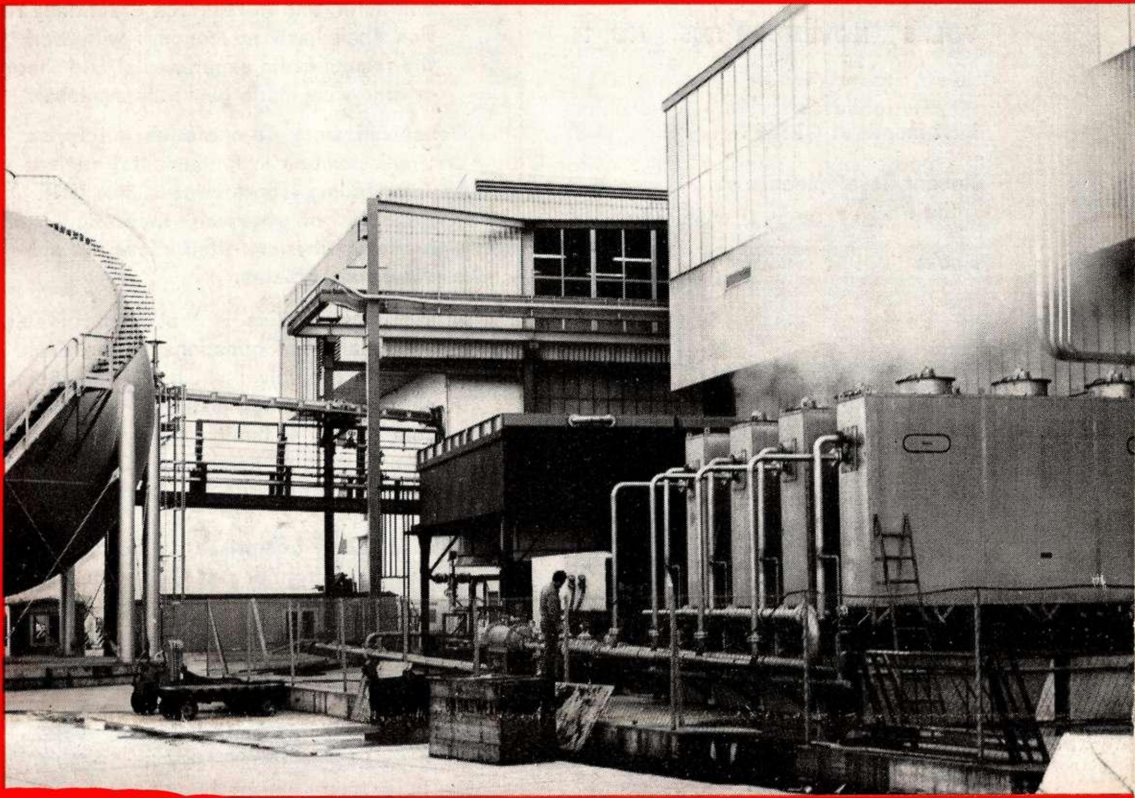
CERN COURIER



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The cover photograph illustrates the subject of the main article in this issue of CERN COURIER – recent developments at the PS. It gives a view of the structures nearing completion next to the East experimental hall, near the hydrogen safety sphere. These are two different types of mobile cooling unit for beam-transport or bubble-chamber magnets, each handling 3 MW. On the right are the four banks of the evaporative-cooling unit, already in provisional operation. Next to them, in the centre of the picture is the forced-draught air-cooled system. Both types are 'mobile' in the sense that they can be dismantled and re-erected in another location if necessary, in contrast to the main 20-MW cooling towers near the main generator building of the PS.

CERN COURIER

is published monthly in English and in French. It is distributed free of charge to CERN employees, and others interested in the construction and use of particle accelerators or in the progress of nuclear physics in general.

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The European Organization for Nuclear Research, more commonly known as **CERN** (from the initials of the French title or the original body, 'Le Conseil européen pour la Recherche nucléaire', formed by an Agreement dated 15 February 1952), was created when the Convention establishing the permanent Organization came into force on 29 September 1954.

In this Convention, the aims of the Organization are defined as follows:

> **'The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.'**

Conceived as a co-operative enterprise in order to regain for Europe a first-rank position in fundamental nuclear science, CERN is now one of the world's leading laboratories in this field. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of **high-energy physics,** often known as **sub-nuclear physics** or the **physics of fundamental particles.**

High-energy physics is that front of science which aims directly at the most fundamental questions of the basic laws governing the structure of matter and the universe. It is not directed towards specific applications – in particular, it plays no part in the development of the practical uses of nuclear energy – though it plays an important role in the education of the new generation of scientists. Only the future can show what use may be made of the knowledge now being gained.

The laboratory comprises an area of about 80 ha (200 acres), straddling an international frontier; 41 ha is on Swiss territory in Meyrin, Canton of Geneva (the seat of the Organization), and 39.5 ha on French territory, in the Communes of Prévessin and St.-Genis-Pouilly, Department of the Ain.

Two large particle accelerators form the basis of the experimental equipment:

– a 600-MeV synchro-cyclotron,
– a 28 000-MeV (or 28-GeV) proton synchrotron,

the latter being one of the two most powerful in the world.

The CERN staff totals nearly 2200 people.

In addition to the scientists on the staff, there are over 350 Fellows and Visiting Scientists, who stay at CERN, either individually or as members of visiting teams, for periods ranging from two months to two years. Although these Fellows and Visitors come mainly from universities and research institutes in the CERN Member States, they also include scientists from other countries. Furthermore, much of the experimental data obtained with the accelerators is distributed among participating laboratories for evaluation.

Thirteen Member States contribute to the cost of the Organization, in proportion to their net national income:

Austria (1.95%)	Italy (10.78%)
Belgium (3.83%)	Netherlands (3.92%)
Denmark (2.07%)	Norway (1.47%)
Federal Republic of Germany (22.74%)	Spain (2.18%)
	Sweden (4.23%)
France (18.57%)	Switzerland (3.19%)
Greece (0.60%)	United Kingdom (24.47%)

Poland, Turkey and Yugoslavia have the status of Observer.

The budget for 1965 amounts to 128 760 000 Swiss francs (= $29 800 000), calling for contributions from Member States totalling 126 400 000 Swiss francs (= $29 300 000).

A supplementary programme, financed by twelve states, covers design work on two projects for the future of high-energy physics in Europe – intersecting storage rings for the 28-GeV accelerator at Meyrin and a possible 300-GeV accelerator that would be built elsewhere ●

Last month at CERN

Conferences

August and September being the traditional peaks of the universities' long vacation, there was, as usual, much travelling to and from CERN in this period. Many students came to the laboratory for the first time, to gain first-hand experience of its research programmes. Many members of the staff travelled to one or other of the Conferences or Summer Schools being held in various parts of the world, and the usual large number of visitors from other laboratories, particularly those in the U.S.A., called in at CERN before or after attending the same conferences.

For the **students,** the CERN Programme was further developed this year, and the 100 who came for various periods attended a comprehensive series of lectures and visits, lasting 1 ½ hours or more practically every morning (Monday to Friday) from 20 July to 24 September, as well as taking part in the work of the Laboratory. A fuller account will be given in next month's *CERN COURIER.*

One of the most important of the conferences was the **Fifth international conference on high-energy accelerators,** held at Frascati, in Italy, from 9 to 16 September. This is the conference founded by CERN in 1956 and now held under the auspices of the International Union of Pure and Applied Physics every two years, alternately in the U.S.A., U.S.S.R. and Western Europe. The last time it took place in Western Europe was in 1959, at CERN*, and at that time the 28-GeV proton synchrotron was not yet finished (in fact the first beam circulated round the ring whilst the conference was in progress). Subsequent meetings were at Brookhaven in 1961 and Dubna in 1963**. This year, most of the accelerators under construction in 1959 are in full operation and more attention was given during the discussions at Frascati to detailed aspects of the design of machines such as the CERN intersecting storage rings and 200-GeV and 300-GeV synchrotrons. CERN's Director General, Prof. V.F. Weisskopf, opened the conference and thirty-five other scientists and engineers from the Organization also took part.

* CERN COURIER, no. 3, p. 3 (October 1959).
** CERN COURIER, vol. 3, pp. 143-145 (November 1963).

Almost immediately afterwards, from 19-25 September, over seventy physicists from CERN, not to mention many other who are working at CERN though not forming part of its staff, travelled to Oxford (U.K.), for the **International conference on elementary particles,** organized by the Rutherford Laboratory and bringing together some five hundred scientists from over thirty countries in the world.

This conference, following those at Aix-en-Provence in 1961* and Sienna in 1963**, is the third in a series instituted primarily for the benefit of the young European physicists working in the field of sub-nuclear research and held in alternate years to the main 'Rochester' international conferences.

A few days before (15-17 September), a more general **Conference on nuclear and particle physics** was held at the University of Liverpool under the auspices of The Institute of Physics and the Physical Society (U.K.). Prof. Ch. Peyrou, leader of CERN's Track Chambers Division, gave an invited talk on baryon resonances.

The extreme importance of electromagnets in the work of laboratories like CERN was reflected in the participation of members of the Organization in an **International symposium on magnet technology** at Stanford University, U.S.A., during 8-10 September.

Another important conference took place in the Free University of Brussels, during 14-16 September. This was the **Third Colloquium of the 'Institut Interuniversitaire des Sciences Nucléaires',** devoted to **the use of elementary particles in nuclear-structure research.** Since the last international conference in this field, organized by CERN and the Weizmann Institute in 1963**, the use of the CERN synchro-cyclotron for nuclear-structure experiments has increased considerably. Many of the physicists carrying out the experiments at CERN (mostly on the interactions of muons and pions with nucleii) reported on their work at the Brussels meeting.

* CERN COURIER, vol. 2, no. 2, pp. 10-12 (Feb. 1962).
** CERN COURIER, vol. 4, pp. 3-6 (Jan. 1964).
***CERN COURIER, vol. 3, p. 35 (March 1963).

Towards the end of September, members of the CERN staff, and ex-members, were among the lecturers contributing, for the third successive year, to the **International school of physics 'Ettore Majorana',** held at Erice, Sicily under the direction of Prof. A. Zichichi, of CERN, and sponsored by CERN, the Italian Ministry of Public Education, and the North Atlantic Treaty Organization. Some 80 students, from about 30 different countries, attended the School, which was devoted to both theoretical and experimental aspects of the structure of elementary particles.

During the same period (27 September - 10 October), other members of the CERN staff went to Herceg Novi, Yugoslavia, scene of the 1964 CERN Easter School, to lecture in an **International school of elementary-particle physics** organized jointly by the 'Département de Physique corpusculaire' of the 'Centre de Recherches nucléaires' at Strasbourg and the University of Belgrade (sponsored by the Yugoslav Nuclear Energy Commission).

Specimens of omega minus found in Europe

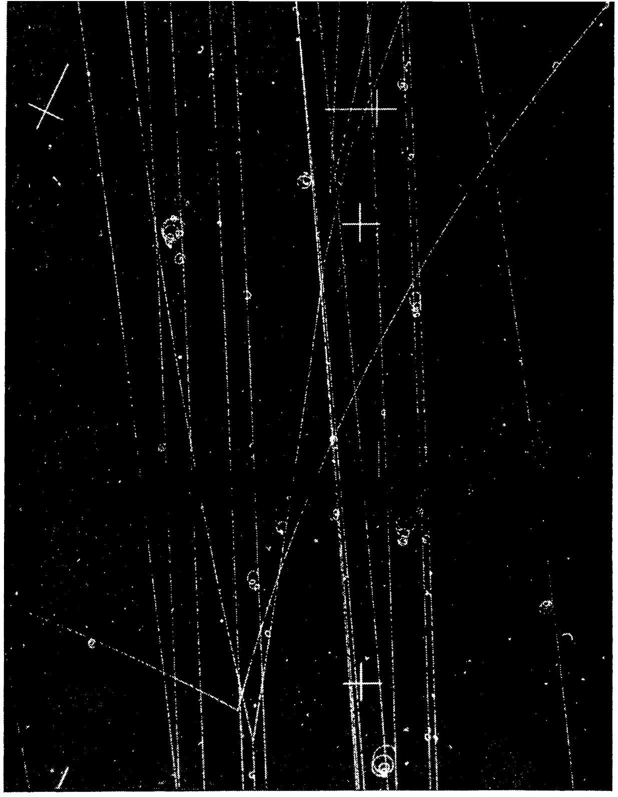
At the Oxford conference in September, three examples were reported of the famous omega-minus particle, which had been sought for several years in Europe but which had seemed more and more to be a native only of the U.S.A. This is the particle that was predicted as a consequence of the 'eightfold-way' version of the symmetry theory SU_3 and provided striking confirmation of the theory when it was discovered in an experiment at Brookhaven National Laboratory early in 1964 (see *CERN COURIER*, vol. 4, p. 27, March 1964). Until recently only five examples had been found, all in photographs obtained on that side of the Atlantic.

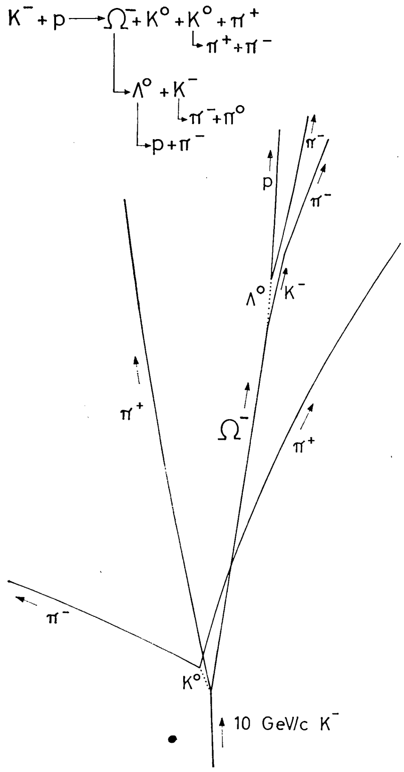
Two of the new examples were photographed in the 152-cm British hydrogen bubble chamber at CERN, during a run with 6-GeV/c negative kaons. The best one, for which details have been published in *Physics Letters**, was found after 400 000 photographs had been scanned,

* Physics Letters, vol. 19, pp. 152-4 (1st Oct. 1965).

Photograph of an interaction between a negative kaon and a proton, taken with the 152-cm British bubble chamber at CERN, in which one of the products was an omega hyperon. As indicated in the accompanying diagram, the omega decayed into a lambda (neutral and therefore leaving no track) and a negative kaon, after which the lambda in turn decayed into a proton and a negative pion whilst the kaon disintegrated into a negative pion and a neutral pion (again invisible). Two neutral kaons and a positive pion were also produced in the initial interaction and one of these kaons decayed into two charged pions. Identification of all the particles, including those not seen, was made from measurements on the tracks and subsequent computer calculations.

N.B. To see the event more clearly, hold the page horizontally at eye level and look along the tracks.





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in which the sum of all the kaon tracks amounted to some 5000 km ! From analysis of the many tracks appearing on the photograph it was deduced that the omega was produced in an interaction between a negative kaon and a proton in which a neutral kaon and a positively charged kaon were also produced. The neutral kaon decayed into a positive and a negative pion, the omega into a neutral xi hyperon and a negative pion ; the xi then decayed into a lambda and a neutral pion and the lambda in turn into a proton and a negative pion. The mass of the omega was calculated as 1666 ± 8 MeV and its lifetime 1.85×10^{-10} second.

The second example reported at Oxford was not so clearly defined, but the most likely explanation of the event in question is that an omega minus was formed.

The third omega, revealed in the photograph shown (with its explanation) on this page, was also produced in the British bubble chamber at CERN, but this time in the experiment that used a radiofrequency-separated beam of kaons of 10 GeV/c momentum.

Underlining the difference in effort required nowadays to find such an 'elementary particle', compared with that needed to discover the neutron, say, or the positron, is the fact that the paper in *Physics Letters* appears under the name of the 'Birmingham, Glasgow, Imperial College, Munich, Oxford and Rutherford Laboratory Collaboration'. Underneath are the names of the 51 university and other physicists involved ! Acknowledgements are also given to the crews of the CERN proton synchrotron and the British bubble chamber, the computing unit at Imperial College, the computer programming staff at the Rutherford Laboratory, and the scanning and measuring teams.

The 10 GeV/c negative-kaon experiment that has produced the third omega is being carried out by a collaboration of groups in Aachen, Berlin, CERN, London (Imperial College) and Vienna. In this respect, at least, the claims of CERN to be both an inspiration and a servant of physics in Europe seem to be not without foundation !

Experimental programme at the PS and SC

During the first two weeks of September no new experiments were introduced at the **synchrotron,** and those previously mentioned in *CERN COURIER* were continued in one way or another. The **CERN heavy-liquid bubble chamber** provided a further 150 000 photographs of stopped positive kaons, during its 4½-days run. The **81-cm liquid-hydrogen bubble chamber,** filled with deuterium, ran during both weeks under review and took about 40 000 new photographs of 5-GeV/c negative pions as well as about 160 000 of 5-GeV/c positive pions.

At the **synchro-cyclotron,** the whole 'holiday' period of August and September was one of intense activity. A number of experiments were completed in time for preliminary results to be presented at various conferences, and others took their place. Further details of all these will be given in the December issue of *CERN COURIER.*

'Rencontres internationales de Genève'

Once again this year, members of the CERN staff took their place among the distinguished representatives of the Arts, Letters and Sciences who participated in the 'Rencontres internationales de Genève', held from 31 August to 9 September. The theme of this year's cycle of public lectures and debates (the twentieth) was 'Le robot, la bête et l'homme' (automata, animals and man), and in six evening lectures, eight speakers presentee' their ideas on the essential differences that enable us finally to distinguish man from animals, on the one hand, and machines on the other.

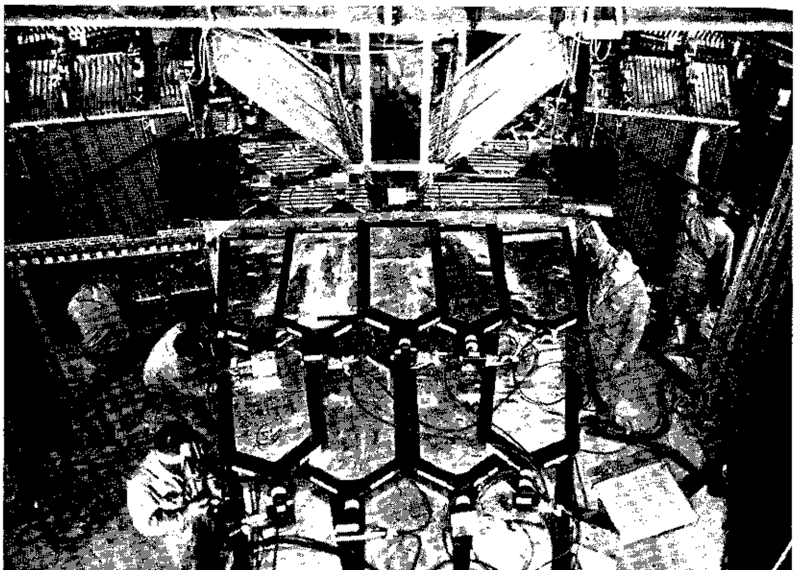
Roger Caillois, writer, editor of the international review *Diogène,* was followed by Guido Calogero, philosopher of the left, and Henri Niel, philosopher theologian, Jacques Monod, biologist, and Julian de Ajuriaguerra, doctor and psychiatrist, director of the Psychiatric Clinic of Geneva, Stanislaw Ulam, mathematician and computer expert, Ernest Ansermet, mathematician and musician, renowned conductor of the 'Orchestre de la Suisse Romande', and Jean Bruller (Vercors), artist and writer. Each of their lectures was followed the next day by a public debate in which the arguments were taken up and expanded by a wider panel of speakers, and a special debate was held on the subject of 'Automation and its social effects'. Included in the framework of the Rencontres, there was also a series of special film showings, related to the general theme, as well as a concert by the 'Orchestre de la Suisse Romande' under the direction of Ernest Ansermet.

Among the discourses, probably the most interesting for those from CERN was that given by Dr. Ulam, with the title 'La machine créatrice ?', in the course of which he summarized the basic operations carried out by computers and speculated on the way in which they might assist Man to understand more of himself. The speaker was introduced by Prof. V.F. Weisskopf, CERN's Director General, and both Prof. Weisskopf and Prof. L. Kowarski were among the personalities of many nations who participated in the debate. Whilst in Geneva, Dr. Ulam also gave a seminar at CERN on a rather different subject : 'Some ideas about quasers'.

'Grand Conseil' visits CERN

Two events in September serve to underline the efforts being made on all sides to increase mutual understanding between the citizens of Geneva and those who come from other parts of Europe to work at CERN.

The first of these was on 18 September, when the elected representatives of the people of Geneva, the members of the 'Grand Conseil', led by their President, Mlle E. Kammacher, spent the morning visiting CERN. In the unavoidable absence of the Director General (in England for the Oxford Conference) the visitors were received by the Directorate Member for Administration, Mr. G.H. Hampton, and were then given an introductory talk on the work of the Organization by Roger Anthoine, Head of Public Information. After a tour of the Laboratory in the care of some of the volunteer Saturday guides from the CERN staff, the Councillors returned to the Administration building where a reception had been arranged by the 'Conseil d'Etat'. A speech of thanks was made by Mlle Kammacher, to which Mr. Hampton replied. The morning was brought to a close by M. André Chavanne, Councillor of State in charge of Education in Geneva, who spoke in very favourable terms of the advantages that Switzerland could derive from having a laboratory such as that of CERN on its territory.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This impressive array of scintillation counters and spark chambers forms part of the equipment for detecting the decay of long-lived neutral kaons into pairs of neutral pions (one of the complementary series of experiments on CP invariance discussed in the September issue of CERN COURIER), set up in the PS East experimental hall by a group of physicists from the Rutherford Laboratory, the 'Technische Hochschule' of Aachen, and CERN. The kaons decay inside a tunnel formed of 100 overlapping plastic scintillation counters, each 80 cm x 50 cm, the top layer of which can be seen in the centre of the photograph. At the end of the tunnel are two sets of spark chambers, with interleaved plastic scintillation counters for triggering; above them are corresponding arrays of strip mirrors, to enable them to be viewed from the top, and large mirrors on either side which reflect their side views in the photograph. The spark chambers are arranged for the detection and subsequent measurement of electron showers arising from the decay of two neutral pions coming from a kaon decay, whilst the scintillation counters detect those cases where a third pi-nought is also produced in the decay.

'Rencontres de midi'

On 27 September it was the turn of the CERN staff to learn something more about Switzerland. In the first of the talks arranged under the general title 'Rencontres de midi', M. Charles Duchemin, Councillor of State of Geneva responsible for the Department of Internal Affairs and Agriculture, gave an instructive account (in French) of 'Democracy in Switzerland and Geneva'.

This series of talks, arranged jointly by the CERN Welfare Section and the Staff Association, will take place on the last Monday of each month, during the lunch hour. It is hoped that the contributions of distinguished speakers from both Switzerland and France will enable many members of the CERN staff to learn much more about the customs and political systems of the countries in which they now find themselves.

Visitors

Among the more important visitors to CERN in the past few months, apart from scientists from other laboratories, a few stand out for special mention.

Thus, on 12 July, members of the **Permanent Delegation of Greece** to the European Office of the United Nations Organizations, with members of the Greek Consulate in Geneva, were received. On 3 and 4 August, Mr. **S. Kenneth Johnsen,** Head of an architectural committee concerned with the design of the 200-GeV proton synchrotron in the U.S.A., spent some time at CERN adding to the information and impressions he is gathering of existing laboratories. The following week, on 13 August, Prof. **P. Lelong,** Chairman of the Scientific Research Committee of France, visited the Organization.

On 2 September, CERN received members of the **'Commission de Gestion' of the 'Conseil des Etats',** one of the two parliamentary bodies of the Swiss Confederation. Another diplomatic visit took place on 11 September when members of the **Hungarian Mission** in Geneva spent the morning at CERN ●

Recent developments at the PS

(The PS shut-down, and afterwards)

Activity around the proton synchrotron tends to be at a peak during a shut-down period, because it is then that major changes are made to the installations and essential maintenance is carried out on those parts of the machine that are normally operating more or less continually. However, much development, testing, and other preparatory work is required on the major installations before the shut-down, and many additions and changes are also made to the accelerator during the shorter shut-downs every fortnight. In this continuation of the article that appeared in the September issue of CERN COURIER (vol. 5, p. 133), therefore, the emphasis is more on the continuous development of the PS facilities than on the shut-down itself, and the title has been changed accordingly. One major group of activities, that concerned with the Linac, is still not covered here, but we hope to include an account of it in a future issue.

Synchrotron ring magnets

As already mentioned in the first part of this article (published in the September issue of *CERN COURIER*) the installation of the new ejected-beam system for the East area of the synchrotron* required many changes to be made to the accelerator itself and demanded contributions from many different sections of the MPS Division. Thus, to continue with an example already referred to, the installation of the special vacuum chambers in the sections of the ring before and after the ejection point also entailed the addition of new corrections to some twenty pole-face windings on the ring magnet units. These corrections, which take the form of a resistance network in the windings, were necessary to ensure that eddy currents induced in the (stainless-steel) vacuum chamber in the early part of the acceleration cycle (during injection of the protons) would not disturb the magnetic-field distribution.

One of the difficulties with any major change to the synchrotron is that the time available for actual work on the accelerator is very limited. Because the machine is inaccessible during operation, and cannot be spared for development work for more than the minimum possible time, as much work as is practicable has to be done away from the machine and almost everything else concentrated into the shut-down period. For this reason, the corrections necessary to ensure that the current in the pole-face windings would continue to produce the required magnetic field, accurate to a few parts in thousand, were first calculated and then checked by means of measurements on an analogue model before the actual changes were carried out during the shut-down.

* For a description of this system, see CERN COURIER, vol. 5, pp. 148-158, October 1965.

The analogue model (which simulates the actual physical system by an arrangement of electrodes on which measurements can be made of quantities representing the magnetic field) was also used to design the special shims and screens for magnets 58 and 59 as well as the magnetic screen for the first part of the external proton beam line. Exact analytical calculations for such complex shapes as those of the shims would be difficult and time-consuming, so in each case an approximate shape was first obtained by calculation and this was then set up in the analogue model. The shape was then changed until, by trial and error, the desired field pattern was obtained, and the final equipment was then manufactured accordingly. The success of the whole ejection system showed how accurate this approach had been.

As indicated in the photograph already published in the September issue, the installation of the 'radial-bump coils' was a major operation from the handling point of view. Those for the ejection-system 58 (ES 58) had in fact been installed during an earlier shut-down to enable tests to be carried out on their effectiveness, and in the July shut-down further coils were added for ES 74. Each ejection system requires coils on eight magnet units (six in the case of ES 62) but ES 58 and ES 74 overlap, so that two independent coils are needed on each of four magnet units, in order to be able to use both systems during the same beam pulse. Because of this, four of the single coils, each with eight conductors, had to be removed again during the shut-down and replaced with double coils having sixteen conductors. Two men were employed full-time in making up the bundles of conductors, in the ring tunnel itself, and help from other parts of CERN as well as outside was enlisted for their installation. Each coil takes a current of 650 amps and the time to rise from zero to maximum current is 25 milliseconds. The 400-V power supply for the coils, incorporating thyristors (controlled semiconductor diodes) was installed in an extension to the ejection power building during the shut-down.

Another magnet development, already mentioned in *CERN COURIER**, has been the replacement of the large quadrupoles, used to control the spread of the proton beam inside the accelerator at injection, by new, very small ironless quadrupoles, moulded in Araldite. The manufacture of these, as well as all the design calculations, was done at CERN.

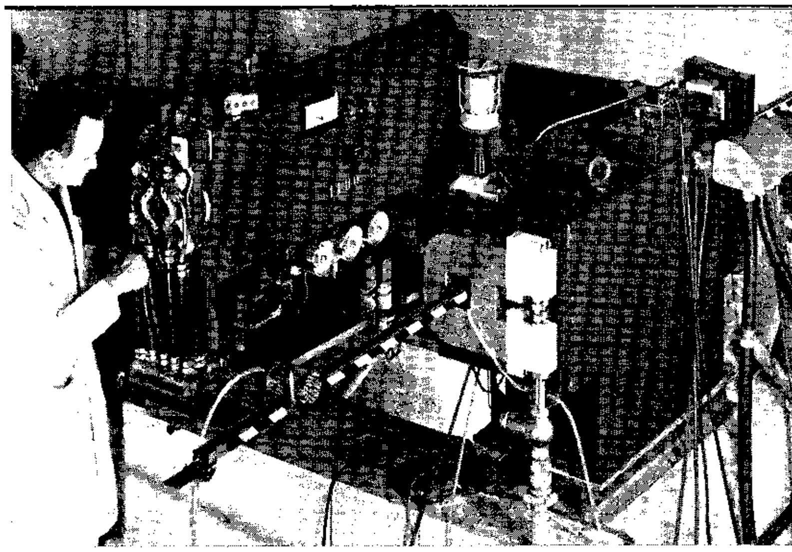
Main power supply

An important and major item of work during the shut-down was the realignment of the main motor-generator set that provides the current for the ring magnet, as well as the rebalancing of the alternator rotor. Owing to gradual deformation of the foundation block on which the generator is mounted, a considerable amount of vibration had arisen, but after this realignment and rebalancing the whole set runs much more smoothly.

Beam-transport systems

During the last two or three years a considerable amount of development work has been done, in a number of CERN Divisions, on more-compact magnets for the transport of secondary beams. Although the power requirements, and consequent cooling problems are greater for these magnets than for the older conventional types, the intensities of the secondary beams can be increased (by accepting particles from the target more nearly in the 'forward' direction) and the angular distance between the beams can be reduced.

* Photo, vol. 5, p. 56, April 1965.



The high-power d.c. 1.2-m quadrupole lens (left) and 1-m C-type window-frame bending magnet developed for the transport of the new resonance ejected beam at the PS. The overall width of the quadrupole is 22 cm and of the bending magnet 38 cm. Visible especially on the bending magnet are the small drilled Delrin blocks that provide all the cooling-water connexions to the coils, replacing the numerous rubber hoses used conventionally up to now. By further reducing the number of coil turns per cooling circuit, current densities of up to 140 A/mm² (instead of the present 50 A/mm²) should be achieved, leading to even slimmer magnets.

Among the new 'slim' magnets developed in the MPS Division are two types of quadrupole, the 'figure-of-eight' and the 'split-pole'*, each having an overall width of 50 cm, instead of the 120 cm of the standard magnetic lens used at the PS, with the same aperture of 20 cm. The C-type window-frame magnet belonging to this series has enabled the separation of the axes of two beams to be brought down to 80 cm instead of 160 cm. These magnets were first put into use rather more than a year ago and have proved very satisfactory in operation.

Ejected proton beams pose even more stringent requirements, because beam-transport magnets have to be put very close to the accelerator structure and there is also not much space available anywhere inside the ring tunnel. Although very compact magnets using pulsed currents could be developed for the fast-ejected beam in the South area, the new slow-ejected beams, with a much longer beam pulse, required magnets that were continuously energized. For this purpose, two new types of quadrupole were designed in the MPS Division, one of them 1.2 metres long, the other 75 cm. Both give a very high field gradient of 5.5 kilogauss per cm and have an aperture of 5 cm, although the overall width is only 20 cm. Two new bending magnets were also developed, both of the window-frame C type, one having an aperture of 7.5 cm × 4 cm and producing a field of 21 kG, the other with an aperture of 10 cm × 5 cm providing up to 22.5 kG (see the October issue of *CERN COURIER*). In spite of the small overall dimensions, the window-frame design of these magnets provides a very uniform field, constant to within 1 part in a thousand at values up to 20 kG.

The small size of these magnets, coupled with the high values of the current that they carry continuously (the current density in the quadrupole windings, for instance, is 50 A/mm²), naturally posed difficult cooling problems. Among the solutions adopted, the most elegant is that in which the numerous connexions to the cooling ducts in the coils are made by means of channels drilled in a single block of plastic material, instead of by using individual rubber hoses.

Other laboratories are interested in the magnets and already the DESY Laboratory, at Hamburg, has decided to construct magnets of identical design for the ejected electron beam of their synchrotron.

Although, strictly speaking, it does not come under the heading of beam-transport equipment, mention should also be made of a special pulsed quadrupole lens which has been designed to fit into straight-section 61 of the PS, as part of the beam-ejection system 62. This lens is of particular interest since it has been made with a horizontal slot in one side, so that secondary beams can still be obtained from internal targets in that section. This quadrupole arrived from the manufacturers early in October and is now undergoing tests.

Magnet power supplies

Since the effect of a magnet on the particle beam passing through it depends essentially on the current in the magnet, it is important to regulate the latter within prescribed limits. Moreover, with beam lines becoming more and more complex the stability requirements have become correspondingly more stringent. During the shut-down, therefore, all the generators supplying direct current to the standard beam-transport elements in the East experimental area were equipped with improved regulators, which maintain the current stable to 0.01 %.

The use of more and longer beam lines also demands more power supplies. Thus 6 new generators and 14 new rectifier units have been brought into service during the past few months, bringing the total number of supply units up to 94. The new rectifier sets are housed all together in an annexe to the East generator building, also recently completed and brought into service.

Ejection power supply

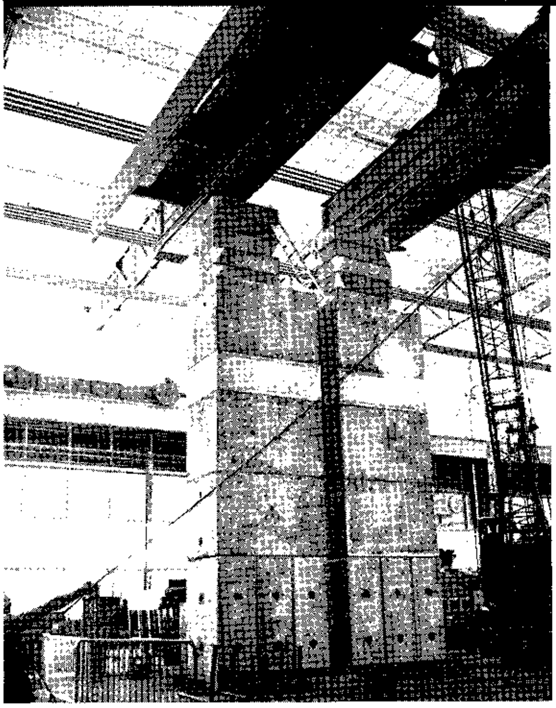
Another important power supply, installed during the shut-down in the newly completed East-area ejection building, was that for the ejection magnets of ES 58. This has to supply a pulse of 16 000 A at 60 V, and again there is a need for high stability, with a ripple of only about one part in a thousand. When first completed, the power supply could not meet this stringent requirement, but with the co-operation of the University of Toulouse an active (electronic) filter, incorporating 150 transistors (see pictures in the October issue of *CERN COURIER*) was developed and installed by the manufacturers in time for the first ejection tests.

Cooling systems

Not only do more magnets need more power supplies, they also require extended cooling facilities, to take away the heat unavoidably generated.

Basic cooling of the magnets is by means of demineralized water which is circulated continuously through the coils, but this water has itself to be cooled again before passing back to the magnets. To provide for the extra capacity needed, two new 'mobile' cooling units — each handling a heat load of 3 MW — have been ordered

* Report CERN 64-5.


CERN/PI 261.6.65

During the July shut-down another overhead crane, with a capacity of 20 tons, was installed in the East experimental hall. As can be seen here, full use was made of the stock of concrete shielding blocks as an aid to its erection.

and are now nearing completion. One of these works on the principle of evaporative cooling, a fine spray of water being directed over the banks of tubes through which the primary water flows from the magnets, the other is a forced-draught cooler, with a powerful air flow instead, rather like an immense car radiator.

A complementary approach has been to reduce the load on the cooling plant by ensuring that large magnets operating at less than full current are not overcooled. Thus a system has been developed which will adjust the flow of water through a magnet so that a given temperature increase is obtained rather than a given flow. This will reduce the amount of demineralized water needed in the primary cooling circuit as well as decreasing the heat-exchanger load. The first units were mounted at the end of October.

Control of accelerating frequency

When the PS was first put into operation, the required increase of accelerating frequency in step with the increasing magnetic field was obtained by means of a 'Hall computer'. This continuously measured the magnetic field in the 101st magnet unit (installed in the computer room in series with the other 100 magnets), computed the frequency and applied the necessary control, with an accuracy of one part in 10 000. However, the success of the beam control system, applied for the first time on this accelerator, to adjust the frequency according to measurements made on the beam itself, meant that such accuracy was no longer essential. A simpler system, essentially providing a predetermined frequency programme, was therefore designed and put into use. One advantage of this new equipment was that it could be housed with the other radiofrequency apparatus in the central building of the PS, instead of in the computer room adjoining the South experimental hall.

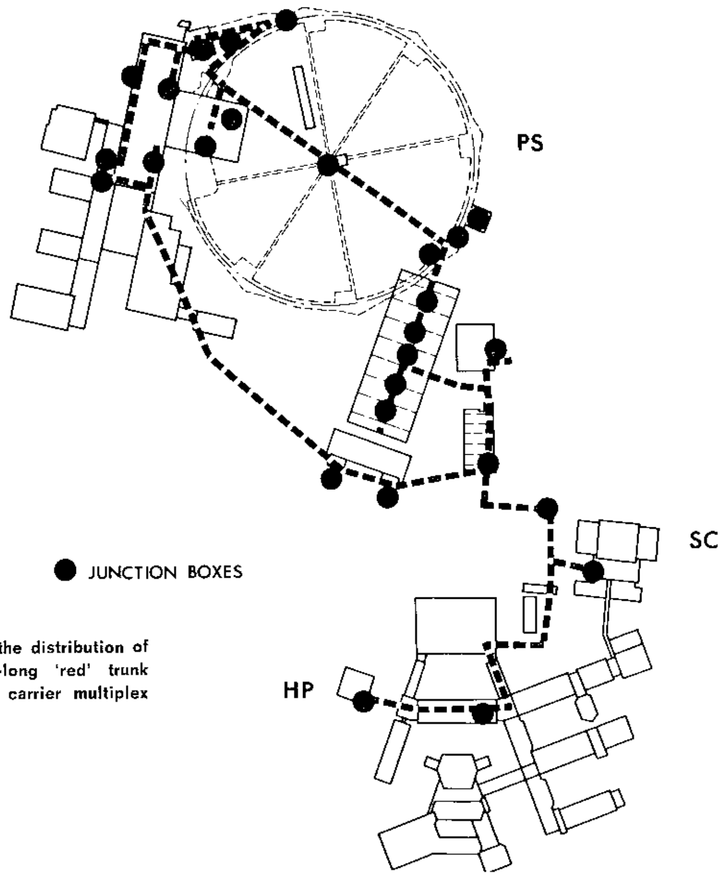
However, two more recent proposals, one to accelerate deuterons and the other to increase the repetition rate of the accelerator, both imply changes to the simple linear rise of the magnet field at present used during acceleration. As a result, it will again become necessary for the frequency to be closely controlled by the field, and a new device has accordingly been developed, and will soon be in operation. This measures the magnetic field (in the 101st magnet unit, as originally), converts the reading to a train of electrical pulses whose frequency depends on the rate of change of the field, and transmits this pulse train to the central building. Here, the second part of the apparatus, a digital-to-analogue converter combined with a series of switched frequency-division circuits, controls the accelerator radiofrequency according to the signal received so as to keep it in correct relation to the magnetic field.

Multiplex and polycanal

Two systems for the transmission of monitoring and control signals have seen full use with the new ejected-beam system. One of these is CERN's unique distributed carrier multiplex system*, for the transmission of digital (essentially on/off) or analogue signals; the other is known as 'polycanal'** and is used primarily for transmitting accurate timing signals.

The carrier multiplex system, of the frequency-division type, was developed in MPS Division with the support of the Accelerator Research Division, partly because it already has certain advantages but also because these advantages (such as simplicity and economy of wiring) would become much more pronounced in any future larger accelerator. A single 'trunk' cable (ordinary mains wiring) has been installed, 3 km long, linking all the major accelerator control rooms and experimental areas as well as computer and health-physics locations at CERN. Standard transmitters and receivers can be plugged into any of about 30 junction boxes on this single trunk line and up to 400 different digital signals can be transmitted at the same time between any desired points. To take the simplest application, that of switching on a piece of equipment from a remote control station, operating the switch sends a continuous signal, at a particular

* Reports CERN 64-21 and CERN 65-28.
** Report CERN MPS/Int.-RF 64-17.



Plan showing the distribution of CERN's 3-km-long 'red' trunk cable for the carrier multiplex system.

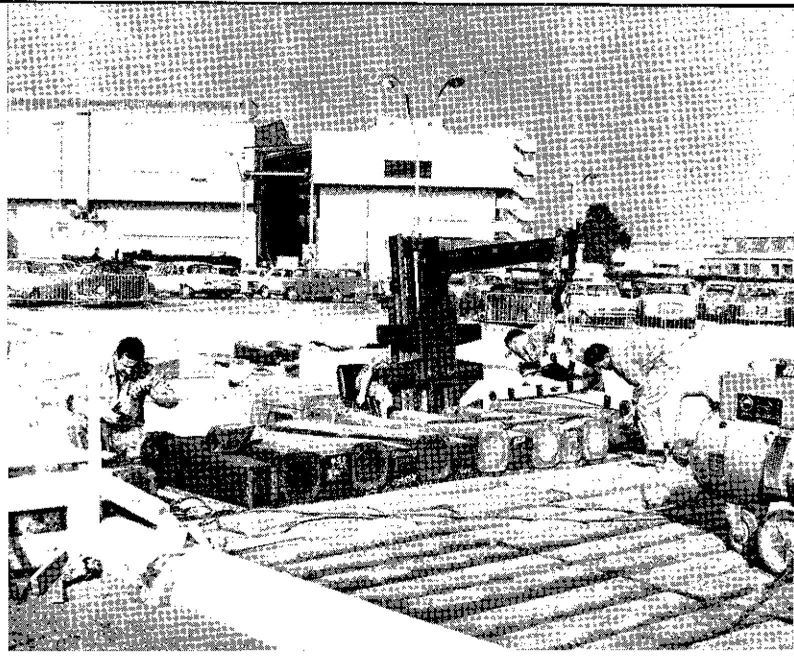
frequency, from the transmitter into the cable ; this signal is picked up only by the corresponding receiver, where it causes a relay to operate to switch on the apparatus. Switching off at the transmitter stops the signal and the relay ceases to be energized, thus moving the remote switch also to 'off'. Each function operates with its own particular frequency and various coding systems enable more complicated information than just on/off signals to be transmitted.

Thus, with the target mechanism for the new external proton beam, any one of twelve target heads can be selected and it can then be moved left or right, up or down, tilted or turned, whilst its position is indicated, with a precision of 0.1 mm, in both analogue and digital form, all from any convenient position on the trunk cable. In this particular case, the target mechanism itself is connected to its control unit in the main control room by means of 500 metres of 30-core cable (15 km of wire !), and the remote-control unit (which would normally be in an experimental area) communicates via the multiplex system with this main control unit. A further point of interest of the whole carrier system is that the 3-km trunk cable also carries the main supply for the control units, so that these are all completely self-contained.

Besides the target mechanism, the beam-transport magnets are also controlled by means of the multiplex system.

Another important use of the system is made by the Health Physics Group, for general radiation monitoring around the site. Monitoring stations can be placed in many different places and just plugged into the trunk cable, with readings from all of them being displayed on a central recording unit.

Polycanal is also a multiplex system, but of the time-division type. It uses a single co-axial cable for the transmission of many different timing signals, and one of its major advantages is that these signals can be very well synchronized with the accelerator cycle by using one of the PS timing pulse trains as reference. Any timing pulse to be transmitted via the cable is first submitted to a delay, which is characteristic of the transmission channel, before entering the common transmission cable. The various delays differ by units of 10 microseconds with a maximum of 1 millisecond, at present, so that 100 different channels are possible. Each receiver is sensitive only to its own particular signal in the sequence.



After part of the PS and NPA car park had been excavated and thick concrete foundations laid down, work started early in October on building up the steel 'neutrino filter' (to absorb all other particles in the beam) for the new neutrino experiment scheduled for the second half of 1966. Part of the PS East experimental hall and the East bubble-chamber building can be seen in the background in this photograph.

CERN/PI 35.10.65

It is characteristic of the functioning of the PS that many operations can occur up to 1 millisecond earlier or later than the optimum time, provided that the time of occurrence is precisely the same from cycle to cycle (to within a microsecond), and the polycanal system is ideally suited to this situation. The system is at present being used to provide the timing signals for the septum-magnet power supply of ejection system 58. Later developments envisage the use of the polycanal system also for the transmission of certain measurements, voltage readings for example. Already, to gain operating experience, it is being used for all the remote controls and monitoring of the septum magnets in section 58 as well as their power supply (60 channels in all). For example, movements of the magnets and readings of their position are all carried out using polycanal.

Plans for improved neutrino beam

The conference on experimental neutrino physics held at CERN early this year* stimulated, among other things, new ideas for further improving the intensity of the high-energy neutrino beam provided by the PS. As a result, a system of high-current, pulsed magnetic reflectors was devised which, used in conjunction with the existing magnetic horn, has been calculated to provide the most intense beam, over a wide range of energies, yet conceived**. Work on the conical inner conductor of the first reflector — demanding high precision over its total length of 5 metres — is well under way in the West workshop at CERN and it is hoped to have the whole reflector ready for test next Spring.

New neutrino area to be built

Although in a rather different category to the other work discussed in this article, it is worth mentioning here that during the July shut-down a start was also made on a new neutrino area, which will be completely separated from all other experiments and hence more flexible in use than the former one in the South hall of the PS. The plan is to eject the proton beam from straight-section 74 of the synchrotron, just beyond the junction of the ring with the East experimental hall, and to install the CERN heavy-liquid bubble chamber in the area between the NPA building and the new PS workshop. Between the ejection point and the bubble chamber, partly underground, will be the external proton beam line, magnetic horn and reflectors, decay path, and neutrino filter. At a later stage it is planned to install the proposed new bubble chamber 'Gargamelle' as detector.

The necessary apertures in the PS tunnel wall and the outlet tunnel through the shielding for the proton beam were finished during the shut-down and sealed off inside and out with concrete blocks. At the end of September work was well under way in the middle of the PS and NPA car park for the bubble-chamber and neutrino-filter installation. It is hoped to prepare most of the beam path and shielding during the rest of this year and the first half of next, and to be ready for new experiments in the Autumn of 1966 ●

* CERN COURIER, vol. 5, p. 38, March 1965.
** Report CERN 65-17.

BOOKS

Elementary particles, by David H. Frisch and Alan M. Thorndike (Princeton, D. Van Nostrand Company Inc., 1964; $ 1.75), is the first of a series of reasonably priced paper-back books (*Van Nostrand Momentum Books*) published for the Commission on College Physics in the U.S.A.

The series, so we are told, was conceived 'to serve the modern enquiring mind. Scientist, engineer, teacher, student, inquisitive layman... each will find that *Momentum Books* provoke new ideas, new questions and new answers while they provide an insight into experimental techniques and the disciplines of the scientific mind'. From this it can be inferred that the authors do not set out to give an exhaustive treatment of their respective subjects, and the book under review confirms this impression. It is both entertaining and instructive to those who have some appreciation of its subject matter, but it is not in itself a complete treatment of elementary particles.

Indeed, the authors make this clear in their preface, where they state that the topics discussed are only representative 'and there are unsubstantiated assertions on nearly every page'.

The first seven chapters deal with some of the facts of elementary-particle physics. In the first, a few of the more 'bizarre' notions serve as an introduction to the subject, followed by a brief history, from the Greek 'atom' to the present day (or, to be exact, the latter part of 1962). This is followed by a chapter on 'Particles we surely need' — graviton (?), photon, electron, pi-meson, proton, neutron and their antiparticles — and one giving brief accounts of the various ways of detecting particles. 'Particles we might do without' comes next, these particles being those whose existence is forced on us by experimental evidence although a simple theory of nuclear and atomic behaviour would not require them — particles such as muons, neutrinos, kaons and hyperons. The next chapter deals with ways of measuring the charge, magnetic properties and mass of elementary particles, and the following one with some elementary-particle reactions. Much of this, in fact, is devoted to a dramatic first-hand account of the experiment in which lambda hyperons were produced artificially for the first time and the hypothesis of 'associated production' was confirmed. The last chapter of this section describes in some detail how the existence of the antiproton was proved experimentally.

In reading this part of the book, one or two things stand out especially. For example, at the beginning of chapter 2 an elementary particle is defined as 'one we do not know how to describe as composite'. This may sound rather defeatist at first sight, but it certainly explains the proliferation of such particles in recent years as well as the consequent belief that there must be some underlying order that will enable all the presently known particles (as well as others to come) to be described in terms of only a few. In the section on the measurement of masses, the use of magnetic fields and electric fields as momentum filters and energy filters, respectively, for beams of charged particles, is clearly shown. Historically, there are also interesting reminders. The pion with which we are so familiar in our work at CERN was first produced artificially only in 1948; antiprotons have been known for only ten years and the experiment that provided 60 examples to prove their existence needed a new accelerator (the Bevatron) before it could be carried out, besides new identification techniques that have now been developed to provide beams of these antiparticles with intensities of tens of thousands of antiprotons per second. In the cloud-chamber experiment on hyperons, some 4000 pictures were taken on the first day and 20 000 in the whole run, compared with today's typical bubble-chamber run of a quarter of a million pictures at the rate of 25 000 a day.

Chapter 8, as the authors state, is rather more abstract, dealing with the important subject of the forces between elementary particles. Gravitational forces, electromagnetic forces, scattering experiments, the quantum idea of electromagnetic forces, nuclear (strong) forces and the weak forces of radioactive decay are all dealt with in an enlightening way. Chapter 9 also deals with an abstract subject, but one that has currently become of particular interest: conservation laws and invariance principles. The relation between these two concepts is clearly explained, using as examples the conservation of linear momentum, of angular momentum, and of energy, the reversibility of time, the conservation of parity, the conservation of electric charge, charge conjugation, the conservation of leptons and baryons, and finally the concepts of isotopic spin and strangeness. The non-conservation of parity in weak interactions is very well described, with the aid of clear helpful diagrams, and the discussion of CP invariance (assumed here, of course, to hold for all interactions) helps to show why its apparent violation in recent experiments has caused such a stir. The book is worth reading for this chapter alone.

One of the deeper reasons why the study of elementary particles has such an attraction is demonstrated in the discussion of the laws of conservation of lepton and baryon numbers. There is no explanation for these laws, yet if they did not exist the proton could decay into a pion and a positron, there would be no nuclei, no atoms, no molecules, and no physicists to wonder about the cause. The last chapter is devoted to some of the attempts to bring order out of the chaos of experimental data now available. Unfortunately progress is so rapid that few of the approaches discussed have retained much interest, except as steps on the road to current ideas. On the other hand, the four major questions with which the book ends still seem as far from being answered today as they were when they were written.

A.G.H.

Controlled thermonuclear reactions, by L.A. Artsimovich (New York, Gordon and Breach, Science Publishers, Inc., 1964; $19.50).

A few months ago (May 1965) we had occasion to note in this column that plasma physics is a relatively new and very fascinating field of research. One of its main potential applications lies in the use of plasma to maintain a fusion that would produce controlled surplus energy. The world has seen a long series of machines all designed to produce fusion energy or to help studies of plasma mechanics with this aim in view (Stellarator, DCX, Ixion, Perhapsatron, Zeta, etc.). None of the projects so far has been entirely successful. It is true that one has been able to prove the occurrence of fusion in some plasmas for short periods (measured in milliseconds) but much remains before a plasma 'heat factory' is constructed that can be switched on at will for any period of time.

The principle is to heat a suitable gas — such as deuterium or a mixture of deuterium and tritium — to a temperature where a fusion reaction (such as $d + d \rightarrow {}^{3}He + n$) takes place with sufficient abundance. The heating is effected by an electrical discharge, which partly ionizes the gas into plasma. This heat, as well as heat generated by the fusion, must be distributed in some way among the particles, preferably according to Maxwell's distribution law. At the same time, heat lost by radiation must be limited. The main problem, however, is the unwanted cooling of the plasma by the walls of its container. At present, the most promising way to overcome this seems to be to design a magnetic field of such an ingenious shape that all charged particles are caught by it and never touch the walls (hence expressions like 'magnetic bottles', 'mirror machines', and so on). But experience shows that, however subtle the arrangements, the plasma always manages (sometimes in conspiracy with the electric field) to break its way out through the magnetic field lines and get destroyed. It does so by constructing magnetic fields of its own, based on its charged-particle motion and by shooting out particles with the right energy at weak spots of the 'bottle'. These phenomena are called instabilities ('pinch', kink', etc., depending on shape). The failure to produce a 'canned' fusion has even led theorists to search for laws that would prohibit stable, isolated high-temperature plasmas in principle !

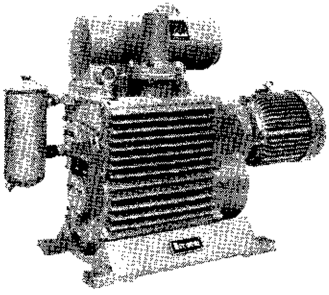
It is natural that the question of magnetic confinement of plasmas takes up a major part of this book by L. A. Artsimovich, a pioneer of Russian plasma research. In the first three chapters, the principles mentioned above are discussed and equations of particle motion and diffusion are treated. The concept of magnetohydrodynamics with plasma waves is dealt with in the next chapter. The remainder of the book is dedicated to the theory and application of discharges and the heating and confinement of plasmas, with many examples. In particular, the last two chapters deal with magnetic confinement and its theory, and instabilities, giving a large number of machines and attempted configurations as examples.

The style of the book (translated by P. Kelly and A. Peiperl from the Russian edition of 1961, revised and augmented by the author and edited by A. C. Kolb and R. S. Pease) makes it very clear and easy to read; this fact, together with the logical reasoning and richness of examples, makes the work an excellent text-book. As it is very complete it may also serve with advantage as a reference book for its subject. One regrets to say, however, that the author has used the older Gaussian c.g.s. system of units, which makes numerical work somewhat difficult and sometimes unnecessarily obscures underlying fundamental connexions (for example, by confusing the magnetic flux density $\vec{B}$, with the magnetic field strength $\vec{H}$). The index is sufficient, but not very detailed. There are no exercises given.

K. Soop

Also received:

Introduction to quantum mechanics, by P.T. Matthews (Maidenhead, Berks, McGraw-Hill Publishing Co. Ltd.. 1963 ;



25 s.) — based on a course of lectures for newcomers to the subject ; in four main parts : basic formulation, atomic physics, nuclear physics and general theory.

Recent research on beta-disintegration, by A.I. Alikhanov (Oxford, Pergamon Press Ltd., 1963 ; 20 s.) — translation from the Russian edition of 1960 ; describes the experimental research in the field of beta-disintegration, carried out during 1957-1959, which established the laws governing the non-conservation of parity in weak interactions.

The dynamics of conduction electrons, by A.B. Pippard (New York, Gordon and Breach Science Publishers Inc., 1965 ; paper $ 1.95, cloth $ 4.95) — text of lecture notes of early 1961, with appendix giving reference to later literature; semi-classical approach aimed at the student of experimental physics rather than the theorist.

Group theory and solid-state physics, vol. 1, edited by P.H. Meijer (New York, Gordon and Breach Science Publishers Inc., 1964 ; $ 5.95) — vol. 7 of *International science review series,* presenting reprints or English translations of selected papers contributing importantly to the understanding of the role of group theory in physics, with the emphasis on solid-state physics.

New physical and chemical properties of metals of very high purity (New York, Gordon and Breach Science Publishers Inc., 1965 ; $ 24.50) — proceedings of the symposium held in Paris in 1959 at the 'Centre national de la Recherche scientifique' ; subjects covered include analytic methods, properties of very pure metals, and improvements in zone-melting techniques ●

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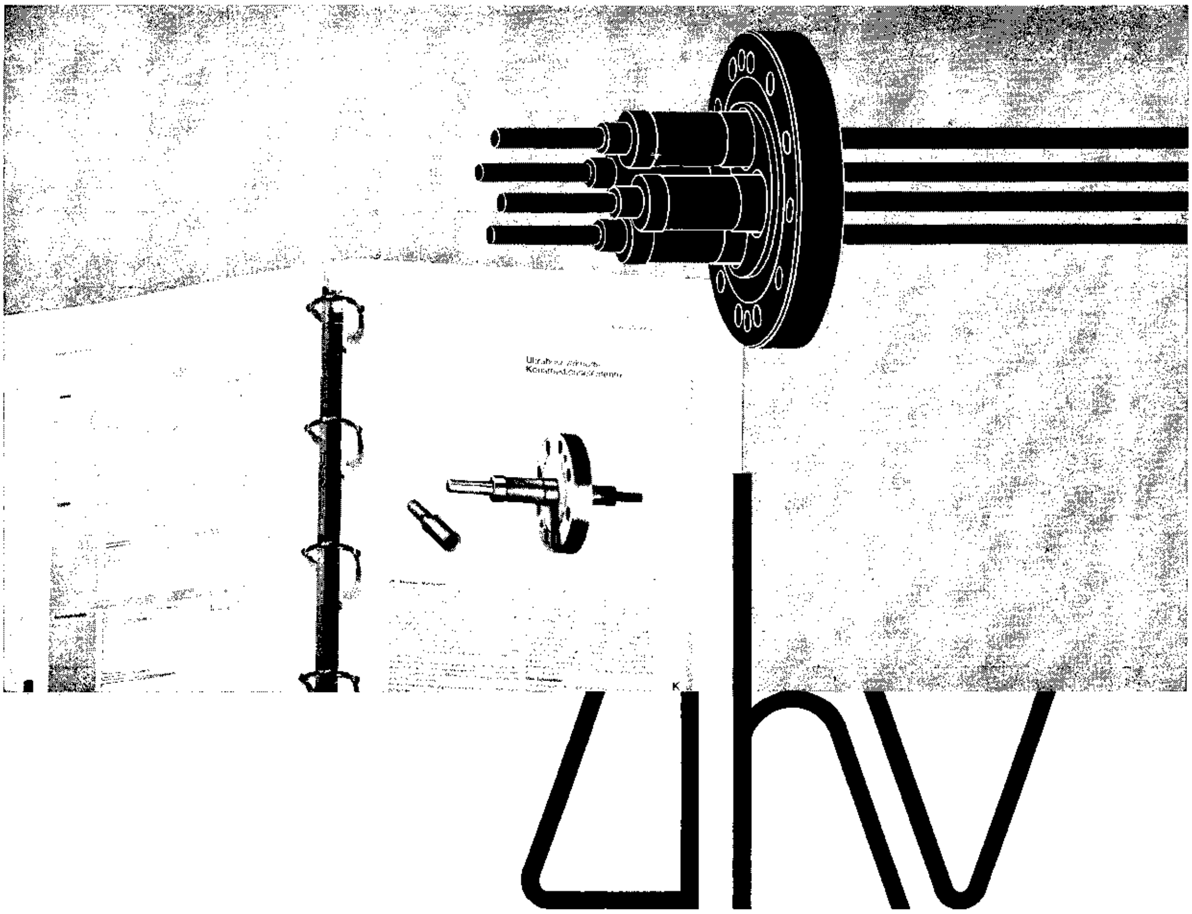

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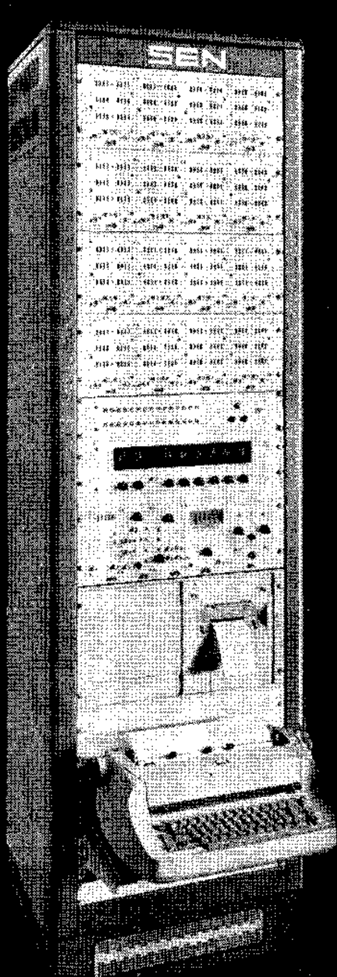

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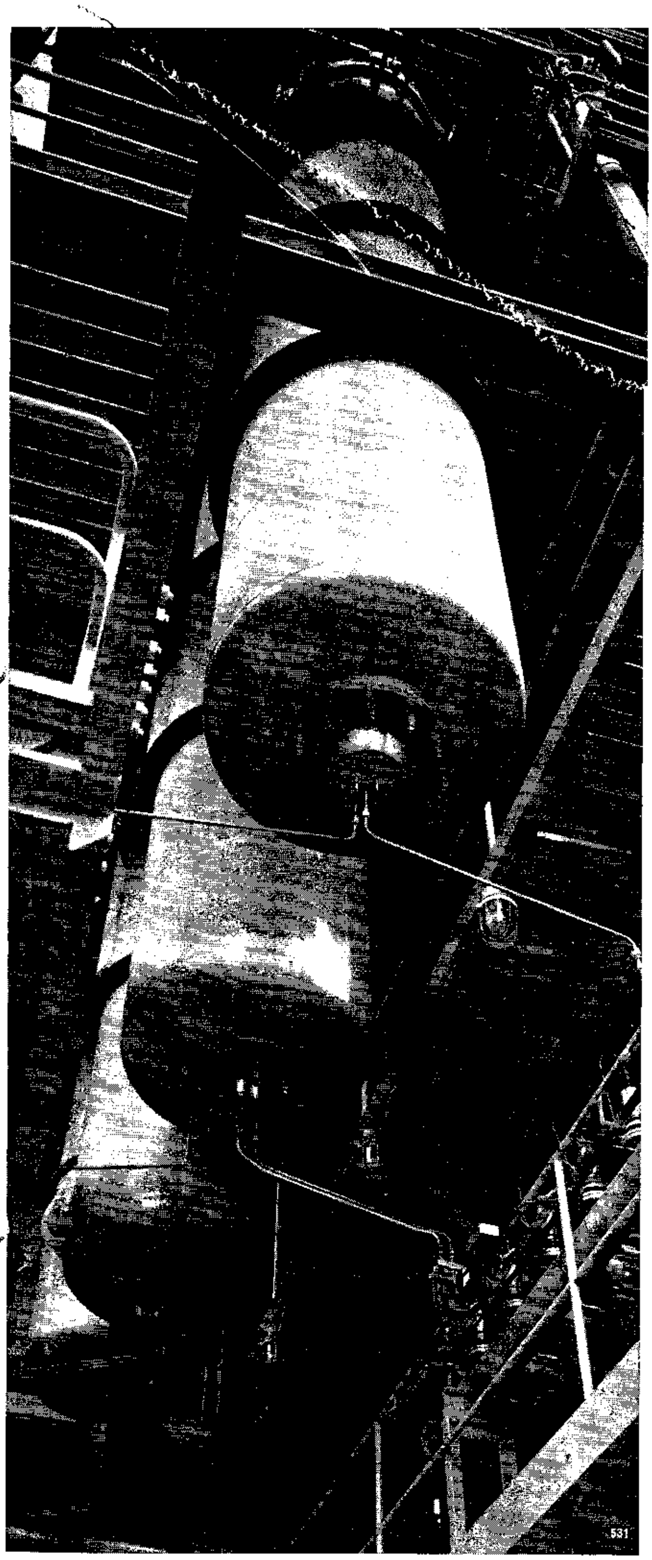

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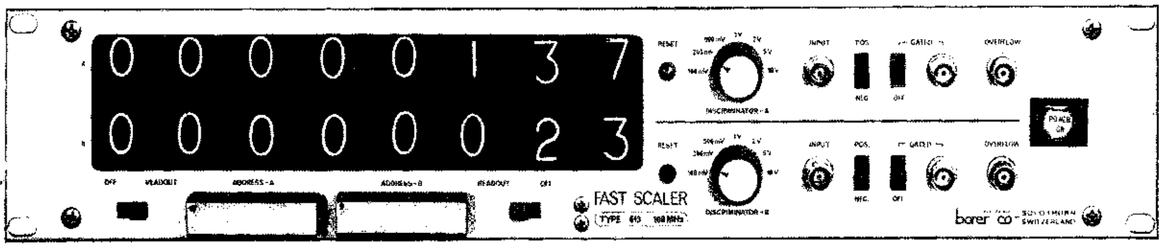

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The cover photograph illustrates the subject of the main article in this issue of CERN COURIER – recent developments at the PS. It gives a view of the structures nearing completion next to the East experimental hall, near the hydrogen safety sphere. These are two different types of mobile cooling unit for beam-transport or bubble-chamber magnets, each handling 3 MW. On the right are the four banks of the evaporative-cooling unit, already in provisional operation. Next to them, in the centre of the picture is the forced-draught air-cooled system. Both types are 'mobile' in the sense that they can be dismantled and re-erected in another location if necessary, in contrast to the main 20-MW cooling towers near the main generator building of the PS.

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The European Organization for Nuclear Research, more commonly known as **CERN** (from the initials of the French title or the original body, 'Le Conseil européen pour la Recherche nucléaire', formed by an Agreement dated 15 February 1952), was created when the Convention establishing the permanent Organization came into force on 29 September 1954.

In this Convention, the aims of the Organization are defined as follows:

> **'The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.'**

Conceived as a co-operative enterprise in order to regain for Europe a first-rank position in fundamental nuclear science, CERN is now one of the world's leading laboratories in this field. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of **high-energy physics,** often known as **sub-nuclear physics** or the **physics of fundamental particles.**

High-energy physics is that front of science which aims directly at the most fundamental questions of the basic laws governing the structure of matter and the universe. It is not directed towards specific applications – in particular, it plays no part in the development of the practical uses of nuclear energy – though it plays an important role in the education of the new generation of scientists. Only the future can show what use may be made of the knowledge now being gained.

The laboratory comprises an area of about 80 ha (200 acres), straddling an international frontier; 41 ha is on Swiss territory in Meyrin, Canton of Geneva (the seat of the Organization), and 39.5 ha on French territory, in the Communes of Prévessin and St.-Genis-Pouilly, Department of the Ain.

Two large particle accelerators form the basis of the experimental equipment:

- a 600-MeV synchro-cyclotron,
- a 28 000-MeV (or 28-GeV) proton synchrotron,

the latter being one of the two most powerful in the world.

The CERN staff totals nearly 2200 people.

In addition to the scientists on the staff, there are over 350 Fellows and Visiting Scientists, who stay at CERN, either individually or as members of visiting teams, for periods ranging from two months to two years. Although these Fellows and Visitors come mainly from universities and research institutes in the CERN Member States, they also include scientists from other countries. Furthermore, much of the experimental data obtained with the accelerators is distributed among participating laboratories for evaluation.

Thirteen Member States contribute to the cost of the Organization, in proportion to their net national income:

Austria (1.95%)	Italy (10.78%)
Belgium (3.83%)	Netherlands (3.92%)
Denmark (2.07%)	Norway (1.47%)
Federal Republic of Germany (22.74%)	Spain (2.18%)
France (18.57%)	Sweden (4.23%)
Greece (0.60%)	Switzerland (3.19%)
	United Kingdom (24.47%)

Poland, Turkey and Yugoslavia have the status of Observer.

The budget for 1965 amounts to 128 760 000 Swiss francs (= $29 800 000), calling for contributions from Member States totalling 126 400 000 Swiss francs (= $29 300 000).

A supplementary programme, financed by twelve states, covers design work on two projects for the future of high-energy physics in Europe – intersecting storage rings for the 28-GeV accelerator at Meyrin and a possible 300-GeV accelerator that would be built elsewhere ●