the project following the decision of the United Kingdom government, in June, that it is unable to participate at this time. It is worth adding here a note of hope from a discussion on the 300 GeV project held in the UK parliament on 24 July. Mrs. S. Williams, Minister of State for Education and Science, concluded her remarks with the words, 'We hope that our decision will not discourage other European States from going ahead with the project if they decide to do so, for it is our view that that would leave the possibility open, should our circumstances later permit, for our joining perhaps at a later stage.'

Italy is one of the major contributors to the present CERN budget (11.24%) and is one of the countries with a site, at Doberdo near Trieste, which is under consideration for the new Laboratory.

In the light of the UK decision a revision of the project is under way and will be presented to the CERN Council at its next meeting on 2 October. The revision takes advantage of the smaller number of participants to reduce the initial annual budgets for the project so that, financially, the situation for the participating countries will remain as it was before the UK withdrawal. The revised version will, however, not compromise the fundamental scientific value of the machine or its ultimate capacity for exploitation.

In the letter from Italy, Mr. G. Medici, the Minister for Foreign Affairs said, 'I am happy to confirm the intention of my government to participate in a project which is destined to maintain for Europe its traditional supremacy in the field of fundamental scientific research.'

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Cover photograph: Four letters of intent to participate in the 300 GeV project lying with a map of Europe on a table in the Director General's office. (CERN/PI 62.8.68)

The first two magnet cores for the intersecting storage rings arrived at CERN from the manufacturers, ASGEN, on 13, 14 August. They are the first of 400 of these magnets which will be used to build up the two interlaced rings. Each of them will be tested in the West experimental hall and the equipment for this has already been installed. The hall itself is nearing completion. The magnet section of the ISR Division has moved over to the ISR site.

The following five items concern improvements around the proton synchrotron taking place during the present shut down.

'Straight flush'

From the beginning of the year until the shut down of the proton synchrotron on 27 May, the performance of the kicker magnet of the fast-ejection system in straight section 97 had been very satisfactory; the time lost through breakdowns was less than 0.3 %. Previous difficulties with the hydraulic ram, which, in about a tenth of a second, pushes the magnet into its position around the beam with an accuracy of a few millimetres, have now been almost completely eliminated.

During the shut down a number of improvements have been made to the kicker magnet system. They have been mainly concerned with the magnet power supply and have considerably increased the versatility of the fast ejection system.

Previously, it was possible to select for ejection, combinations of 1, 2, 3, 4, 5, 6, 17, 18, 19, or 20 bunches from the twenty bunches of protons orbiting the machine. Furthermore, the selection of a combination could only be done once per cycle, so that, for example, it was impossible during one cycle to send three bunches to one experiment and then three to another. It is these limitations which have now been overcome.

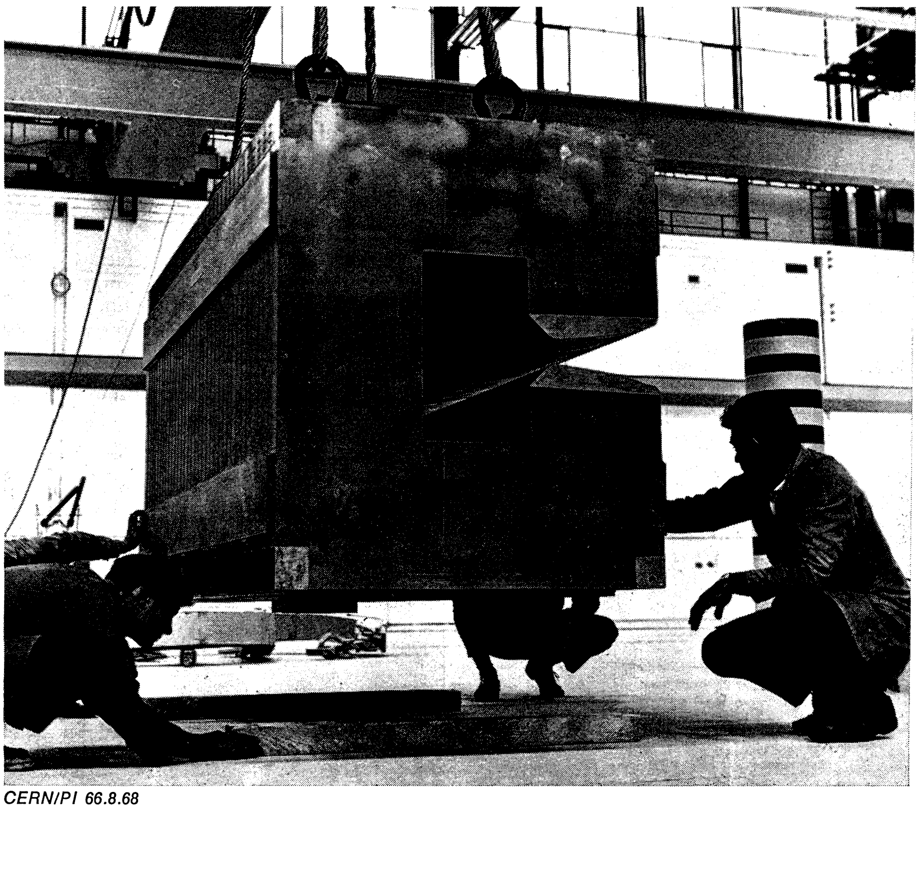
The pulse fed to the magnet is produced by discharging a line and the discharge time obviously varies considerably between the ejection of twenty bunches and of one bunch. In the old system, two separate lines were used: one to give a pulse length equivalent to the ejection of six bunches and the other equivalent to twenty bunches. The discharge time for a given line could then be shortened to some extent, to make it possible to select from 1 to 6 and from 17 to 20 bunches. Changing from one line to the other could only be done manually and, as this involved going inside the PS tunnel, operation of the machine had to be stopped for up to 15 minutes at each change over. The time taken to charge the line was of the order of a second, so that not more than one discharge to power the magnet could be used during the flat top of the PS cycle.

The new power supply uses only one line but enables any number of bunches between 1 and 20 to be selected. The line provides a pulse long enough for the ejection of all twenty bunches and a spark-gap between the line and the magnet can be fired to short-circuit the pulse to give the desired pulse length at the magnet. This can be programmed in advance and any changes do not require manual intervention.

A further improvement is that the line recharging time has been reduced to less than 300 ms, so that at least two pulses can be produced per cycle. It will be possible to provide the hydrogen bubble chamber, for example, with at least two pulses per cycle; similarly, a large number of bunches per cycle could be sent down the neutrino beam line, while retaining a few bunches for another experiment.

Another refinement concerns improved control for reversing the magnetic field in the kicker. Previously an operator was needed to reverse the field but it can now be done automatically and programmed in advance. The switching time has been considerably reduced and it is possible to reverse the field during a cycle, so that some of the proton bunches can be deflected towards one septum magnet and, after reversing the field, the rest can be deflected to another, perhaps thus feeding experiments in different experimental halls.

With all these possibilities now available, the system has earned the nickname 'straight flush'.

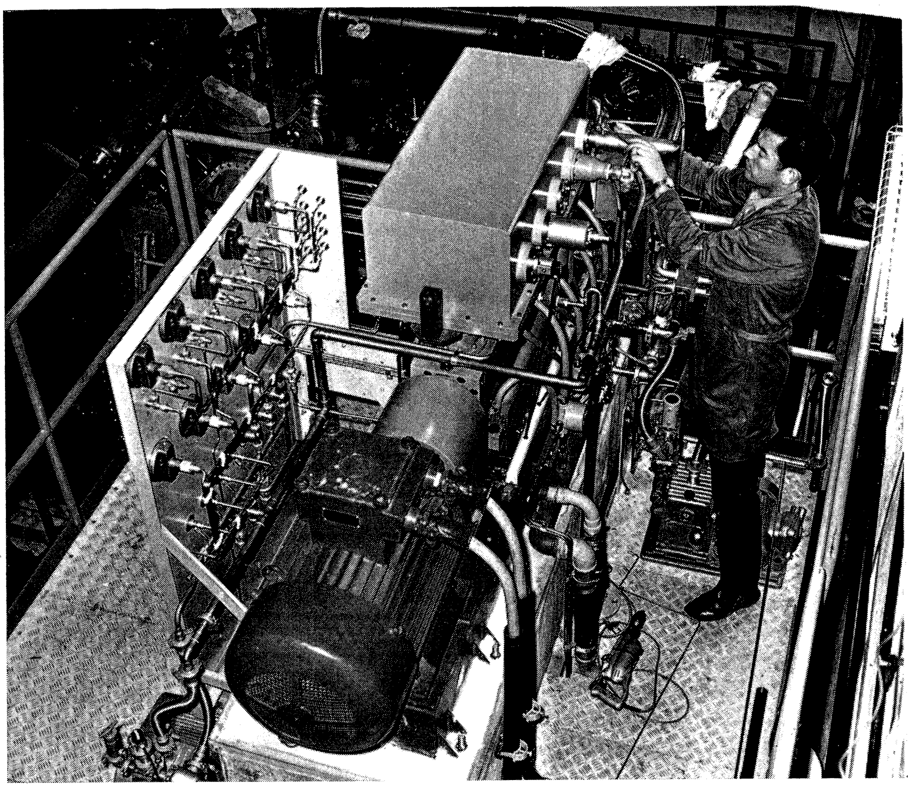


CERN/PI 66.8.68

Measuring the beam radius

When protons have a certain energy, they follow an orbit in the magnetic field of the synchrotron, whose average radius is directly related to the frequency of the r.f. accelerating system.

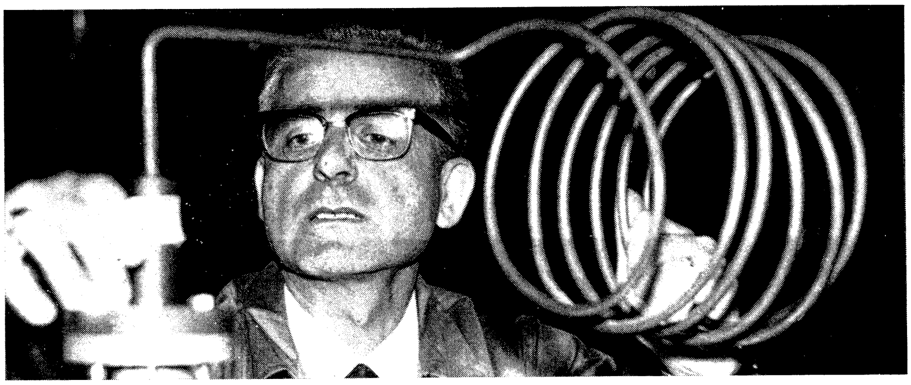
This relationship has been used at the proton synchrotron to measure the average radius. A system of electronic circuits calculated the radius knowing the beam energy and the r.f. frequency. It has thus been possible to obtain readings in the Main Control Room of the position of the

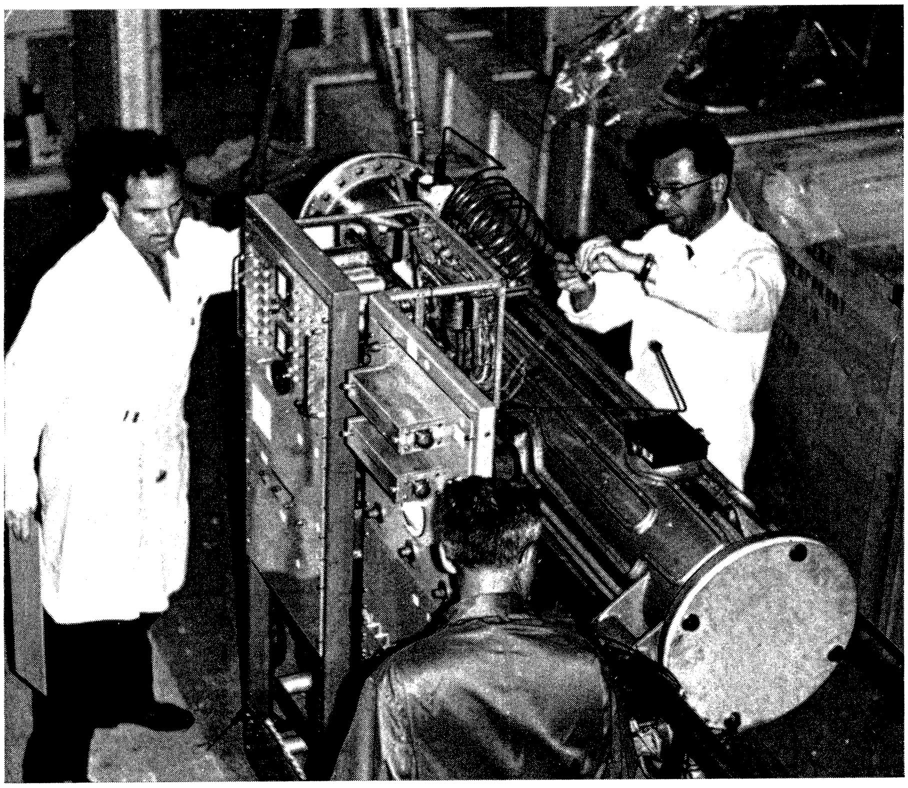


CERN/PI 250.7.68

The new liquefier to supply the 81 cm hydrogen bubble chamber with liquid hydrogen.

Below, two photographs taken in the experimental hall at Serpukhov when the CERN-Serpukhov experiment was being set up.





beam in the vacuum chamber of the machine. The system has been in operation since 1961.

The acceleration frequency was compared with a reference frequency (selecting from six reference frequencies depending upon the energy range being examined). To achieve an accuracy of about 0.1 mm in the position of the average radius, the measuring time was about a hundredth of a second. The measurement was, however, only precise at 22 GeV, and the error increased the further one went from this energy, due to the use of a fixed measuring time.

In May 1968, following a proposal by E. Schulte, a new method for determining the frequency difference by measuring the period rather than by counting the number of oscillations, was adopted. A prototype was brought into operation quickly to gain some experience of its performance before the shut down began on 27 May.

The new method has shortened the measuring time to about a thousandth of a second while still achieving the same accuracy and, by using a frequency synthesizer, it is possible to perform accurate measurements at any energy above 5 GeV (the transition energy). The reduction in measuring time is particularly important because the beam can change its position in the machine considerably in a hundreth of a second.

When the machine comes back into operation in October, the measurements from the new system will be available as a numerical read-out in the Main Control Room.

New hydrogen liquefier

Up to the time of the PS shut down in May, the liquid hydrogen used in the 81 cm bubble chamber was produced at a central liquefying station and taken to the chamber in dewars, from which it was distributed by long transfer lines. The losses of liquid hydrogen involved on this process, as the liquid was converted into gas by heat, represented more than a quarter of the total consumption and the gas had to be returned to the central station through a long underground conduit.

Recently, a great deal of progress has been made in the design of liquefiers, *1: New beam-observation station. Twenty stations of this type are being installed around the synchrotron ring. The unit on the right remains virtually unchanged, but the electronic units (a valve pre-amplifier in the centre and a variable-gain transistorized amplifier on the left) are new. The units were developed in the Proton Synchrotron Division and they are a considerable improvement on those previously used.*

2, 3: Photographs taken in the 1 m model of the European bubble chamber during its first run (see vol. 8, page 129). On the left are tracks of Compton electrons using a gamma source close to the chamber. 'Bright-field' illumination is used (the tracks appear black on a white background). The gamma source is not pulsed or synchronized with the bubble chamber cycle which accounts for the large number of parasite bubbles and tracks. The black regions correspond to areas of the chamber seen by the camera which are not covered by Scotchlite; the white flare is a direct reflection on flash illuminating the chamber. On the right, is a photograph taken during one of the first tests ever made of the use of laser beams in a bubble chamber. The beam crosses the chamber at right angles to the axis of the camera and the black region in the centre is due to a thermocouple attached to the camera lens. These tests are investigating the possibility of using crossing laser beams to fix the fiducial marks (the distance measuring reference points) in a chamber. A continuous emission argon laser (4880 Å) built at the Institut für Angewandte Physik, Heidelberg, was used.

and there are now machines available that are lighter, less bulky and easier to maintain. It was decided in June 1967 to install one of these machines close to the 81 cm chamber and this has been done during the shut down. The initial trials on the machine were satisfactorily completed on 15 June and the liquefier will be fully operational when the PS is restarted in October.

The advantage is threefold : it relieves the central liquefying station the capacity of which became inadequate with the bringing into operation of the 1 metre model of the large European chamber (see vol. 8, p. 129); there is no need for dewars, with all the handling involved; the liquid hydrogen consumption is reduced.

The assembly

To keep the liquid hydrogen in the 'useful volume' of the bubble chamber at its operating temperature of about 26°K, cooling is required to compensate for the heat produced by the movement of the piston and for heat transferred. The temperature is controlled by means of an intermediate hydrogen circuit, the 'jackets', surrounding the useful volume of the chamber. Excess heat in the chamber is transferred to the 'jackets' which, in turn, pass it to an external circuit connected to the liquefier.

This external circuit is closed. The hydrogen liquefied by the machine passes to the exchanger of the chamber, where it is heated and reverts to the gaseous state. It then returns to the machine to be liquefied again, and so on. The operating pressure is close to atmospheric.

The flow of liquid hydrogen is effected by gravity, and the first thing that strikes the eye in the bubble chamber hall is the sight of the liquefier perched six metres above the ground on a pile of concrete blocks.

The liquefier

The liquefier was manufactured by Philips in the Netherlands. It is driven by a 45 kW synchronous motor and has a capacity of about 35 litres per hour at 20°K, representing an average power of 310 W. The overall efficiency is therefore no more than 7‰, but this is a normal figure for a cryogenic installation.

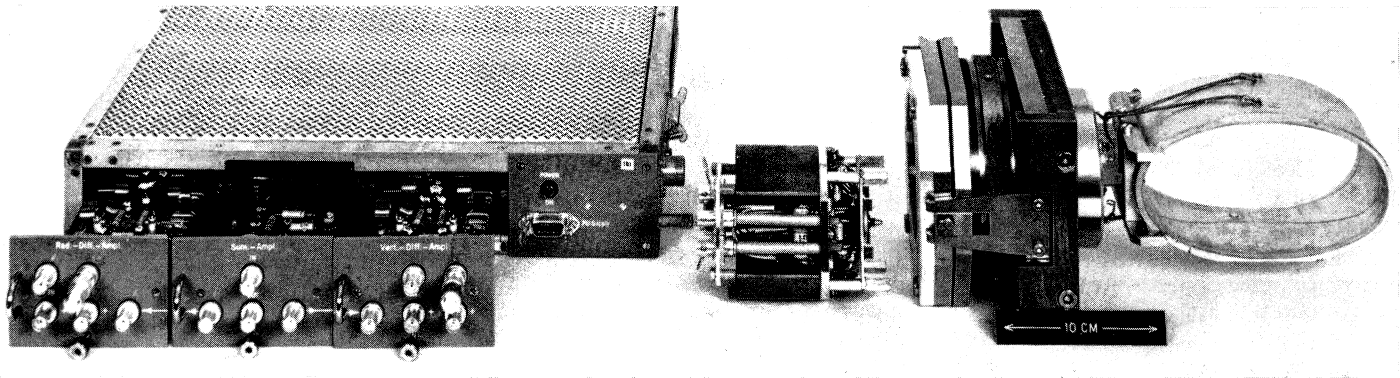
The liquefier generates only enough hydrogen to keep the chamber supplied during normal operation. Whenever a major filling of the chamber is needed, for example at the start of a period of operation, the hydrogen is supplied, as before, from the central liquefying station.

CODD

It was decided two years ago to install a Closed Orbit Digital Display (CODD) system at the proton synchrotron. Using beam-observation stations liberally distributed around the machine, it makes it possible to observe the behaviour of the beam in great detail. It could lead to almost instantaneous control of the trajectories of the proton bunches.

The first tests on the system took place in August 1967 and showed that various improvements would be necessary to achieve the desired precision. It was decided to link the improved CODD to the IBM 1800 computer which was installed in the Main Control Room in 1967 (see vol. 7, page 183).

Twenty new beam-observation stations (the units of one station can be seen in



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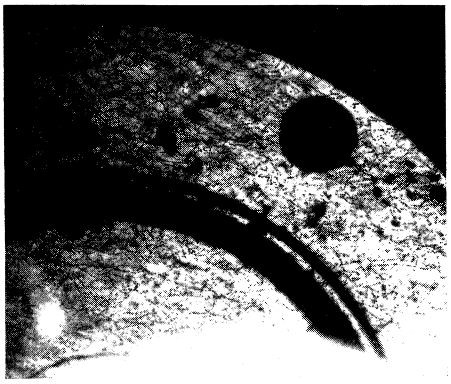

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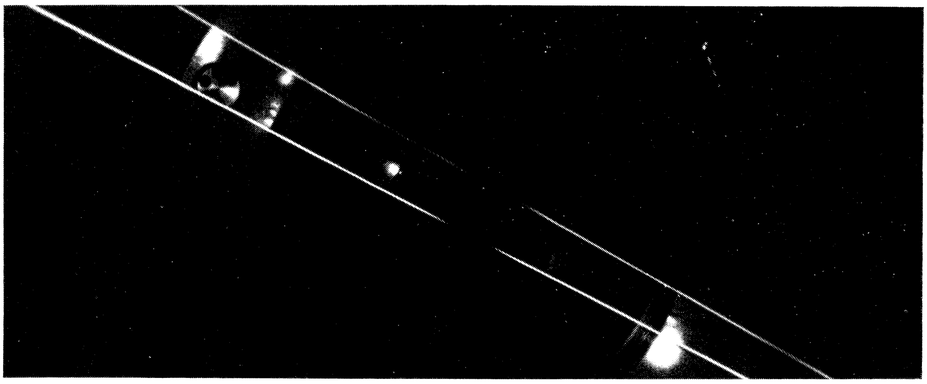

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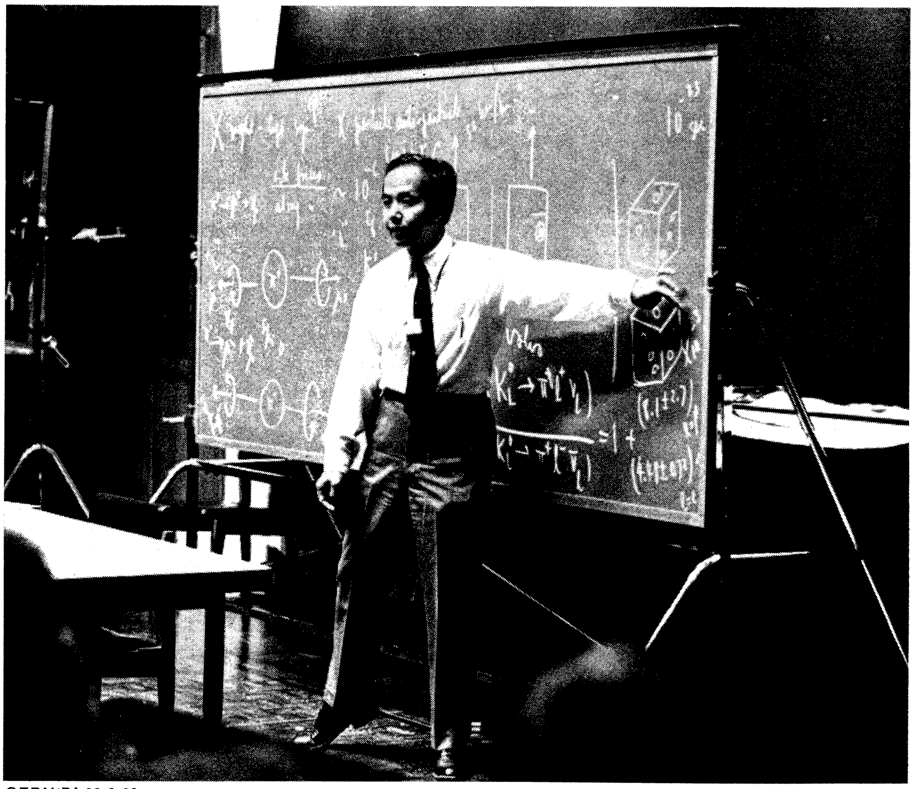
Professor T.D. Lee, who is one of the visiting scientists working at CERN during the summer months, lecturing to the vacation students on 9 August. The subject of his talk was 'Symmetry principles in physics'.



CERN/PI 33.8.68

the photograph) are scheduled to be put in place around the synchrotron by 1 October, so that CODD can be brought into operation using some of the old stations and some of the new ones. If the latter produce the results expected, the electronics of the old stations will be brought into line with the new ones.

Initially, CODD will make it possible to study the effects of adjustments to the machine controls on the orbits followed by the protons. When this has been done, CODD could be linked directly to an automatic system for closed orbit correction. The protons could be tracked around the machine at the beam-observation stations and then, via CODD and the IBM 1800, any necessary correction could be calculated and applied.

The new stations

The electronic units which amplify the pulses coming from the electrodes in the observation stations have been improved. The amplifiers have a gain which can be switched to values from 1 to 10. The variable gain makes it possible to measure the position of the beam precisely whatever its intensity. The amplifiers are transistorized and must be protected from radiation. They are positioned in narrow trenches 1.5 m under the floor of the PS tunnel.

CODD

A main feature of CODD is that it can follow the trajectory of a given bunch of protons as it goes round one turn in the machine. In this it differs from the system already in operation at the Brookhaven synchrotron which gives the average orbit of all the bunches over a large number of turns.

Each station has circuits, known as 'linear gates' to select the pulse corresponding to a particular bunch. The sequential opening of the gates as the bunch goes round is controlled by a delay line to which are connected as many outputs as there are observation stations. A particular delay line corresponds to a particular beam energy, which limits the number of energies at which this type of measurement can be made (the number of delay lines available). As a further development it may be possible to link the gate-opening controls to the radio-frequency system of the accelerator so that measurements could be taken at all energies.

The difficulty of bringing into operation a system as complex as CODD will be compensated for by the ability to observe the behaviour of the proton beam in the machine in detail never achieved before. A similar system is being planned for the Booster.

Reinforcement of shielding

The shielding covering the proton synchrotron ring in the region of the internal targets, which supply particles to the North and South experimental halls, is being reinforced. This precaution is needed in preparation for the increased intensity of the machine.

The tunnel was already covered at this point with earth 2.3 m deep but this could not be made deeper without increasing the support. It was decided therefore to build an additional roof, 2 m above the first, to support another 2 m of earth. Its frame consists of 13 pre-stressed beams, 30 m long and 2 m wide coupled along their length covering a total surface area of 750 m^2.

A pre-stressed assembly has been used because of the limited time available to build the extra roof (the four months of the PS shut down). This made it possible to prefabricate the beams over a longer period of time.

Each beam has eight sections (of which the largest weighs four tons) cast on the site and assembled on a tubular steel platform near the tunnel from which they are moved on small caterpillar trucks. The eight sections are cemented end to end with a special quick setting colloidal mortar, and are threaded together by twelve cables each consisting of twelve steel wires with 160 kg/mm^2 breaking stress. They exert a pressure of 68 tons on the beam. The method of anchoring the cables was developed by the former SB Division Leader Ch. Mallet, using self-locking pins.

Vacation students

The annual invasion by a group of over a hundred students is taking place at CERN. They come from Universities and Engineering Colleges throughout Europe to follow the summer vacation course.

The students have been drawn from a list of applicants about four times longer than the list of places available. The selection is usually done at Divisional level on the basis of questionnaires filled in by the students and reports from their lecturers.

Applicants come from Member States and must have completed at least three years study at University level. Travelling expenses are reimbursed and a grant of 25 Swiss francs per day is payed for the duration of the stay at CERN. The Housing Section helps to find accommodation and as many students as possible are housed in the hostels usually occupied by the students of the University of Geneva, for part of their stay. The course usually lasts from two to four months.

While at CERN, the students work directly with the groups carrying out experiments or developing research equipment. They can also follow a series of lectures on the scientific activities of CERN, including courses in physics and computer programming, which is specially arranged.

Industrial implications of large, international research enterprises

An examination of the technical and industrial problems associated with doing pure research requiring large and technologically advanced equipment and how these problems have been handled at CERN. This article is taken from a talk given by Dr. M.G.N. Hine, Director of the Applied Physics Department, to the annual meeting, in May, of the European Industrial Research Managers Association (EIRMA) at Scheveningen, Netherlands.

M.G.N. Hine

CERN's mission has two parts :

— to build and operate accelerators and other very large high-energy physics facilities for the use of physicists from all over Europe,

— to run an 'in-house' research effort of the highest attainable quality accompanied by an advanced training programme at postgraduate and postdoctoral levels for fellows and visitors.

These two aspects — research and service — can come into conflict, but it has been possible to arrive at a reasonable balance, in which the Laboratory is strong and open enough to provide for many outside users, while maintaining quality and technical leadership through more stable local research and development groups. The programme is established via a network of planning committees with strong outside membership.

CERN's mission is a continuing one, not like an aircraft development project which has a well defined end, after which the staff and money can be used for other purposes. The operation of a large accelerator Laboratory after the machine is built costs more per year than it did during the construction phase*.

The return for the money invested must be seen in the output of physics the laboratory permits, and in the training that young scientists receive while working there. Return in other forms, such as 'fall-out', must be considered as secondary and not allowed to stand in the way of the Laboratory achieving maximum efficiency in its primary scientific mission.

By now (1968) the number of physicists using CERN has increased to about 1000 and more than half the particle physics of Europe is thus based on one Laboratory. This is possible for three reasons :

— the great capacity for exploitation of modern accelerators if properly designed operated and developed

— the technical possibility of 'physics at a distance' whereby visiting groups are able to prepare experiments and analyse the resulting data in their home laboratories

— the fact that a high-energy proton accelerator is nearly a 'universal instrument' for creating the many different particles and reactions to be studied, and that several important particle detectors, such as the bubble chamber, are also general-purpose instruments.

The large Laboratories, in their service relation to the university physicist, are analogous to the power companies, supplying high voltage protons rather than electrons. It is helpful to think of this analogy in considering the timing and scale of capital equipment programmes for high-energy physics, and how the equipment should be built and operated.

Cost and scale

Heavy investment in such general-purpose facilities can be seen to be quite economic when the cost is spread over their useful life and the total number of experiments performed. A large accelerator will take five to seven years to build, and have a useful life of twenty years or more, provided it is continually developed; large detectors will take three to four years to build and will probably run for ten years.

As orders of magnitude, the capital cost of the two CERN accelerators (the 28 GeV proton synchrotron and the 600 MeV synchro-cyclotron) is now about 180 million Swiss francs (at present prices) and the general-purpose research equipment going with them has cost about 100 million Swiss francs. These facilities now support some 1000 user scientists at an average capital cost, if spread over 10 years of operation, of about 30 000 francs/year.

Operating costs of the programme based on CERN now come to about 250 million francs/year, including the home costs of the outside users (i.e. 250 000 francs/year/user scientist). The cost, if spread over all scientists and engineers involved, would be less than 200 000 francs/year, including salaries, equipment, overheads, buildings, power, etc. This figure is typical of advanced industrial research and development work.

Purely national programmes are operated by the larger countries using their own accelerators and about 350 million francs/year is spent in this way, supporting about 700 user scientists. The 50 % higher cost per head shows the advantages of scale which CERN permits.

One can ask, in view of these facts, in what sense high-energy physics is a 'Big Science'. It does imply the construction of a few large facilities on the scale of a medium-sized factory whose cost, if properly prorated, is not, however, large. The individual physicist still works in fairly small groups with individual pieces of equipment which are not very different in size or cost from those of an advanced worker in say biology or metallurgy. The physicist himself does have to become competent in a wide range of advanced technologies and to learn to deal with industry. He also has to accept the discipline of planning his work carefully in advance and of competing with his fellows for running time on the accelerator. High-energy physics does not tie together large numbers of researchers on a single experiment or on a plan of research laid down from outside, nor does it require large amounts of new capital equipment, like rockets, for each experiment.

Although the cost is large by past standards and is highly concentrated and visible to the public, it should be remembered that it is only a small part of science budgets in a broad sense. For example, in the USA, high-energy physics costs only about 3 % of the civilian space programme, less than 10 % of biomedical research, about 30 % of atmosphere and water research and slightly less than the cost of US Government scientific and technical information services. In Europe, high-energy physics is also an insignificant fraction (about 2 %) of the total research and development expenditure and it uses considerably less than that fraction of the university-trained manpower. This is not to say that the cost is trivial or should not be examined critically, but the figures do have some importance in considering the influence on industry which could be expected from the high-energy physics programme, compared with, for example, what the full US research and development programme is said to have produced on the American economy.

Design and construction of equipment

The large clientele and the long life of accelerators have some immediate

* *This led to a quip from J.B. Adams that this was one good reason why governments should continue to build accelerators — it is cheaper than operating them.* *Ed.*

consequences on the way in which they are specified and built :

- they have to be able to run intensively and reliably for many years from the start
- they have to be adaptable to new uses in ways not foreseen in any detail at the beginning; usually they have to have a major 'refit' once during their lifetime as well as a series of minor improvements
- their size and planned performance will often be an order of magnitude greater than anything built before, and yet they must 'work first time'
- there can be no prototypes or trial launchings.

As a result, they must be designed and constructed conservatively, and within, if at the limit of, current industrial technology or at least with all innovations studied and tested in detail beforehand.

This kind of daring specification with conservative construction calls for a building group of physicists and engineers working indistinguishably together throughout the design and building phase. In the operational period, in addition to the 24 hour/day shift teams, a similar group is needed to plan and execute all the changes and improvements expected during the working life of the machine. There is therefore a natural development from the project's construction group into a combined operating and development organization large enough to contain most of the necessary professional skills.

Large general-purpose instruments like bubble chambers have to be handled in the same way, though if not too big they can be built in other Laboratories and brought to the accelerator to run. Other smaller standard equipment, such as film-measuring machines or fast electronics, can be developed in prototype form in one of the large Laboratories and then built in series in industry for sale to university users.

These requirements, and the international nature of CERN, also influence the organization of work and the administrative procedures for dealing with industry.

For the reasons given above, the detailed design has to be made by the project staff. In consequence, full specifications can be written for components to be purchased by competitive tendering, as in fact the CERN financial rules demand. Particularly for the more conventional types of equipment, even if one type of design is suggested in the specification, firms are encouraged to suggest other designs if they think fit.

Development work on new techniques has to be done before the final project design is crystallized, and, where industry is involved, the studies must be carried out jointly with CERN so that the results are fully understood and available for general use in inviting tenders for the final equipment.

In effect, CERN normally acts as if it were its own 'prime contractor', with industry supplying components on sub-contract. The responsibility for the success of the project then rests squarely on the shoulders of the project leader and his group, which can be staffed and organized to carry it.

This decentralized organization of development and engineering in separate project groups carries some risks, particularly of duplication of effort and of difficulties arising from rapid build-up of staff; it is believed that these are outweighed by the better personal contacts around each job and greater flexibility in adjusting programmes to changing circumstances. CERN tries to be a scientific institute forced to operate on an industrial scale, not an industrial establishment producing science. In practice it has not worked out at all badly: the original CERN accelerators were built within the scheduled time and with only a small (10-20%) cost increase above the estimates. Experience with other large projects, in particular the Intersecting Storage Rings, in which PERT control is now standard practice, indicates equally good or better performance in these respects.

The system of ordering project components individually allows a wide choice of firms, either small, medium or large depending on the particular job. Very often the best offers have been made by medium-sized firms. These are usually the easiest to collaborate with since the management will take a personal interest in the success of the work, and, very important, one can most easily get direct collaboration with the design and production engineers.

The choice of firms is almost always made by full competitive tendering, if possible among European firms, but without excluding non-member States, i.e. the USA, if significant advantage in performance, delivery or price can be obtained. CERN has never had a system of allocating a quota of contracts to different Member States, such as is practised in some other organizations. CERN's primary mission is already a stringent one. High-energy physics research is difficult, international collaboration is difficult — doing both well and within planned long-term budgets, when so much of the Laboratory's programme is strongly influenced by the many outside users, is only possible if the Laboratory has first-class staff who are free to aim for the best and cheapest solutions. A policy of a priori distribution of contracts would add a quite inconsistent extra mission which could only encourage double standards and nationalistic tendencies in the Organization, and certainly lead to reduced success at considerable increases in cost.

Personnel

A wide range of skilled personnel is needed for the project and development work, mainly in the fields of electromechanical engineering, electronics, computer science and general applied physics. Construction of large projects and their future development is a long-term activity, and needs experienced staff willing to pursue this kind of work on a long-term basis. Small projects and general development work can be handled with a higher proportion of young or short-term workers, who need not even be staff members of the Laboratory. A recent survey showed that there were about 300 academic level: applied physicists, engineers, etc. on the CERN staff, including 70 involved in computer programming. In addition there were some 15 fellows and 80 visitors, staying typically between one and two years at CERN for the same type of work.

Staff members are recruited from other high-energy physics laboratories, universities, technical high schools and from industry. Older staff do not come frequently from industry, partly because CERN

Dr. M.G.N. Hine, Director of the Applied Physics Department.

CERN/PI 169.6.66

salaries are kept in some relation with academic scales and are not attractive for a well established engineer in many countries. Fellows and visitors tend to come from sister laboratories or universities, though there is no bar to industry. However, industry has not in general seemed interested to detach scientists to work at CERN when it has been suggested in the past.

Although they were good at the start of CERN, connections with technical high schools have not been built up in the same way as they have been with university physics departments. However, a fellowship programme for applied physicists is now being built up, which should in time strengthen ties with technical high schools and similar institutions.

Results from CERN

CERN must, in the end, be judged on whether it has succeeded in its primary mission of enabling particle physics in Europe to be maintained at world level. The return to the Member States appears in the contribution that CERN makes as part of their whole system of higher education and research.

As an indication of how CERN is viewed from the outside, many US official documents now treat CERN as the equivalent of the best American Laboratories, and European planning of high-energy physics through CERN is referred to, in Europe and in the USA, as a model for scientific collaboration in other fields.

Interest in the possible secondary effects of CERN and of high-energy physics generally has increased recently, with the growth of the cost and the proposal for the 300 GeV Laboratory. These effects can be described under three headings :

— financial return in the form of contracts
— use and training of manpower
— technical advances and 'fallout'.

The first point seems in reality to be the least important, if only because the total amounts involved are small. Any special importance of CERN contracts lies in their technical interest rather than in the possible financial profit, although it may be a helpful feature of the present system that contracts tend to go to countries where industry is temporarily working below capacity.

The main facts on engineering and applied physics manpower at CERN have been described above. Their effects on the outside world fall into three classes :

— the attraction of valuable people away from other possibly more important fields
— the training of younger workers at CERN for short stays
— the development of more senior people who could go to university chairs or industrial research laboratories.

The first effect is very small; even recently during the build-up of the ISR and other project groups, the net intake has been about 40-50 academic level staff per year. The turn-around of short-term visitors, etc. (about 100 per year) is quite a considerable fraction of those working in the Laboratory and this could be more oriented towards people coming from industry if the demand existed, but the number could not be much increased without creating a heavy load on the longer-term staff and the project groups which have to look after the visitors and provide opportunities for useful work.

The possibility of more experienced and older staff leaving CERN depends essentially on the outside demand and the interest of the jobs offered : CERN does not keep people by paying salaries which industry or technical universities could not easily match if they wished, and CERN long-term contracts do not offer tenure in the academic sense. However, such people when in their forties are often well established, with children at school, and a move means changing country, not just changing jobs. It does not seem that many people have received interesting offers from outside, and the number leaving has been small, though not zero.

Technical 'fallout' has been produced either in industry, when a contract involved developing a new material or process, or from work in the CERN Laboratory itself. Besides sometimes requiring quite new ideas, CERN's work has in many cases implied pushing existing techniques to new limits, or introducing them in firms not already using them.

CERN policy on patents and technical know-how has been aimed at helping the spread of knowledge or of technique so created. CERN does not take out patents on its work; rather, its policy is to publish such results so as to make them freely available to industry anywhere, and it requires that ideas worked out in collaboration with industry will be similarly put in the public domain.

A list showing where CERN has itself produced, stimulated or spread more widely technological advances which could be of general interest would include :

— the development of very low carbon steel and precision stamping techniques for making electromagnets, which have later been applied by industry in the manufacture of generators and transformers
— high-quality insulation for water-cooled coils
— r.f. amplifiers at 200 MHz of 2-5 MW peak power
— large ferrite assemblies
— materials, components and welding

techniques for large ultra-high vacuum systems
- ultra-high vacuum pumps going down to 10^{-13} torr
- air-pad transport devices
- large-scale precision survey and metrology (CERN has probably the most advanced laboratory in Europe in this field)
- geotechnical studies involving large-scale ground stability measurements and load tests
- economical multiplex control and indication systems
- components and surfaces for handling very high voltages and fields in vacuo
- high-intensity proton ion sources
- extremely stable regulation (about 2.10^{-5}) for Van de Graaff generators
- very stable controlled d.c. supplies in the MW range of power, using semiconductor rectifiers
- high-power pulse generators for tens or hundreds of kilovolts and pulse lengths of nanoseconds or microseconds
- large components made from loaded or reinforced epoxy resins
- dose measuring instruments for high-energy radiation
- modular electronics for nanosecond pulses: standard ranges of scalers, discriminators etc.
- on-line data processing using very large multiprogramming computers
- precision film-measuring machinery, using mechanical and cathode ray tube scanning
- cryogenic systems for liquid hydrogen and helium, involving turbine refrigerators
- very large vacuum-tight optical windows to run at liquid hydrogen temperatures
- the development of large superconducting magnets, including solenoids and quadrupoles.

It is difficult to assess the importance of this work for the technical development of European industry. In some fields — the use of large computers, ultra-high vacuum systems, superconducting magnets, precision survey, very fast electronics, for example — CERN is possibly one of the earliest or most important users in Europe, but, as mentioned earlier, the total amount of money involved is very small compared with that in aerospace or nuclear energy projects.

Prospects for the future

The future of high-energy physics in Europe is being critically examined by Governments at this time, partly because of the proposed 300 GeV accelerator project, but partly for more general reasons. On the one hand, it is agreed that high-energy physics is an important fundamental subject, one of the few concerned with those basic facts and laws of nature which underlie all branches of science, in which Europe, through CERN, is at world level, and that CERN is an example of very successful international collaboration. On the other hand, there are fears that it has in some ways been too successful, taking money and talent away from other branches of science or industry which are said, by comparison, to be under-supported.

Although in such discussions the cost and scale of high-energy physics tends to be exaggerated, it is clear that its recent rapid growth, particularly in scientific personnel, cannot and should not be maintained far into the future, now that the subject is well re-established in Europe. For this reason, the long-term plans produced last year by the European Committee for Future Accelerators assumed an overall personnel growth-rate of only a few percent per annum.

Even so, it was clear that a new international Laboratory would be needed after 1975, when the CERN machines would be nearly 20 years old, and there was complete agreement that a new accelerator of about 300 GeV energy was required. Such a machine, with energy twelve times that of the present CERN proton synchrotron, sounds a very large project. In fact, by applying the knowledge and experience gained since 1960, it has been possible to make a much more economical design, so that the cost of the machine is only about six times that of the CERN machine, spread over eight years, with the same annual budget as at CERN-Meyrin now.

A professional scientific and engineering staff of about 150 will be needed in the construction group. At the start of the Laboratory, there will be a higher proportion of conventional engineering than at CERN now, since it is the construction of experimental equipment which needs the widest range of technologies. The 300 GeV accelerator will, approximately, double the scale of international high-energy physics equipment building over the next ten years, but this should not in any way exceed the technical capacity of Europe, to judge from surveys recently made by CERN.

If its coming into use is accompanied by some transfer of research from CERN-Meyrin the scientific effort involved with the international Laboratories in 1980 will be little larger than the total European programme at present. Further growth in overall numbers of scientists, which from now on, is not expected to be large, can be supported by some replacement of existing national accelerators, which will in any case be out of date by then. The 300 GeV accelerator is the essential key item in any future plan for European high-energy physics, since it alone can give the qualitative improvement in technique needed, and ultimately replace the aging CERN facilities; on the other hand its construction is quite consistent with any likely policy for future growth in scientific manpower working in the field and does not over-commit European sources. Its absence will cause a repetition of the situation in 1950, when the capacity of Europe in this field was suddenly reduced to insignificance by the start up of the large US accelerators.

How are the techniques of high-energy physics going to develop in the next decade? It is a sobering thought that almost none of the present-day standard experimental techniques were known or in use when the Laboratory was designed. This may not happen to such an extent a second time, but one can certainly hope for new ideas for detecting and measuring elementary particles to be evolved or brought into general use.

Data-taking rates with the new accelerators will increase by 2-3 orders of magnitude, with corresponding demands on fast electronics and on data-handling systems. Computing load in all the major Laboratories has increased steadily by a factor of two per year since about 1960 and CERN now has one of the largest installations in Europe. Current forecasts do not predict so fast a growth-rate in the future, but at least a factor of ten increase in capacity is needed by 1973-4 and it is clear that high-energy physics is one of the fields in which the potential demand exceeds the capacity of the computer industry to supply equipment, and which in the past have been the stimulus for the production of the largest machines.

Superconducting magnets are already being used in individual experiments at CERN, and if the technique continues to develop, a widespread use can be foreseen in ten years' time. It is interesting to note that, at the moment, high-energy physics is about the only field of application of large superconducting devices, and much of the development of experience in European industry in this field will probably be via magnets for CERN and the other high-energy research Laboratories.

In this framework, the Meyrin Laboratory will cease to be the centre of European high-energy research by about 1980, and a policy for its long-term future must be agreed in the early 1970s if this change of role is to be handled smoothly. In general, it could be expected that the importance of technical work at CERN will increase, unless of course the Laboratory were closed down completely, which is not an unthinkable hypothesis given adequate advance warning. Otherwise, it could be used partly as a collaborative centre for building equipment and preparing experiments to be run at the 300 GeV Laboratory, as well as maintaining some specialized first rank research work, for example with the ISR. It could also be given at that time a different kind of mission in a wider field of science or in associated technologies. If so, it would be very important to establish the right academic and industrial environment, since there is just as much danger in establishing an ivory tower in applied science as in pure physics.

These are questions which will have to be debated very thoroughly in the coming years if CERN is to have a continuing existence with anything like the success it has had until now.

Superconductivity Summer Study

For six weeks in June and July, experts from research centres and industry pooled their ideas and announced the progress of their research on superconductivity at a Summer Study organized at Brookhaven. This article summarizes the background and brings out some of the topics which excited most attention during the Study.

From 10 June to 19 July, the '1968 Brookhaven Summer Study on Superconducting Devices and Accelerators' drew some 200 people to the Brookhaven National Laboratory. They came predominently from accelerator Laboratories throughout the USA and Europe and from Japan. (CERN participants were A. Asner, Ph. Bernard, B. de Raad, D. Gorlé, D. Leroy, B. Langeseth, P. Lazeyras, M. Morpurgo, L. Resegotti, J. Schmid and F. Wittgenstein.) There was also extensive participation from industry which is gaining much of its early experience in this field working in association with accelerator Laboratories. Some of the speakers from industry made major contributions. The Summer Study was organized by a group from Brookhaven led by J.P. Blewett and including H. Hahn, A. Paskin, A.G. Prodell and W.B. Sampson.

Accelerator Laboratories have an obvious interest in the progress of the attempt to bring the phenomenon of superconductivity under complete control. Magnets are an essential component of all the stages of collecting information on elementary particles — essential in guiding them during acceleration and transfer and in measuring their momenta. Superconducting magnets to produce higher fields can be expected to have a great impact on this research especially if these higher fields can be gained at less cost than conventional magnets. In addition, superconducting radio-frequency cavities which have very small power losses are a very important application for the acceleration of particles.

Main features of progress so far

Superconductivity was discovered some fifty years ago when it was found that certain metals become perfect conductors at temperatures near absolute zero. (In practice, it is convenient to operate superconductors immersed in liquid helium at 4.2°K, and thus advances in superconductivity have been closely tied to advances in cryogenic engineering.) This means that at very low temperature the electrical resistance of the metals disappears, there is then no power loss in the conductor.

Early efforts to make use of superconductivity using so-called Class I superconductors such as mercury and lead, failed because it was found that the property disappears in magnetic fields of a few kilogauss. In 1961, however, interest grew again with the discovery of superconducting alloys (Class II superconductors) which retain their properties undisturbed by high magnetic fields while carrying high currents. For example, niobium-tin retains its properties in fields of up to about 200 kG. Two other alloys are niobium-zirconium and niobium-titanium which have a critical field of 80 to 90 kG.

Further problems then arose which are still not completely cleared. Above certain values of current density and magnetic field the alloys are unstable when wound in coils — it appears that discontinuous penetration of flux into the superconductor when there are field changes creates local pulses of heat which destroy the superconductivity. To overcome this effect a 'stabilizer' can be added in fabricating superconducting strip, so that the strip is built up, for example, of thin filaments of the alloy embedded in a conductor such as copper which provides an alternative path for the current when a temporary loss of superconductivity arises. It requires an amount of stabilizer many times the amount of the superconductor and the strip is called a composite conductor.

Despite these difficulties, the effort to master the production and use of superconductors is obviously worthwhile when one considers the enormous amount of power consumed in electrical installations. Superconductors could reduce this to near zero and though power is needed in the refrigeration plant there is a great overall saving. In addition to their specialized uses in accelerator Laboratories, superconductors could profitably be used, for example, in the construction of transformers, motors, generators and transmission lines.

However, a lot of spadework on the fundamental properties of superconductors is proving necessary before any large-scale application can open up.

Projects at accelerator Laboratories

We will now consider applications of superconductivity at the accelerator

Faces from the Summer Study

Left: W.B. Sampson, one of the organizers of the Study, who leads the work on pulsed superconducting magnets at Brookhaven.

Below: Left to right — M. Morpurgo (CERN) who spoke on forced cooling of magnets ; A. Asner (CERN) who spoke on the CERN superconducting quadrupole; J.M. Rayroux (Oerlikon Engineering Co) who spoke on experimental a.c. studies; W. Bergmann (Argonne).

Laboratories in more detail, selecting some examples of current projects. In these paragraphs we indicate where the interest lies and not where the difficulties lie.

Bubble chamber magnets :

Magnetic fields applied across the liquid volume of bubble chambers produce the curvature of charged particle tracks from which the momentum of the particles is deduced. Higher fields improve the accuracy of these measurements and hence the interest in superconducting magnets.

The first application was at Argonne where a 25 cm diameter, 35 cm long, helium chamber was brought into operation in March 1966. The superconducting magnet produces a field of 41 kG in the chamber and is estimated to save up to 5 MW of power compared with an equivalent conventional magnet. Argonne also has under construction a 3.7 m hydrogen chamber with a superconducting magnet to produce 20 kG. The magnet is scheduled for testing towards the end of this year and will save over a million Swiss francs a year in electricity costs compared with an equivalent conventional magnet.

Construction of the large European bubble chamber which is now under way at CERN involves a superconducting magnet to produce a field of 35 kG (see vol. 7, page 43). Brookhaven and the Rutherford Laboratory (vol. 8, page 109) also have large bubble chamber projects, not yet funded, which involve superconducting magnets and Brookhaven have built a 210 cm model with a superconducting magnet to give 30 kG. This magnet is now ready for testing.

Polarized targets :

Polarized proton targets involve the use of magnetic fields to pull the spins of the protons into line. The spinning proton acts like a tiny bar magnet which the applied field points in a particular direction. The higher the field the higher the polarization produced and the very high fields from superconducting magnets could conceivably make it possible to dispense with the elaborate techniques which are necessary at present to achieve high polarization (vol. 7, page 28). They can also have advantages in allowing more space around the target for particles to pass.

Superconducting magnets have been used in polarized targets for example at the Cambridge Electron Accelerator Laboratory and at Saclay (in a target used in an experiment at CERN — see vol. 8, page 154).

Beam transport :

Beam transport systems to guide charged particles from place to place, involve the use of two types of magnet — bending magnets, which change the direction of a beam and serve to select particles of a particular momentum, and quadrupole magnets, which keep the beam well focused. With the higher fields of superconducting magnets, beam transport systems could be more compact liberating space in the overcrowded experimental halls and they would be particularly useful for handling short-lived particles.

Brookhaven have already built several superconducting quadrupoles of very compact design using niobium-tin tape, and have achieved field gradients of around 8 kG/cm. CERN have a quadrupole under construction which is 70 cm long with an aperture 10 cm in diameter (vol. 8, page 24). Rutherford Laboratory have a large superconducting bending magnet under construction. It is 140 cm long with a diameter of 14 cm and a field of 40 kG and is scheduled for completion at the end of this year.

Linacs :

Linear accelerator cavities are currently constructed with copper inner surfaces to keep the radio-frequency power dissipated in the cavity, due to the electrical resistance of these surfaces, within reasonable bounds. Nevertheless, r.f. power consumption is very high and is the reason for restricting the operation of linacs to short pulses at low repetition rates. If a superconducting material could be used to coat the linac surfaces there would be a dramatic saving in r.f. power, perhaps by a factor of 10^5, and continuous or near continuous operation would be feasible.

These possibilities have been considered for example at the Rutherford Laboratory six years ago and recently at Karlsruhe for

Right: H.A. Schwettman, Chairman of the first week of the Study, one of the leaders of the superconducting electron linear accelerator project at Stanford University.

Below: Left to right — I. Weissman (Varian Associates) who spoke on the fabrication of solid niobium cavities; D. Leroy and D. Gorlé (CERN).

proton linacs, and at Stanford for electron linacs where full-scale experimental work is in progress which will lead to the construction of a linac 150 m long.

Another r.f. device which could benefit from the use of superconducting surfaces to save power is the radio-frequency separator (vol. 7, page 125). Some work on this is under way at Brookhaven and Rutherford.

Synchrotrons :

The possibility of producing higher magnetic fields using superconducting magnets introduces the possibility of building smaller synchrotron rings to reach particular energies. This has been considered for example at Rutherford, where a 40 GeV conversion of the existing 7 GeV Nimrod was tentatively worked out, at Brookhaven and other Laboratories where various aspects of the problem of pulsing a superconducting magnet is receiving attention.

Some topics from the Summer Study

The highlights of the first week, which was devoted to superconducting r.f. cavities and linacs and chaired by H.A. Schwettmann (Stanford University), were the reports from Stanford on the progress of their superconducting electron linac project. The group under W.M. Fairbank and Schwettmann are full of enthusiasm and confidence, and have already obtained remarkable experimental results on niobium cavities cooled with superfluid helium (for example, an X-band cavity with $Q = 5 \times 10^{10}$).

Since we hope to give a fairly detailed account of the Stanford project in the near future we will not go into more detail here.

The second week was devoted to cryogenics under the chairmanship of T.R. Strobridge (National Bureau of Standards). Refrigeration techniques, cryostat design, and safety aspects all seem well under control. Firms in the USA and in Europe are competitive in this field both in terms of their technical know-how and the cost of their equipment.

The efficiency of refrigeration has been developed to the stage where 500 W of refrigeration capacity is needed to extract 1 W of heat at liquid helium temperatures for large systems while for smaller systems to deal with up to 10 W the usual figure is 1 kW for 1 W.

More work is needed to fill in the figures on heat-transfer for superfluid materials and no-one has yet tackled the problem of piping liquid helium, for example, to a series of magnets distributed throughout a large experimental area, though a cryogenic system 150 m long will be produced for the Stanford linac using superfluid helium.

Superconducting materials was the topic of the third week under the chairmanship of A. Paskin (Brookhaven). Two alloys now seem to be in the commanding position : niobium-titanium for fields levels up to 50 kG (niobium-zirconium has proved more difficult to build into composite conductors), niobium-tin for fields levels over 50 kG (niobium-tin is generally avoided for lower fields because it is brittle and cannot be drawn into wires).

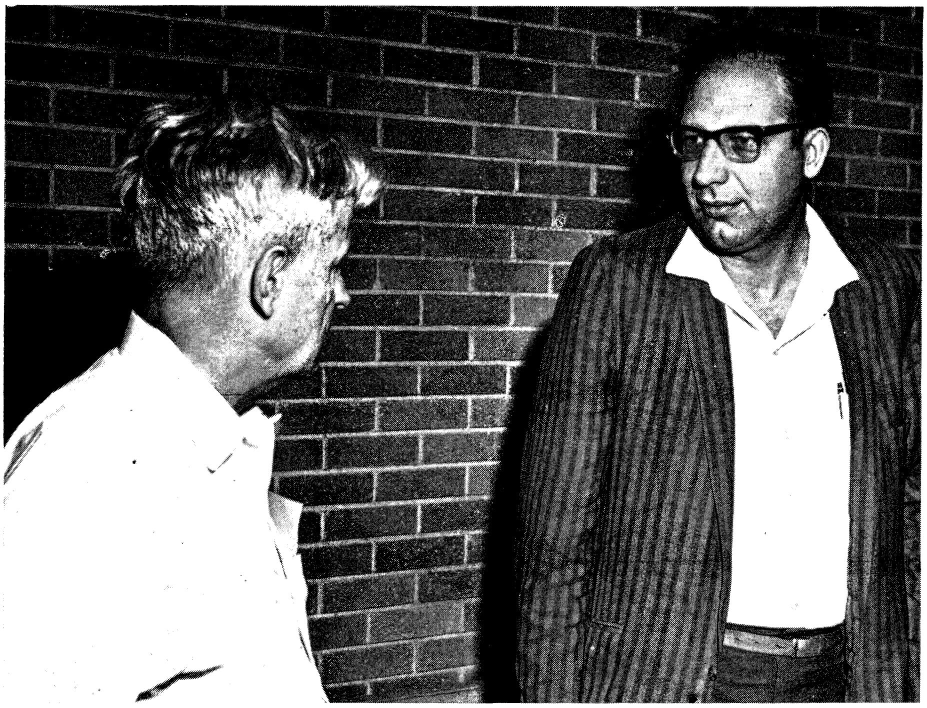
The fourth week was devoted to a.c. effects and flux pumps under the chairmanship of S.L. Wipf (Atomics International). Here began the important discussions on the problems of pulsing superconducting magnets and on their instabilities in this regime which are still not completely understood. H. Hart from General Electric gave an excellent review of the instability problem.

Whenever the current is changed in a superconductor there is a loss of energy. It behaves as if the flux, normally excluded from the superconductor, penetrates the conductor causing local heating which destroys the superconducting property. This can be recovered by means of the stabilizer but there is an energy loss per cycle, like a hysterisis loss, which depends upon the magnitude of the change in field but not upon the current levels at which the change occurs. To remove the heat produced when cycling a superconductor then requires extensive refrigeration plant.

Indications that this problem may be solved came in the fifth week, devoted to superconducting magnets under the chair-

J.P. Blewett from Brookhaven (left) who led the organization of the Summer Study, in conversation with B. de Raad, head of the beam transfer section of the ISR Division at CERN.

(Photos Brookhaven)



manship of W.B. Sampson (Brookhaven). P.F. Smith from the Rutherford Laboratory gave a paper which excited a great deal of interest and which will probably reorientate research programmes in many Laboratories. His team (including M.N. Wilson, C.R. Walters and J.D. Lewin) has succeeded in producing conductors which are intrinsically stable.

Theoretical work on this problem (particularly by R. Hancox of Culham Laboratory) led to the development a few years ago of models for the electrical and thermal processes which occur during a 'flux jump'. Some remarkably simple criteria emerged indicating that flux-jumping should not occur if the superconducting wires are less than about 0.005 cm in diameter (about a factor of ten down on the size usually used at present). Reliable ways of manufacturing such filaments became available in 1967 provided the filaments are embedded in a normal metal.

A further step has to be taken, if the magnets are to be pulsed, to combat current loops between parallel superconducting filaments embedded in a metal. It should be possible to suppress these by twisting the composite conductor and formulas for the necessary pitch of the twist have been worked out. Using a higher resistance metal instead of the usual copper brings the pitch to manageable values (around 5 cm, for example).

Tests on a series of samples produced by Imperial Metal Industries applying these ideas have been in progress at Rutherford for six months and the early results are in good agreement with the theory. No big coils have yet been built but for small coils, using a composite conductor 0.05 cm across with 0.005 cm filaments embedded in copper, 120 A at 50 kG has been typically achieved corresponding to a current density of 40 000 A/cm^2. This work promises that in the not too distant future it will be possible to produce stable coils much more compact than those in use at present and to conquer the problems of pulsing superconducting magnets.

The week on superconducting magnets showed that the approach to design at present varies with size. For the large magnets to be used with bubble chambers, the stored energy can reach 100 MJ and the consequences of a sudden release of such an energy could be catastrophic, the more so in the presence of a large volume of liquid hydrogen. Designers are understandably conservative. The magnets are built 'fully stabilized', so that the copper can take the total current if trouble develops with the superconductor, and current densities are kept comparatively low (about 25 A/mm^2). With the smaller magnets, quadrupoles and bending magnets, designs are more adventurous.

M. Morpurgo reported the work at CERN on forced cooling of superconducting coils. Coils are normally operated immersed in a bath of liquid helium but if it proved possible to wind coils from a hollow conductor through which helium was circulated, more evenly distributed cooling would be achieved, a more compact coil could be built using a much simplified cryostat, and the necessary amount of helium would be reduced. Such a system has been built and tested and the results look promising especially for the cooling of large coils (see yellow report CERN 68-17).

The final week considered accelerators and storage rings using superconducting or cryogenic magnets and was chaired by J.P. Blewett (Brookhaven). It covered the most exciting possible use of superconducting magnets in accelerator technology, though at present it is rather like designing a house without having demonstrated convincingly that one can produce reliable bricks. However, the work at Rutherford means that the knowledge is now available to design and manufacture a superconductor of sufficiently low a.c. loss.

An interesting comparison was drawn between the use of superconducting synchrotron magnets as discussed by P.F. Smith (Rutherford), M. Green (Berkeley) and W.B. Sampson (Brookhaven), and cryogenic synchrotron magnets, which are not superconducting. G.T. Danby of Brookhaven described some work on cryogenic magnets using very pure aluminium conductor cooled to temperatures between 10 and 30°K. This reduces the electrical resistance of the conductor by a factor of over a thousand and the advantage of such a magnet is that it requires less refrigeration equipment compared with a superconducting magnet. For the first cryogenic magnet produced at Brookhaven the price of the very pure aluminium was high ($200 per lb) but large-scale production could reduce this to around $15 per lb.

A tentative cost comparison has been made at Brookhaven between a synchrotron ring with cryogenic magnets to produce a field of 40 kG, and with superconducting magnets to produce 60 kG. The costs came out comparable.

Two other papers worth picking out from the final week were one by H. Brechna (Stanford Linear Accelerator Centre) who stressed the need for extensive investigations of radiation effects on superconducting materials, and one by G. del Castillo (Argonne) who illustrated some of the problems in measuring and positioning superconducting magnets.

The Summer Study was a great success. The informal atmosphere of the discussions helped to ensure a very open presentation of the present 'state of the art'. It was generally agreed that, despite the unknowns which still exist, superconducting magnets and radio-frequency devices will come more and more into practical use. Also, within the foreseeable future, major applications of superconductivity can be expected to open up in other fields.

Education of children of CERN staff

This article presents the background and main conclusions of a survey, carried out by the Welfare Section in collaboration with the Staff Association, on the education of the children of CERN staff. A report entitled 'Enquête sur la scolarisation des enfants des fonctionnaires du CERN; Problèmes d'intégration européenne', which gives the detailed results of the survey, has been published this month and is available on request from the Welfare Section.

It is obvious that the bringing together at CERN of people from thirteen European countries introduces special problems for the education of their children. The CERN community is one of the first examples of its kind, calling for 'mobility' of people from one European country to another. For some of its staff it is also definite policy that this mobility shall not be in one direction only — that the setting up of a 'centre of excellence' shall not drain national centres of their highly qualified personnel — but that these staff shall return to their home countries after comparatively brief stays at CERN. Educational systems, however, are not yet geared to cope with this mobility, and problems connected with the education of the children of people working at CERN have come to the fore more and more in recent years.

Considering the educational possibilities in the environment of the Laboratory, only children who are French-speaking or English-speaking have access to full-time education in their mother tongue. This, in itself, need not be an impossible drawback. Far more serious is the great disparity between the educational programmes in Europe and the attendant fact that qualifications do not carry over from one country to another.

Only French, Swiss and English children have the opportunity to study for their national qualifications. All others have no legal guarantee of access to the Universities in their home countries with the qualifications that they can obtain locally. Added to this, Geneva University, like the Universities in most other countries, does not open the doors of all its Faculties to foreign students. Thus children of CERN staff can find themselves in the predicament where their qualifications entitle them to further education neither in the country in which they live nor in the country from which they came. Even if they do achieve full professional qualifications, they may still be without the legal right to practice their profession in any country.

For people with children of school age, the prevailing situation with regard to education in Europe is a bar to the mobility which is essential for a centre like CERN. Highly qualified people are needed to meet the specialized needs of the Laboratory and their aspirations for their children are high. It is not surprising therefore that the problems of education have been of deep concern to people working at CERN.

However, these problems have usually been expressed on the basis of personal experience and before any sensible programme of action could be put forward, it was important to have a broad and objective assessment of the needs of the staff as a whole. To this end, an 'Enquiry concerning schooling questions' was organized by the Welfare Section and the Staff Association at the beginning of 1967.

The survey aimed to find out how CERN staff were confronting the problems of educating their children, what factors they regarded as most important, and how well the existing opportunities were meeting their needs. A questionnaire was sent to the 1075 members of the staff working at CERN at that time who had children between 3 and 19 years old, and 752 completed questionnaires were returned. This high participation (70 %) made the results of the survey valuable as being truly representative of the staff as a whole and also confirmed that the staff attaches great importance to these questions.

A very thorough analysis of the replies has been carried out, and the final report has been published in French with the title 'Enquête sur la scolarisation des enfants de fonctionnaires du CERN; Problèmes d'intégration européenne' by Mme L. Goldschmidt-Clermont. There are two volumes — Volume 1 : Commentaire; Volume 2 : Tableaux.

As may be deduced from the sub-title of the report, the scope of the survey was enlarged in the analysis to comment, using the CERN community as an example, upon the educational problems which come in the wake of European integration. The situation confronting CERN staff at the moment may be expected to confront many more groups of people in the years to come.

Conclusions from the survey

The survey revealed a remarkable degree of agreement among the thirteen nationalities represented at CERN as to what the main objectives in the education of children of mobile parents should be.

It emerged that these objectives were in line with what could be expected in the perspective of mobility, with the main emphasis on equiping the children to meet change (solid grounding, training for individual work, command of languages and so on).

They can be grouped under four different headings — educational, family, social and international aspects.

Educational aspects :

Predominant importance was given to the need for the children to acquire a solid grounding and training for individual work.

Similar importance was given to the need to master modern languages, and to pedagogical factors (such as the number of children per class) which influence the quality of the education that the children receive.

Family aspects :

The parents wish to be involved directly in the education of their children and attach predominant importance to the need to retain the children within the family circle where the parents can make this direct contribution.

Social aspects :

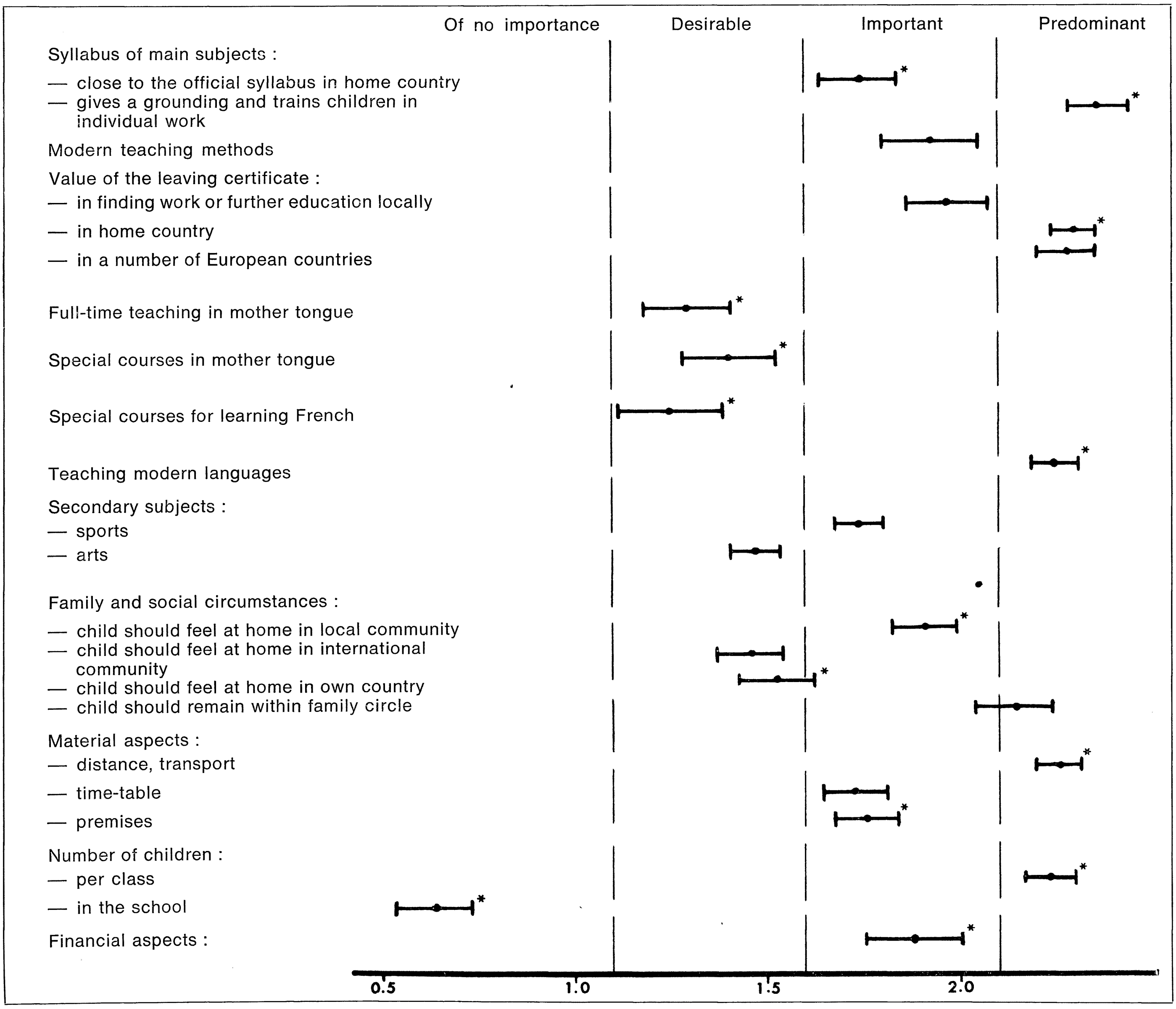
Two topics received strong support under this heading — one, that there should be equality of access to education; two, that a socially varied environment is preferred.

International aspects :

The survey revealed a willingness to integrate in the local community while retaining contact with the home country and while seeing the future in terms of mobility within Europe.

Predominant importance was given to the need to achieve formal recognition by all European countries of the qualifications which the children obtain.

It can be seen that under the first three headings the survey has brought out objectives which are already accepted in educational spheres in many countries. There is no suggestion that CERN staff are looking for an educational Utopia. Under the fourth heading the major problems in education brought about by European integration are underlined.



These objectives are nowhere fully met by the local schools. In particular, *there is no possibility of obtaining qualifications which are valid throughout Europe* and no possibility of education in schools adapted to the needs of mobility. The international schools go some way towards meeting these needs but their teaching is only in English, they are expensive, and the number of school places is limited. They are thus not accessible to the children of all the staff. It is necessary, therefore, for the parents to decide to continue to educate their children in the system of their home country (for those nationalities where such possibilities exist) or to accept the risks described above with regard to their children's future.

The decisions taken by individual parents have been based on an amalgam of many factors — availability of national education, international status of mother tongue, intention to stay more or less permanently away from the home country, and so on. These factors weigh differently with the different nationalities, but for all nationalities the education problem is a limiting factor in the recruitment of staff. CERN cannot recruit or retain all the qualified personnel that it wants when they have children of school age, unless the personnel are willing to take risks — varying according to nationality — on the educational and professional future of their children.

A European solution

Similar, though not identical, situations to that confronting the CERN community have arisen elsewhere in Europe during the past fifteen years and have resulted in interesting educational developments.

Some international schools have, on their own initiative, developed the project of the 'international baccalauréat' — a qualification which is a promising solution to a major problem if it receives wide acceptance in many European countries. The most methodical and far-reaching approach which has already been implemented is that of the 'Ecole européenne'. This was aimed at the short-term solution of the educational problems of communities drawn from the six countries of the Common Market and at the longer-term development of collaboration in education between these countries.

The Ecole européenne has shown that international collaboration in this field is feasible, including a formal recognition in the six countries of the qualifications obtained. It has also shown that the national educational systems benefit from the direct confrontation of methods and points of view. Both by its successes and its failures it has provided a spring-board for further progress.

An opportunity for such progress presents itself at CERN. Here not six but thirteen countries are grouped together and educational collaboration has to search for a formula which will meet the needs of a still broader community. The results of the survey carried out at CERN give a first approximation as to what those needs are. When such a formula is found, it will make the education of children no longer a stumbling-block to integration, but a contribution to integration.

The diagram shows the results from the section of the questionnaire concerned with factors influencing the choice of a school. It assembles the replies of all the staff who filled in the questionnaire.

Different degrees of importance (predominant; important; desirable; of no importance) were assigned to the series of factors listed on the left and a statistical analysis of the replies led to the results presented. (The points give the average value and the bars set the 95% confidence limits. The statistical techniques used in dividing the replies into the categories as shown and in assigning the confidence limits are described in an appendix to the report.)

The replies were broken down and separately analysed by nationality, and the stars (*) indicate the factors which were given different emphasis by different nationalities.

It is mainly from these results that the conclusions of the report were drawn as to the objectives to aim for in the education of children of 'mobile' parents.

It should be noted that the surprisingly high ranking accorded to the factor concerning distance and transport, is due to local conditions in the neighbourhood of the Laboratory which require a local solution. It is not therefore incorporated in the main conclusions.

Thanks to the initiatives mentioned above, the search for an adequate solution does not start from scratch but with the experience of several fruitful efforts in this direction already behind it.

The moment is ripe for a new step forward. At a meeting called by UNESCO in November 1967, the European Ministers for Education unanimously affirmed the willingness of their governments to continue with the exchange of experiments and of information with a view to bringing the different educational systems sufficiently into line to make the transfer of students from one system to another an easy matter. The situation at CERN provides an opportunity for converting this willingness into a practical application. It is of a scale sufficiently small to make the demands on resources quite modest, yet sufficiently broad in its implications to constitute a new step forward in the field of education in Europe.

News from abroad

Construction go-ahead for Weston

After serious fears that the budget for the American 200 GeV project at Weston would be limited to 'design money only' for the fiscal year which has just started, there is great relief that a sufficiently large sum has been granted to enable construction to begin. The danger of a year's stagnation for the project has been avoided.

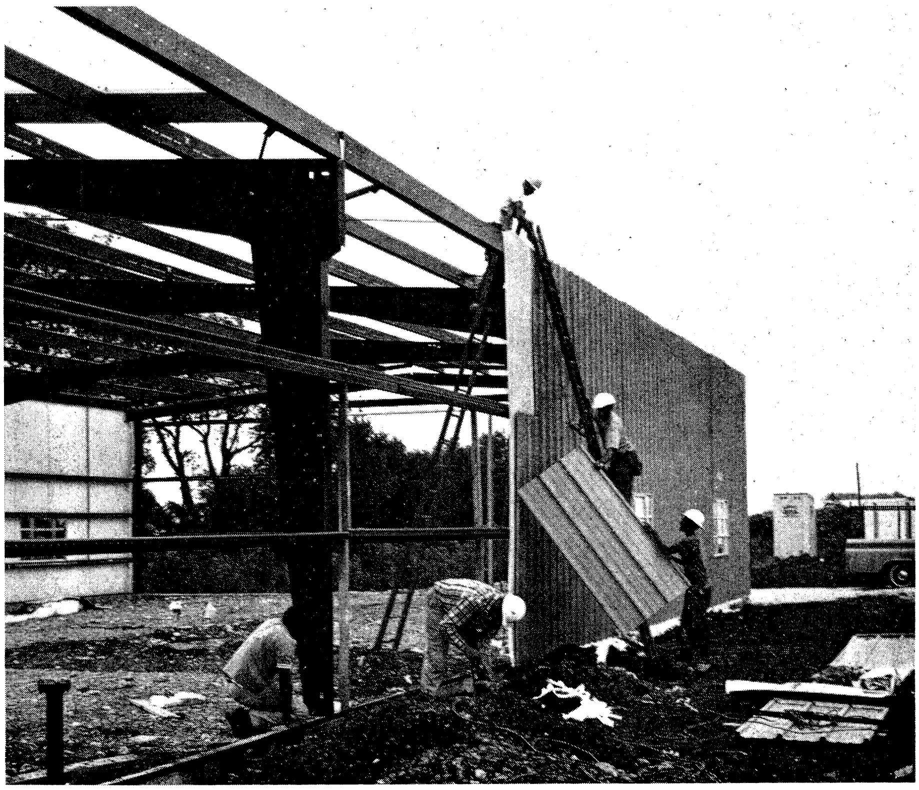
In the context of the present severe restraint on public spending in the USA, the House Appropriations Committee had cut the budget to $7.1 million to be used for further design studies only. Since the project is now at a stage where contruction is the natural next step, it seemed likely that this would lead to the break-up of the strong team which has come together at the National Accelerator Laboratory under Professor R.R. Wilson to build the machine.

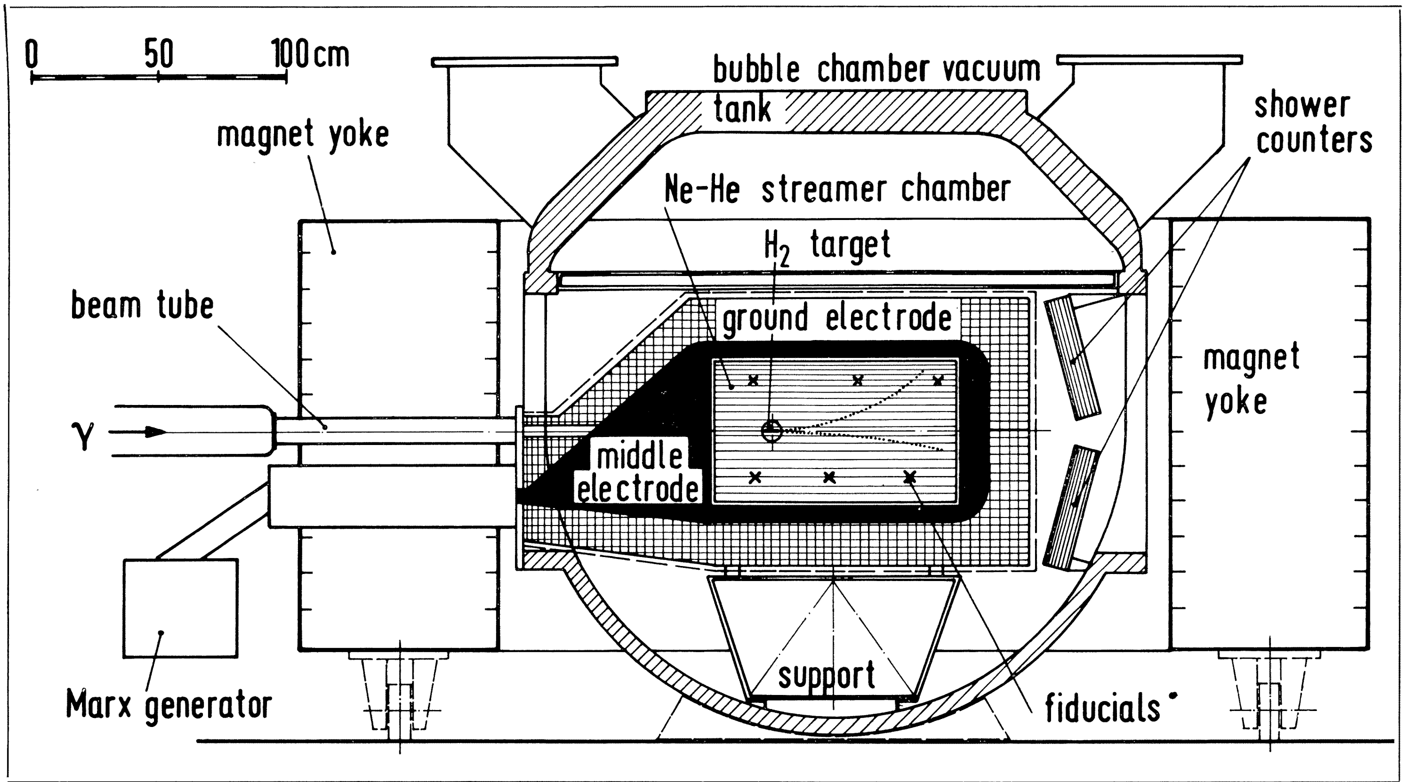
The budget has now been increased to $12.074 million plus $2.5 million carried over from the previous year and approval has been granted for construction. It is one of the very few 'go-aheads' to be given to new projects in America for the coming year. Work will start on such things as the linac and the booster buildings.

Tests are under way on a main-ring magnet model and the results are as expected, showing 3 - 4 % saturation at 18 kG and 15% saturation at 22 kG. 'Good field' is retained up to 18 kG. A booster magnet model will be tested in September. Work on the injector components is well advanced.

The Laboratory hopes to have moved from its temporary premises at Oak Brook to 'the campus' at Weston by 1 September, and, despite the restrictions imposed by the reduced budget for the present fiscal year, Professor Wilson continues to hold to the scheduled beam date of 30 June 1972.

A photograph taken at Weston on 31 July showing construction of the third Laboratory building — the r.f. building. The Laboratory hopes to have moved from Oak Brook to the 'campus' at Weston by 1 September.





DESY streamer chamber

The report on the work at Daresbury, in the May issue, described (page 104) the streamer chamber detector to be constructed at the Laboratory. The collaboration between Daresbury, Glasgow, Manchester and Sheffield was referred to as 'the first European group' to construct such a large universal detector using streamer chambers. (See CERN COURIER vol. 7, page 219 for a description of this new technique).

At that time we were unaware of the work of a group at DESY led by Dr. A. Ladage which has advanced much further. They have brought a streamer chamber into operation this month.

As in the Stanford and Daresbury designs the assembly has two streamer chamber compartments separated by a central electrode to which short, very high voltage pulses are applied. Earthed electrodes are then on each side of the high voltage electrode (this is a little difficult to visualize from the diagram which views the chamber perpendicular to the electrode planes). The electrodes are planes of wires so that it is possible to photograph particle events in the chamber through the wires.

Each compartment is filled with a helium-neon gas mixture and has a volume of 16 × 60 × 100 cm³. This size has been dictated by the decision to use the magnet of the 84 cm bubble chamber, previously in use at the Laboratory, to provide the field for the streamer chamber. The bubble chamber had completed some very successful runs. Photon-proton interactions had been investigated up to 5.8 GeV with hydrogen in the chamber. The chamber was then filled with deuterium and the latest run gathered about 2½ million photographs to investigate photon-neutron interactions. The bubble chamber has now been dismantled to make the magnet, and the optics (which needed only slight modification), available for the streamer chamber assembly.

A tagged photon beam (coming in from the left in the diagram) will be used in the streamer chamber experiments onto a small liquid hydrogen target (4 cm long, 2.5 cm diameter) surrounded by a scintillation counter. The use of liquid hydrogen is an advance over the gaseous hydrogen used in the Stanford chamber, since it presents a more dense target which will increase the interaction rate, but it brings with it tricky problems of refrigeration.

The physics programme for the chamber is under discussion and will take shape when the tests which began this month are completed.

LAMPF Users Meeting

On 20 June, the first Users Meeting for the Los Alamos Meson Physics Facility was held at the Los Alamos Scientific Laboratory. LAMPF will be operated as a national facility with experimental time being shared probably about equally between teams based at Los Alamos itself and teams from Universities and research centres throughout the USA. More than a hundred scientists from outside the Laboratory attended the meeting.

LAMPF will produce meson beams about ten thousand times more intense than those at present available at comparable energies. The machine is a 800 MeV proton linear accelerator to provide 1 mA average beam current with a 6 to 12 % duty-factor. It involves some new design concepts which were described in the June issue of CERN COURIER, page 132.

Dr. L. Rosen, leader of the project, reviewed the progress in an introductory talk. The construction schedule aims for a beam by July 1972. However, the LAMPF budget was cut by $7.5 million this fiscal year 1969 ($26.4 million was requested) by the House Appropriations Committee and this could cause delays. It seems possible to hold the schedule using $7 million held in reserve by the Bureau of the Budget.

The injector components are well advanced. An acceptable ion source has been built and a 750 kV power supply is on order. Work continues on a negative ion source and a polarized ion source. The linac section to take the beam to 100 MeV using a drift-tube structure is also well in hand. The copper-clad steel is ordered and prototypes of the drift-tubes, quadrupoles and r.f. power supplies are coming together. Ordering of the tanks and power supplies can go ahead as soon as money is available.

The linac section for energies above 100 MeV will use the new concept of side-coupled cavities. An electron model (24 MeV, 1 mA) is working very well and is being used to study beam-beam and beam-cavity interactions at high intensities, to identify any problems due to heavy beam-

A side view of the streamer chamber assembly built at DESY. The assembly uses the magnet, vacuum tank and optics of the 84 cm hydrogen bubble chamber which has been dismantled. The three electrode planes are parallel to the page. Photo DESY

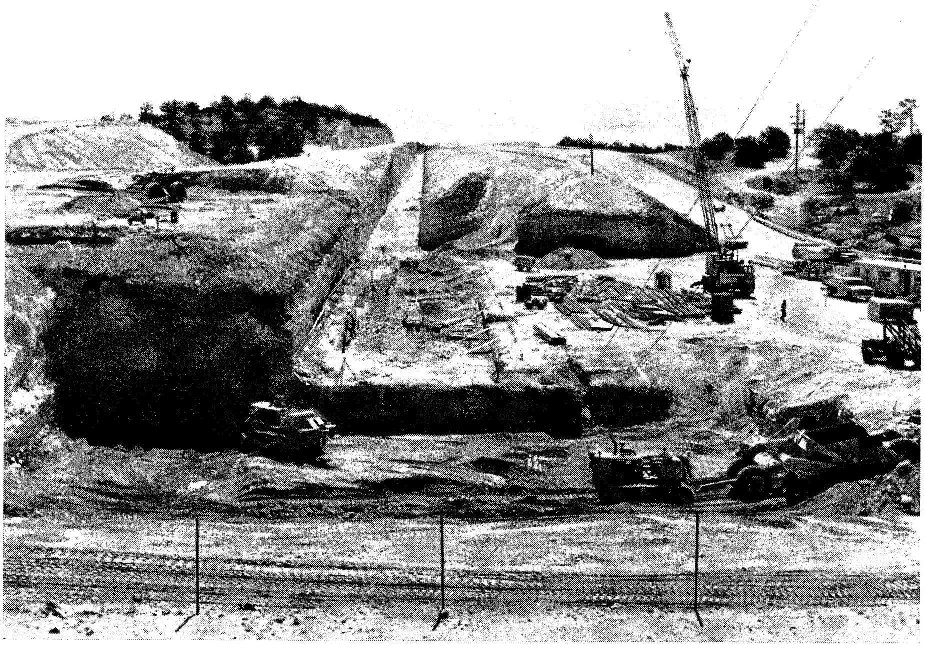
loading and to develop a computer-based control system. Work on the experimental area lay-outs has not gone very far yet.

A Policy Advisory Committee for LAMPF has been set up consisting of R.R. Rau, V. Hughes, H. Feshbach, H.L. Anderson, G. Meier, C. Goodman, G. Cowan and R. Hofstadter.

After introducing some tentative ideas about how the experimental programme might be managed Dr. Rosen concluded with what he called an 'Orsen Welles type of remark' :

'Within the next five years, changes in computer technology may bring new management problems. I refer to the possibility of remote data links between an on-line computer at the site of an experiment and an experimental group 2000 miles away. Such links would allow some degree of participation of a user in the running of an experiment, without actually being in close proximity to his equipment. I think this might offer some real advantages, especially if one can transmit visual displays as well as voice and printed messages. We may yet have to worry about how much importance one attaches to suggestions relating to the strategy for an experiment, which are made 2000 miles from the experimental site, while the experiment is in progress and perhaps while the strategist is sipping martinis'.

As is pointed out elsewhere in this issue, very few of the techniques now in use at CERN had been thought of when the Laboratory was conceived. Dr. Rosen's remark underlines that when thinking of experimental programmes far in the future we have to be prepared for some major changes... Physicists may grow to like martinis.



Excavation work for the Los Alamos Meson Physics Facility. The site is a finger-shaped mesa bordered by canyons to the north and south (canyons to the right of them, canyons to the left of them...). LAMPF will point 850 metres along the finger. To the east (just visible in the background of the photograph) is the Sangre de Cristo mountain range, and five kilometres to the west is the main technical area of the Los Alamos Scientific Laboratory. (Photo Los Alamos)

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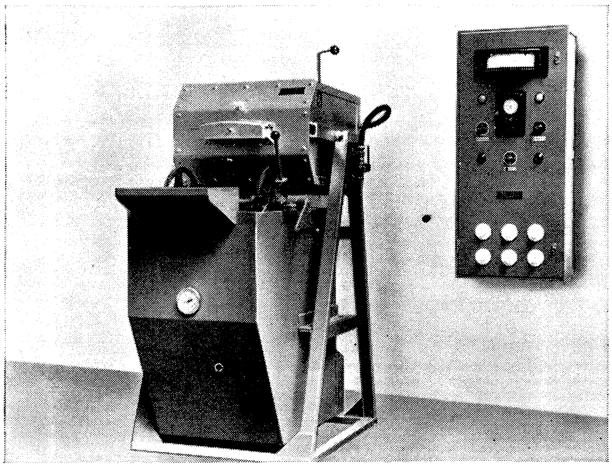

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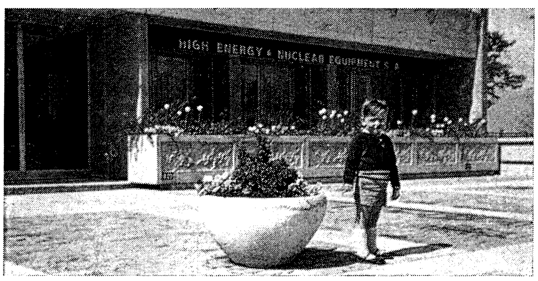

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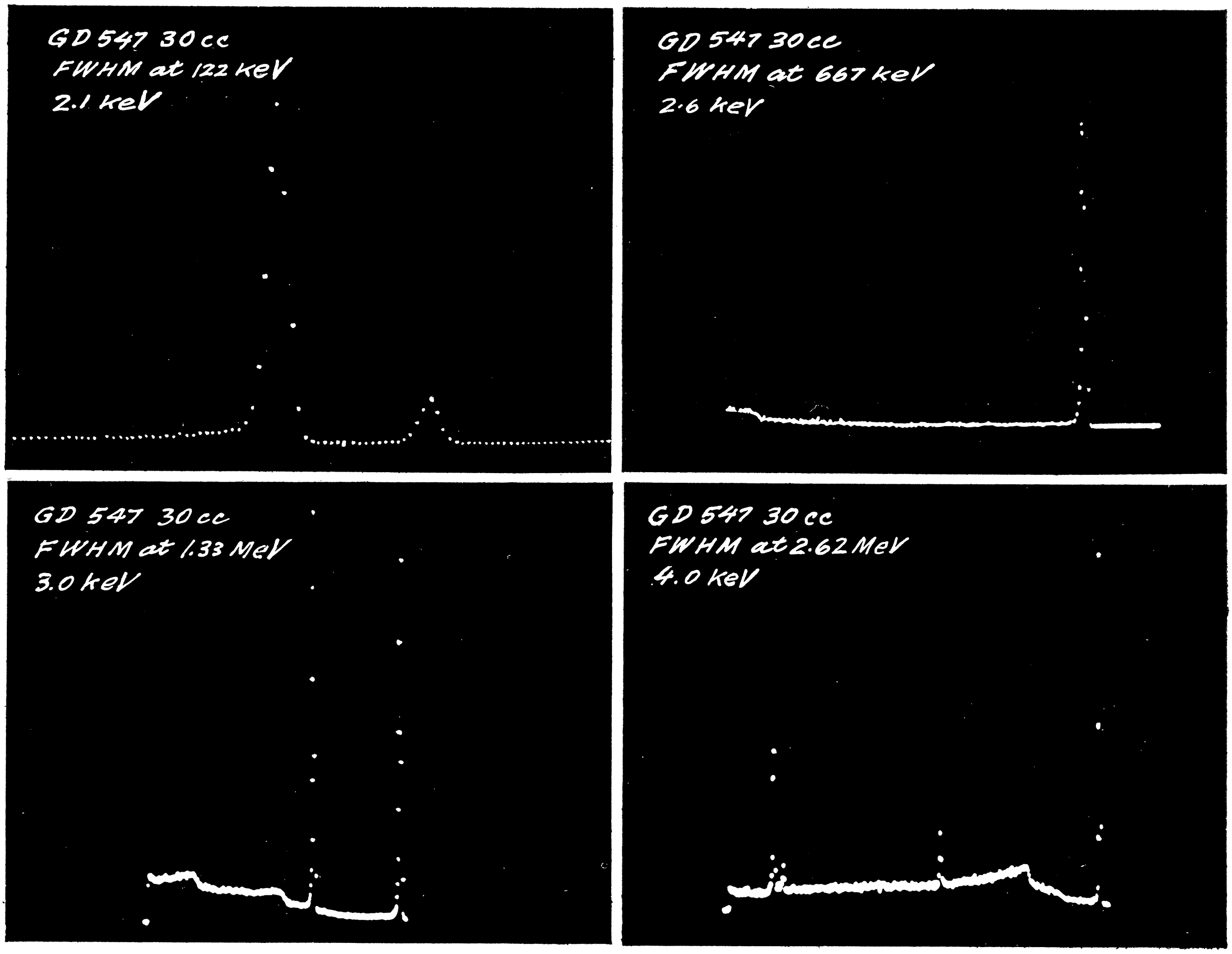

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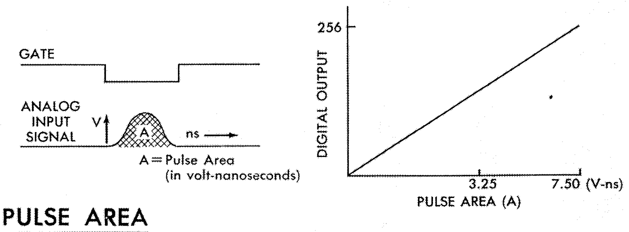

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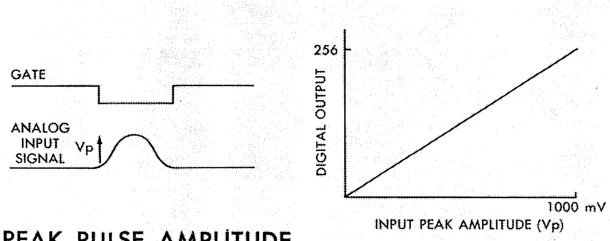

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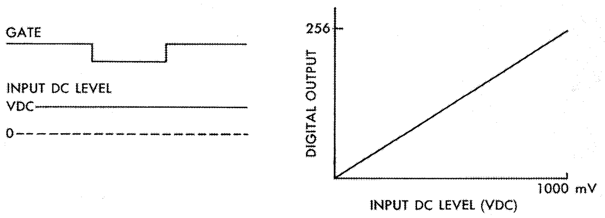

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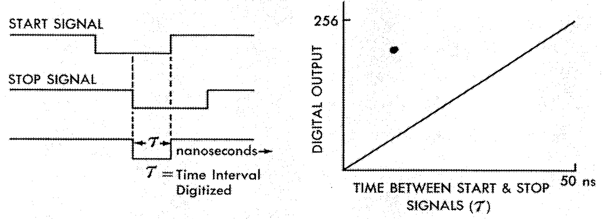

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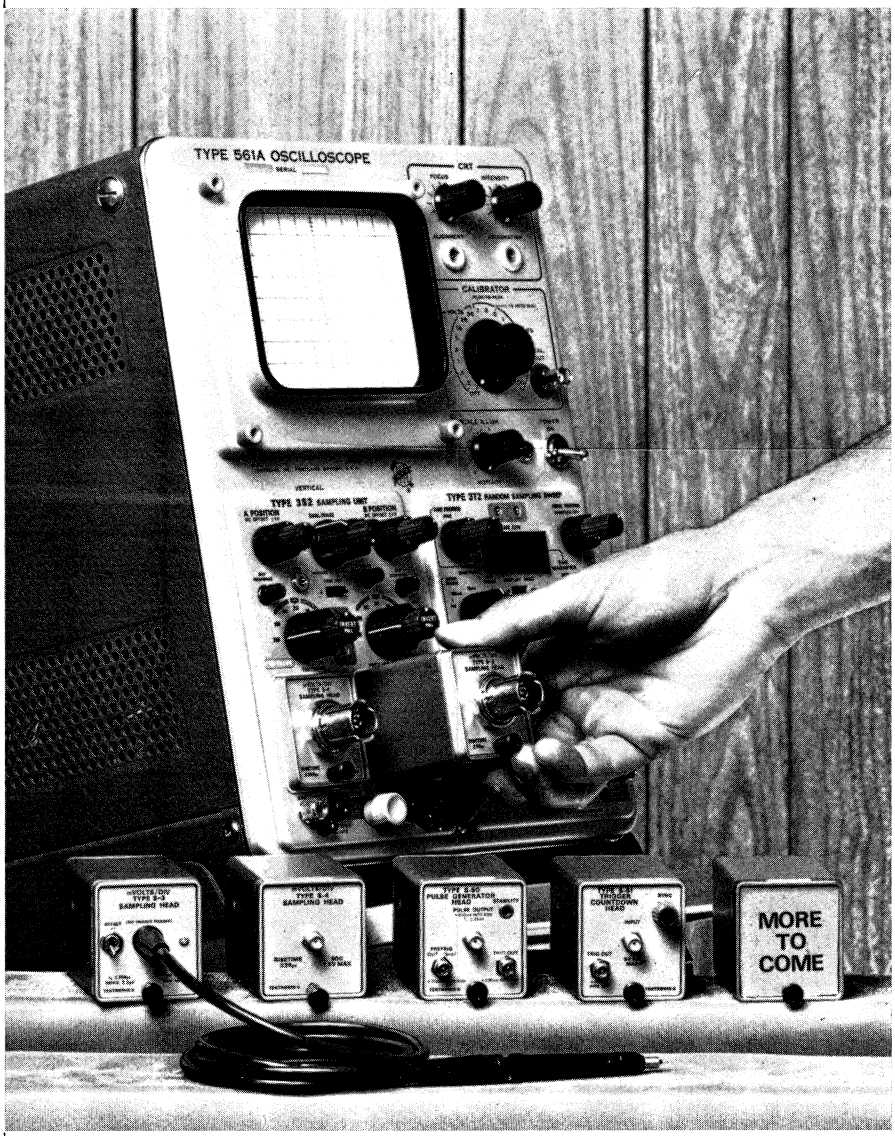

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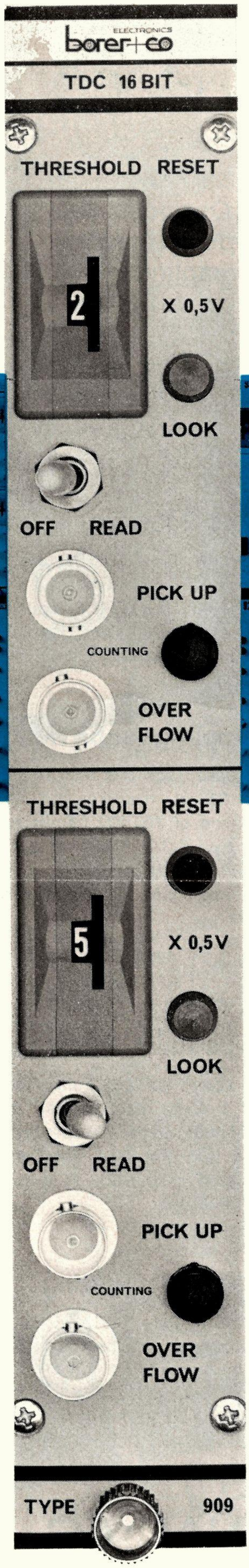

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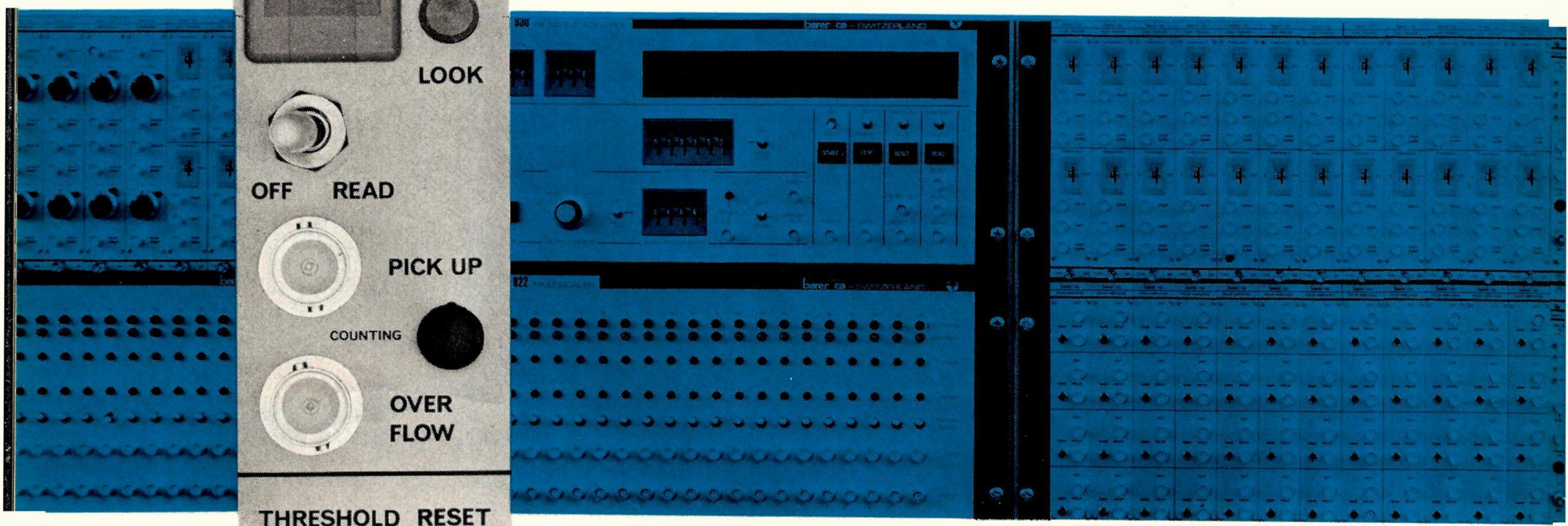

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