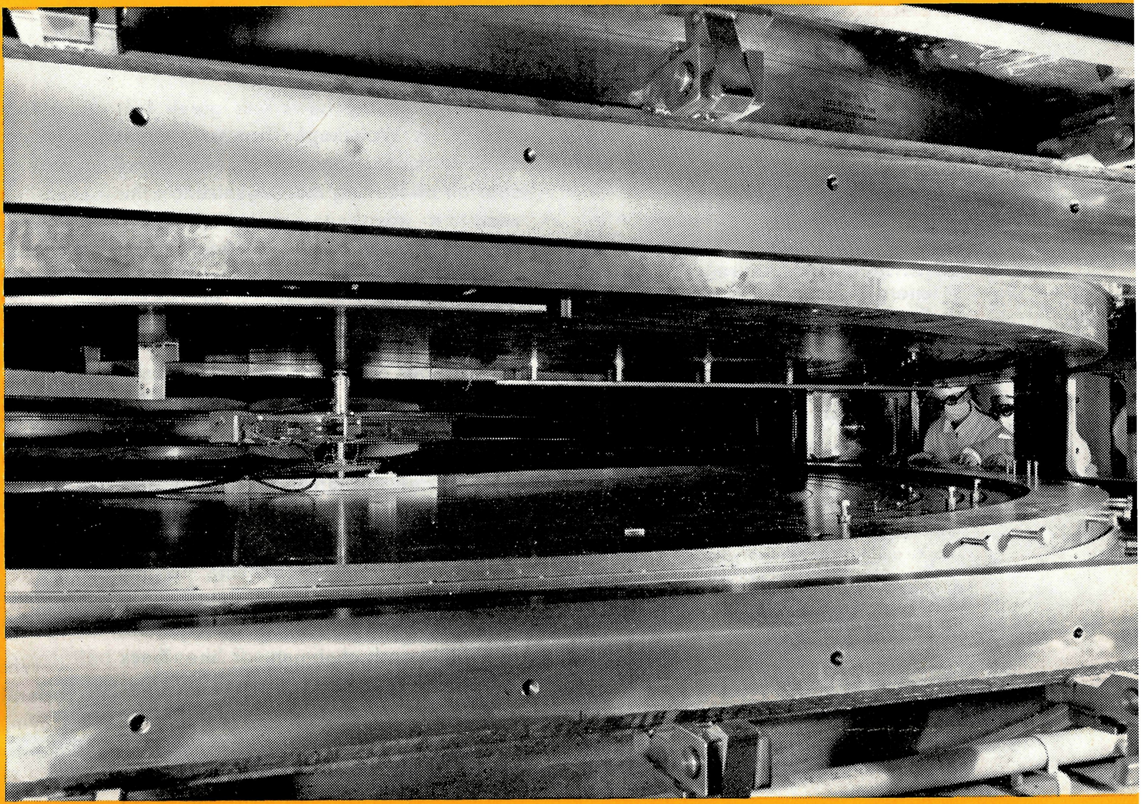
CERN COURIER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February 1964

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

The European Organization for Nuclear Research (CERN) came into being in 1954 as a co-operative enterprise among European governments in order to regain a first-rank position in nuclear science. At present it is supported by 13 Member States, with contributions according to their national revenues : Austria (1.96%), Belgium (3.85), Denmark (2.09), Federal Republic of Germany (22.86), France (18.66), Greece (0.60), Italy (10.83), Netherlands (3.94), Norway (1.48), Spain (1.68), Sweden (4.25), Switzerland (3.20), United Kingdom (24.60).
Contributions for 1964 total 107.2 million Swiss francs.

The character and aims of the Organization are defined in its Convention 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.'

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The cover photograph shows the interior of the vacuum tank of the 600-MeV synchro-cyclotron at CERN, opened for work during the January/February shut-down. Clearly visible are the two circular pole faces, 5 metres in diameter, of the 19 500-gauss electromagnet which is responsible for the spiral orbits of the accelerating protons. The 'dee' used to accelerate the protons can just be seen in the rear half of the gap. Goggled and masked as protection against radioactive dust, Rémy Blanc and Gérard Critin (of the cleaning staff) are cleaning the inside of the tank. Between them and the 'dee' can be seen the exit port for the extracted proton beam. The apparatus in the centre of the magnet gap was being used for measurements on the magnetic field.

CERN COURIER

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Last month at CERN

During January news was given that **Prof. V. F. Weisskopf, Director-general** of CERN since August 1960, would not after all be leaving the Organization this year. It was announced that, at its session in December, Council had extended his term of office for a further period of twelve months, until August 1965.

A number of changes in the organization and senior personnel of CERN have taken place, and these came into force on 1 January. The new **Directorate Member for Research** is Prof. **Bernard Gregory,** Professor at the École Polytechnique, Paris, responsible for the physics programme of the highly successful Saclay/École Polytechnique 81-cm liquid-hydrogen bubble chamber at CERN, and chairman of the Track Chamber Experiments Committee from 1960 to 1963. His appointment will be part-time until 1 August, after which it will be whole-time. Prof. **G. Puppi,** his predecessor as Directorate Member for Research, remains closely linked with CERN with a part-time appointment as Guest Professor.

In the course of the normal rotation of the post of **Leader of the Accelerator Research Division,** Dr. **A. Schoch** has taken over from Dr. C. Zilverschoon. Dr. **K. Johnsen** is responsible for the work of the interim supplementary programme.

Dr. **F. Grütter** has been granted leave of absence for one or two years to work in the Lawrence Radiation Laboratory, Berkeley, U.S.A. The **Engineering Division,** of which he was leader, no longer exists as a separate entity, and most of the staff are now the responsibility of the MPS Division. Other groups have been transferred to the divisions for which they were already working.

In the **Site and Buildings Division, P. Tirion** has been appointed 'Head of Services' and will be responsible for : transport and labour pool ; workshops ; stores ; cleaning services and clothing issues (these two formerly under Administration Division). The leader of the division, **Ch. Mallet,** will thus be more free to concentrate on the 1964 supplementary programme.

The **Personnel Division** (PE) has been formed under **G. Ullmann** and has taken over most of the work of the Administration Division, which has been dissolved. Exceptions are : the cleaning and clothing service, already mentioned; the Purchasing Office, which has been transferred to Finance Division ; Staff Housing Projects (but not individual questions and installation), Fire and Site Security Service, gardening, space allocation, and the Scientific Conference Secretariat, which are now the responsibility of B. W. Gamble, under the Directorate Member for Administration ; the Translation and Minutes Service and the Public Information Office, responsible directly to the Directorate Member for Administration.

When the proton synchrotron began operation again after the Christmas shut-down, the 'main user' was an experiment in the East hall, using the o_3 beam and the **École Polytechnique 1-m heavy-liquid bubble chamber** equipped with an internal liquid-hydrogen target. This is the first time in Europe that such a technique has been used and, in spite of the inevitable pioneering troubles, the run was completely successful. Over half a million photographs were obtained. The beam was set to give negative pions, first of momentum 8 GeV/c afterwards of 16 GeV/c ; these interacted with protons in the target, and the tracks arising from the reaction products were photographed in the freon filling of the chamber. Because this liquid has both a greater density and greater effective atomic number, neutral particles, especially gamma rays, neutral kaons (K^0_2) and neutrons, have a probability of decaying into observable particles some 20 to 500 times higher in the heavy-liquid chamber than in a liquid-hydrogen chamber of comparable size. The idea of separating the functions of target and chamber in this way was therefore specially evolved for the study of neutral products of the pion-proton interaction.

The arrangement had in fact been first tried before Christmas, when the **proton synchrotron** established another of its

Continued on p. 22

Discussions on future high-energy accelerators in Europe

by E. H. S. BURHOP, University College, London

In Europe no less than in the U.S.A. and U.S.S.R., physicists studying the fundamental concepts of the constitution of matter are finding more and more problems that only experiments at much higher energies can hope to solve. By the end of the next ten years, about the time it would take to design and build the type of apparatus required, it is certain that the need for such experiments will be very strong. The problem has been investigated by a committee of European physicists under Prof. E. Amaldi, and this article describes the background to the present situation, the proposals made by the committee, and the estimates of cost and manpower requirements that they arrived at. The author spent a year as a Visiting Scientist at CERN, during which time he acted as Secretary of the committee.

The period since the end of the Second World War has witnessed a remarkable increase in activity in all branches of science, fundamental and applied. In no field, however, has the rate of development been more spectacular than in high-energy physics. The epoch-making discovery of the pi meson by Powell, Occhialini and Lattes at Bristol, no less than that of the strange particles by Rochester and Butler at Manchester, relied on the use of high-energy particles present in the cosmic radiation. However, the detailed studies of these particles and their interactions, and the understanding that has gradually emerged of their significance, have relied almost entirely on the availability of intense beams of a variety of particles produced by high-energy accelerators. The strong-focusing alternating-gradient proton synchrotrons built at CERN and at Brookhaven (U.S.A.) represent the highest and most sophisticated stage so far reached in accelerator technology. Their successful operation has opened up new horizons for the work of the physicists and they are destined to play an irreplaceable role in our understanding of nature in this region for many years to come.

The far-sighted and devoted body of men responsible for the concept and subsequent development of CERN could not have foreseen even one per cent. of the important discoveries and investigations that the Organization has made possible. Nature, in this field of the physics of high energies and short distances, has proved infinitely more diverse than the most visionary of those who planned the laboratory could possibly have imagined.

The very successes achieved through the use of high-energy accelerators, however, have raised new problems which are not capable of solution at the machine energies presently available. Although so many new and unexpected phenomena have been revealed, and the importance established of the new concepts required for their classification, it cannot be said that they are understood in any real sense. The situation has been well summarized by Prof. Robert Oppenheimer, who wrote : “ The description of nuclear and subnuclear physics is incomplete and full of arbitrary and little-understood numbers and parameters. Essential clues are missing, buried in high-energy phenomena. Such are the nucleon ‘ core, the masses of the elementary particles, and the interaction constants themselves. We think it likely that essential novelty will appear at the ‘ super-high energies ’ that will promote this understanding. We are confident that a knowledge of what does in fact occur in this domain will take us a long way toward understanding. ”

To achieve the ‘ super-high energies ’ envisaged in this statement, new machines capable of accelerating particles to energies effectively greater by orders of magnitude than those achieved by the CERN PS are needed. Unfortunately such machines take many years to design and build. At the present time, their need can be discerned like a small cloud on the horizon ; in ten years’ time, as a result of the vigorous exploitation of existing facilities at CERN and elsewhere, the demand for particles of higher energy will have become overwhelming. Unless steps are taken very soon to design and begin the construction of suitable new accelerators it will not be possible to meet the demand, and the great advantages for high-energy physics in Europe that have come about as a result of CERN will be in danger of being lost.

EUROPEAN COMMITTEE ON FUTURE ACCELERATORS

With this situation in mind the then Chairman of the CERN Scientific Policy Committee, Professor C. F. Powell of Bristol University, together with the

Prof. E.H.S. Burhop was born in Melbourne, Australia, and educated at Melbourne University and Trinity College, Cambridge (England), where he carried out research in the Cavendish Laboratory during 1933-35. After 10 years as a Lecturer in the University of Melbourne he returned to England as a Lecturer in mathematics at University College, London University. He was appointed Reader in physics in 1950 and has been Professor of physics since 1960. He was elected to Fellowship of the Royal Society in 1963. As well as many papers on atomic and nuclear physics, he has published a number of books ; his main interest outside university work is the furtherance of international scientific co-operation.

CERN/PI 41.11.63

With a 300-GeV synchrotron it would be essential to have extracted primary beams, with all secondary beams starting from an external target, and arrangements like the above would no longer be seen. Here, the evacuated tube for the experimental slow-ejected beam in the South target area of the CERN PS can be seen in the centre of the photograph. Slightly to the right is the line of beam-transport magnets for the fast-ejected beam, leading to the magnetic horn. Two of the ring magnets of the synchrotron fill the right-hand side of the picture, while on the left a bending magnet and three quadrupoles of the secondary pion beam, d_{15}, are clearly visible. In the case of the 300-GeV machine, the ejected beam would pass through a tunnel 100 - 200 m long before hitting the target. Secondary beams would be selected by a powerful magnet and extracted through suitable gaps in a massive shield (estimated to require 3 700 tons of steel and 90 000 tons of barytes concrete) designed to absorb the muons produced. The experimental hall would be altogether about 60 m wide and 400 m long – three and a half times the length of the present PS East experimental hall.

Director-general of CERN, convened a meeting of leading high-energy physicists from CERN Member states and from CERN itself on 17-18 January, 1963. This meeting, which constituted itself into the European Committee on Future Accelerators (ECFA), appointed a small working party under the chairmanship of Prof. E. Amaldi (University of Rome) to prepare as quickly as possible a comprehensive report on the desirable programme of large accelerator construction for Europe and the practicability of carrying out such a programme in the light of its financial and manpower implications. The working party, consisting of ten physicists from outside CERN and three from CERN, held nine meetings over a period of four months and reported its findings * to a full meeting of ECFA on 7 June, 1963. These findings were endorsed by the latter and passed on to the Scientific Policy Committee, which gave them its general blessing and in turn passed them on to the CERN Council for consideration.

At the meeting of CERN Council in December 1963, approval was given for a supplementary budget in 1964 to enable the further development of design studies for the new accelerators envisaged in the report of the Amaldi Committee, but it was made clear by all concerned that this move did not imply any commitment for later years.

The main conclusions of the Amaldi Committee were that there should be two types of programme for Europe : a so-called **' summit ' programme,** of machines that should be built jointly by physicists and engineers from all the Member states, and a supplementary, or so-called **' base-of-pyramid ' programme,** of accelerators that should be built on either a national basis or, through a few countries linked together, on a regional basis. It was felt very strongly that the second type of programme was essential if the Member states were to obtain the full advantage of the ' summit ' programme, since physicists or engineers to work on the latter would generally need to get their training and to have their interest and enthusiasm for high-energy physics stimulated by working first on national or regional projects.

' SUMMIT ' PROGRAMME

For the summit programme two recommendations were made. The main one envisaged the construction of a **machine to accelerate protons to an energy of 300 GeV.** This machine would have a diameter of 2.4 km and might be expected eventually to accelerate up to about 10^{12} protons per second to this energy. Generally, but not in detail, it would resemble a large version of the CERN PS. There would be twelve straight sections, each 52 m long, around wich experimental areas could be built if desired. The acceleration would take place in three stages : a linear accelerator would first give the protons an energy of 200 MeV ; they would then be injected into a high-repetition-rate (25 pulses/second) proton synchrotron, which would accelerate them to an energy of between 6 and 10 GeV before they were injected into the main machine, where they would be accelerated to the final energy of 300 GeV.

No recommendation about the site for such a machine was made by the committee, but it is known that there are several possible suitable sites in the territories of the CERN Member states.

In addition to this large accelerator, the committee recommended that a pair of **intersecting storage rings** should be constructed for operation in association with the CERN PS. The attraction of a device such as this is that it enables a certain limited number of experiments to be carried out at a much higher effective energy than is possible with more conventional machines. Owing to the peculiarities of the mechanics of relativity, only a small fraction of the energy of high-energy particles impinging on a stationary target is available for producing new particles or processes. Most of it is required to ensure that the overall momentum is conserved. In fact, the effective energy of a conventional accelerator only increases as the square root of the actual energy of the high-energy particles.

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* CERN document FA/WP/23.

EUROPEAN COMMITTEE ON FUTURE ACCELERATORS

Forty-four independent representatives of the CERN Member states and twenty members of CERN itself attended meetings of the full committee. Representatives of the U.S.S.R., U.S.A., and Finland attended one meeting.

MEMBERSHIP OF THE WORKING PARTY

The members of the working party were as follows :

	Member	Alternate
Italy :	**E. Amaldi** (Chairman)	—
United Kingdom :	**J. M. Cassels**	—
Scandinavia :	**G. Ekspong**	**J. K. Bøggild**
France :	**B. P. Gregory**	**A. Berthelot**
Federal Republic of Germany :	**W. Paul**	**W. Gentner**
Belgium and Netherlands :	**S. A. Wouthuysen**	**J. Geheniau**
CERN :	**E. H. S. Burhop** (Secretary) **K. Johnsen** **G. Puppi**	

Technical advice was given by many others.

In the case of experiments with intersecting beams, however, the momenta of the two interacting particles are almost equal and opposite so that the resulting momentum is small. Almost the full energy of the two particles is then available for producing new processes. For example, the effective energy in the case of the collision of two protons, each of energy 25 GeV, moving in opposite directions would be equal to protons of about 1400 GeV from a conventional accelerator impinging on a stationary target.

The design and essential parameters of a suitable set of storage rings (as indeed for the 300-GeV proton synchrotron) have been worked out by the study group of the CERN Accelerator Research Division, and these were accepted by the Amaldi Committee. They envisage the storing of about 700 pulses of 25-GeV protons from the CERN PS in each of two storage rings of mean diameter 270 m. The beams in the two rings will be arranged to weave in and out of each other, intersecting in eight places at an angle of 15 degrees. The current stored in each ring will reach about 20 ampères.

The storage rings should be regarded as an exploratory device. They will not produce super-high-energy beams of secondary particles and can only be used for the study of proton-proton interactions. They cannot therefore be thought of as an alternative to the 300-GeV accelerator. Nevertheless, they would provide a ' window ' through which the future course of experimental physics at the highest energy could be viewed. They would of course have to be constructed near the present CERN accelerator.

' BASE-OF-PYRAMID ' PROGRAMME

No very detailed recommendations were made about the machines that should be built as part of the ' base-of-pyramid ' programme. It was pointed out, however, that these should include the following :

— **A pion ' factory ' :** this machine should accelerate at least 100 microampères of protons to an energy in the range 500-750 MeV and would provide very intense beams of pions and muons.

— **A kaon ' factory ' :** this should accelerate intense beams of protons ($> 10^{13}$ per second) to an energy of about 10 GeV, in order to produce intense beams not only of K-mesons but also of antiprotons and higher-energy pions.

— **A high-energy electron accelerator :** this would produce intense beams of electrons of energy at least 10 GeV.

In addition it was noted that at least six other machines had been proposed by physicists for construction in one or other of the CERN Member states, and a strong case could be made out for every one of these machines. Subsequent estimates of the cost of the programme were based on the assumption that all nine machines would be built.

COST AND PROFESSIONAL-MANPOWER REQUIREMENTS

Estimates of the cost of the programme are necessarily very approximate, since there are so many imponderables. It has been estimated that the 300-GeV proton synchrotron would take 8 ½ years to complete and would involve a total expenditure of 1460 million Swiss francs *. A set of storage rings for the existing CERN PS would take 6 years to complete and would cost 250 million Swiss francs. Allowing for reasonable expenditure on experimental areas, equipment and staff, and supposing the programme to commence in 1965, it is estimated that the whole summit programme would, by 1977, involve an annual rate of expenditure of something less than 500 millions Swiss francs. At the same time, the expenditure on the present CERN laboratory would probably be running at about 200 million Swiss francs per annum. To these figures would need to be added about 500 million Swiss francs per annum for the new ' base-of-pyramid ' programme envisaged, together with 400 million Swiss francs for expenditure on existing national projects. Taken altogether this would mean a total overall expenditure yearly of 1600 million Swiss francs on high-energy physics by the Member states of CERN.

It is estimated also that by 1977 about 2500 physicists of Ph.D. standing and above, together with 1500 pro-

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* All costs are estimated on the basis of 1962 prices. Very roughly, 4 Swiss francs equals 1 U.S. dollar.

fessional engineers, will be needed to carry out the full programme. Many of these physicists will be university staff members who will spend part of their time teaching. In addition, however, the programme will provide research facilities for the training of many hundreds of Ph.D. and advanced engineering students every year. The report of the Amaldi committee analysed in a preliminary way the questions raised by these manpower requirements and concluded that it should be possible to meet them without upsetting the balance between physicists going into high-energy physics and those going into other fields.

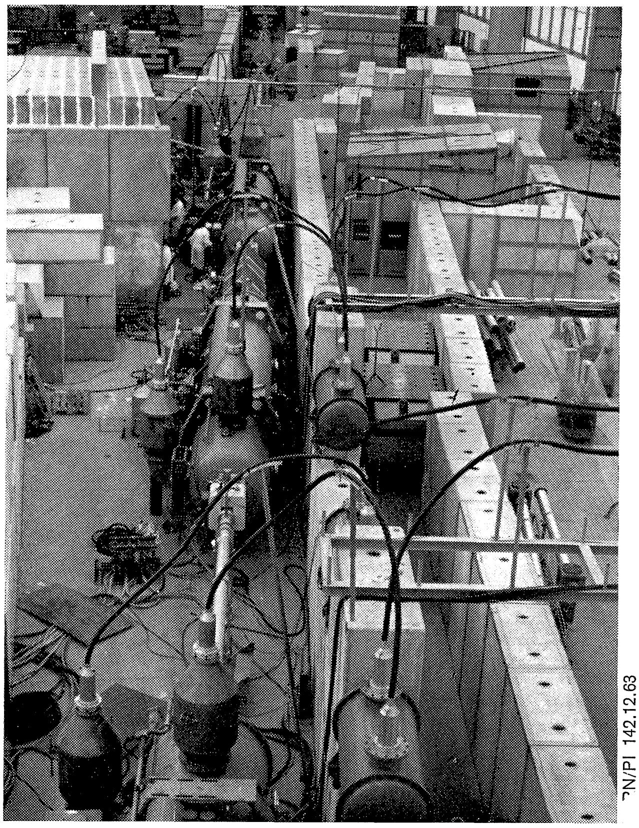
The expenditure requirements are large ; high-energy physics is certainly a very expensive branch of research. The financial commitment has to be viewed, however, in relation to the gross national product of the CERN Member states. It is estimated that by 1977 this will reach a figure of 2.2 x 10^6 million Swiss francs, so that the expenditure envisaged on high-energy physics at that time (about 1600 million Swiss francs) would represent a proportion of about 0.072 per cent. This is to be compared with the figure of 0.027 per cent. of the gross national product at present spent by the CERN Member states on all high-energy physics.

" 1600 million Swiss francs per year for high-energy physics by 1977 ", " 0.072 per cent. of the gross national product of the Member states of CERN " ; such figures, some apparently large, some looking much smaller, may be confusing to many people, particularly when an unfamiliar currency is involved. Another way of looking at the situation is to consider how much money is spent per person (man, woman or child) by each country. As an example, just over 100 million Swiss francs is to be contributed to CERN in 1964, shared among thirteen Member states. If, for each country, its contribution is divided by its total population, a rough idea can be obtained of what each person might consider to be his or her share in the cost of the Organization for the year. The results are as follows :

Austria	**1.8 Sch**	**Italy**	**35 Lit**
Belgium	**5 Fr**	**Netherlands**	**30 ct**
Denmark	**80 øre**	**Norway**	**75 øre**
Fed. Rep. of Germany	**40 Pf**	**Spain**	**85 ct**
France	**50 ct**	**Sweden**	**75 öre**
Greece	**55 I**	**Switzerland**	**65 ct**
		United Kingdom	**10 d**

Such figures are, of course, only a guide, but they do indicate that the amount of money spent each year on co-operative high-energy physics is still relatively small — the price of a few drinks, say, for the average family.

The proposed expenditure must also be judged in relation to the desirable fraction of the wealth of the community that should be spent on all aspects of basic scientific research. This, for advanced industrial countries such as the U.S.A., the U.K. and France, is already running at about 0.2 per cent. of the gross national product. As pointed out by the Amaldi Committee, however, with the present rate of technical development in the more advanced industrial countries it is most desirable, and in fact seems inevitable, that the proportion of the gross national product spent on fundamental scientific research should increase. A figure around 0.4 or 0.5 per cent. by 1977 seems not unreasonable.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It is probable that a good separated-particle beam from the external target of a 300-GeV synchrotron would be up to 1 km long, or ten times longer than the section of the o_2 beam seen in this photograph of part of the PS East hall, taken last December. Instead of the electrostatic separators that can be seen here, the higher energy beam would need radiofrequency separators, such as those under development in CERN's Accelerator Research Division.

As Professor Weisskopf said in his talk quoted in *CERN COURIER* last September: "Fundamental science clearly plays a dominating role in our culture ; its study is the greatest adventure of the human mind ". Yet at the present time in the United Kingdom (to take just one example), 7 per cent. of the gross national product goes in expenditure for military purposes — 260 times the average spending on all high-energy physics. The sum envisaged for *all* basic scientific research would still only amount to about 7 per cent. of the current military expenditure.

Within the budget for basic research as a whole the Amaldi report suggests that one seventh should be spent on high-energy physics. This may seem a large fraction but it must be viewed against the present background of activity and scientific interest in the subject. As we have seen, results of great importance are being obtained in this field and these may have a profound influence on our understanding of nature. The price of obtaining this information is inevitably high. It may be that other fields of research of comparable interest will require comparable resources for their further development. When that is the case the support should be forthcoming. The granting of large sums of money for work in one sector by no means necessarily makes it more difficult to obtain support for others. On the contrary, insofar as it helps to foster a realization that effective scientific research in any field must dispose of adequate resources, it may even assist in obtaining proper support for all ●

International Conference on Cosmic Rays

Jaipur, India 2-14 December, 1963

a review by W. O. LOCK, Nuclear Physics Division

Towards the end of last year the 8th International conference on cosmic rays, held under the auspices of the International Union of Pure and Applied Physics (I.U.P.A.P.) and the Department of Atomic Energy of the Government of India, was held at Jaipur, India. Among the participants was W.O. Lock, head of CERN's Emulsion Group, who gave an invited talk on recent work in the field of what is normally known as high-energy physics – though in the context of this conference such energies seem quite low. In this article, Dr. Lock gives a general review of the conference and of the subjects discussed.

The 1st International conference on cosmic rays after the war was held in 1949 at Como, in Italy. The 8th conference of this series was held last December at Jaipur, India, over a period of two weeks. Of the 250 delegates, about 140 came from outside that country, the largest numbers being from the U.S.A. (45), U.S.S.R. (19), U.K. (15) and Japan (12). Some 240 papers were presented during the conference, of which 55 were invited review talks lasting half an hour each. The most active countries in the field of cosmic-ray research can be gauged from the origins of the papers presented, and in this way it can be seen that the U.S.A., India and the U.S.S.R. have extremely flourishing research groups : 59, 49 and 47 papers originated from these countries respectively. From Japan came 31 papers and from the U.K. 21. All the papers presented were of a high standard. In contrast, very little is being done in the countries of Western Europe (excluding the U.K.), where there is perhaps one research group in each country. Presumably the existence of CERN is, to a large extent, responsible for this diminution of cosmic-ray work in Europe !

The conference occupied twelve complete working days, with a break of one day in the middle to visit the Taj Mahal at Agra. Its extensive scope can be seen from the number and the titles of the different sessions : six on extensive air showers, two on primary electrons and photons, three on cosmic-ray composition, three on origin, two on solar particle radiation, eleven on modulation, two on plasma, ten on cosmic-ray history based on isotope studies, ten on high-energy interactions, six on muons and neutrinos, and one each on techniques, radio-astronomy, and radiation belts.

To survey all the material presented in these fifty sessions is quite beyond the scope of a short article. Instead, an attempt will be made to pick out a few topics of general interest. Measurements of the **primary energy spectrum** of cosmic rays now extend up to 10^{20} eV (that is, in more familiar terms, 10^{11} GeV). Such measurements have been achieved using a scintillation-counter array, spread out over an area of 8 square kilometres, to detect very large **extensive air showers** (which originate high in the atmosphere from a single 'primary' particle). This array has been operating at the M.I.T. Volcano Ranch Station in New Mexico at an altitude of 2000 metres (atmospheric depth 820 g/cm^2). Data reported by Linsley (M.I.T.) suggest that there is a change in the slope of the integral primary-energy spectrum (the graph showing the number of particles with energies greater than any chosen value) between 10^{15} and 10^{17} eV. Thus, as the lowest energy considered rises above 10^{17} eV the flux of primary particles appears to decrease less rapidly than it does in the region between 10^{15} and 10^{17} eV. One interpretation for this effect, mentioned by Linsley, is that the cosmic rays from our own galaxy die out above 10^{16} eV and that the particles of higher energy come from outside the galaxy. It was further suggested that the heavy nuclei observed in the primary cosmic radiation may be of galactic origin only, so that the radiation of energy between 10^{17}-10^{20} eV might be solely protons. Linsley found no evidence that the particles producing the extensive air showers came from any particular direction, even at the highest energies observed.

Studies of extensive air showers in the energy range 10^{14} - 10^{16} eV were reported by McCusker (Sydney). The Sydney group found that an appreciable fraction of the showers appeared to have two or even three cores when observed at sea level. They interpret these multicore showers as being due to primary heavy nuclei which break up in the first collision, the products subsequently interacting to give rise to the several central components of the shower. In the energy range 2 x 10^{14} to 2 x 10^{15} eV, approximately equal numbers of single-cored showers (presumably caused by protons) and multiple showers were observed, whereas above 2 x 10^{15} eV, 21 multiple-cored showers and only two possible single-cored showers were found. This suggests a change in the composition of the primary radiation at about 3 x 10^{15} eV, in favour of the heavy primary component. This is in apparent contradiction with the suggestion of Linsley, just mentioned, that only protons are present in the primary radiation above 10^{17} eV. Clearly much more data is needed in the energy region 10^{15} - 10^{16} eV.

One of the major points of interest in the **composition** of the cosmic radiation incident on the upper atmosphere of the earth is the flux of electrons and photons. An elegant spark-chamber and scintillation-counter arrangement, flown by balloon by Meyer (Chicago), has measured the ratio of positrons to positrons plus electrons, for energies in the range 50-500 MeV. The ratio obtained is much less than expected if the electrons arise from pions produced by proton-proton collisions in space, as postulated by Hayakawa. There is, as yet, no conclusive proof that these electrons, observed at the top of the atmosphere, are of galactic rather than of solar origin, but it seems rather likely. A somewhat simpler experimental arrangement has been flown by

SOME BACKGROUND INFORMATION

Extensive air showers : when a high-energy cosmic-ray primary particle (for example a proton) enters the earth's atmosphere it soon collides with the nucleus of one of the atoms in the air, giving rise to many secondary particles. These particles in turn make collisions, and this is a cascade process. At sea level, therefore, one may find some millions of particles — nucleons, mesons, electrons and photons —, spread out over a few square kilometres, all of which have been derived from a single incident particle. Such an event is called an extensive air shower. The relationship between the estimated number of particles in the shower, N, and the energy of the primary particle, E, is : $E = 2 \times 10^9 N$ electronvolts.

The flux of very energetic particles arriving at the top of the atmosphere is rather weak compared with that for the lower-energy beams from accelerators. For energies per nucleon above 2×10^{13} eV, for example, the average flux is only one particle per square metre every two minutes.

Solar flare : A violent disturbance on the surface of the sun giving rise to the ejection of a large number of low-energy particles.

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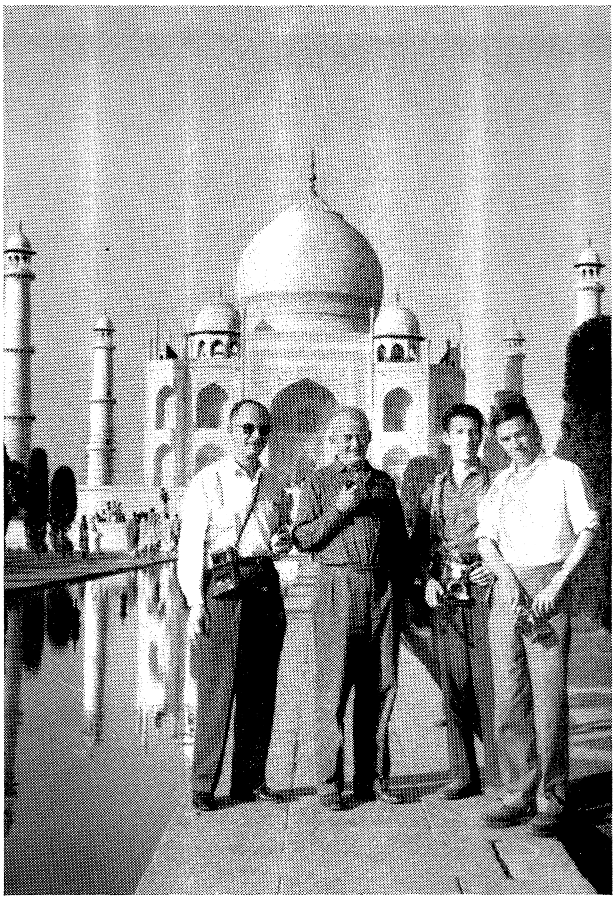
the Milan group to detect electrons of energy greater than 4.5 GeV. Preliminary data give the flux for electrons of mean energy 6 GeV as 1.5 per cent. of the proton flux. It is of interest to note that this apparatus was calibrated using particle beams at Saclay and at the CERN proton synchrotron (d beam for electrons and c beam for protons).

A problem related to that of the composition of the cosmic radiation concerns its **variation** (if any) in intensity and composition **with time** (measured in millions of years !). From studies of radioactive elements found in meteorites it appears that the cosmic-ray intensity has probably not changed by more than a factor of two in the last hundred million years. There are indications, mentioned by Wänke (Mainz) and by Schaeffer (Brookhaven), that some meteorites have been subject to irradiation by protons from the sun, presumably by passing rather close to the sun in the last stages of their life.


A visit to India, even for a scientific conference, would hardly be complete without being photographed in front of the Taj Mahal ! The author is on the right.

The radioactivity of materials exposed in **artificial satellites** was discussed by Fireman (Smithsonian Observatory), who presented evidence for the existence of tritons (^{3}H) in the incident radiation to which the satellite (Discoverer 17, launched in 1960 just after a solar flare) was exposed. Schaeffer has similar evidence for the presence of ^{3}He. These observations raise the problem of how the ^{3}H and ^{3}He can be formed in the solar flare. Again this can be linked to work with accelerators, where one can do control experiments to check different hypotheses aimed at accounting for the ^{3}H and ^{3}He found in the different materials flown in the satellite.

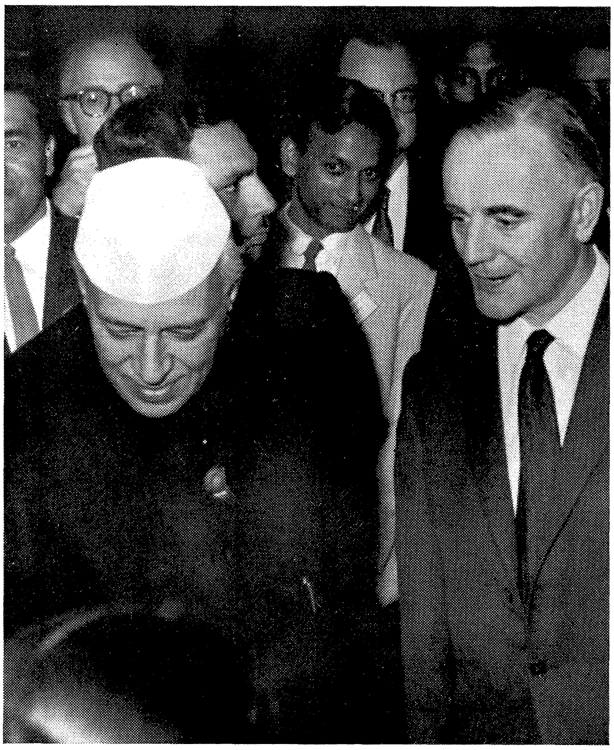
Consideration of the nature of the composition of the cosmic radiation brings one naturally to the question of its **origin.** There is now a veritable flood of different hypotheses. Burbidge (La Jolla, California) reviewed the evidence for the occurrence of violent events in galaxies in which energies in the range 10^{55} - 10^{61} ergs (6×10^{66} - 6×10^{72} eV), are released. He showed that such events are probably short-lived (of the order of a million years) and that they are then recurrent. Such outbursts give rise to the phenomena of strong radio sources ; they are also powerful sources of high-energy particles and may contribute strongly to the primary cosmic-ray flux. It was suggested recently by Burbidge and Hoyle that the halo surrounding our own galaxy was produced by an explosion at the centre some ten million years ago. Further studies of meteorites should yield more information on this interesting speculation.

In the field of **high-energy interactions** some 40 papers were presented, but not many important problems have been solved. The extensive work in the Soviet Union on nuclear interactions in the energy range 10_{11} - 10_{13} eV was summarized by Dobrotin (Lebedev Institute, Moscow). He presented evidence for the occurrence, in some 10-15 per cent. of the events, of almost catastrophic interactions in which a large fraction of the primary energy is transferred to a small number of neutral pi-mesons. In order to obtain more data on such events and on related problems, several new large-scale installations are now under construction at mountain stations in the Soviet Union. For example, in Georgia, at an altitude of 2200 metres, there is now being set-up an arrangement of cloud chambers (0.5 x 2 x 2 m) above and below a lithium-hydride target, together with 1000-ton electromagnet and a multitray ionization calorimeter. Results from installations such as this will be awaited with great interest during the next few years, particularly as they should give more information for the planning of experiments for the next generation of accelerators.

At rather lower energies than those mentioned above, Subramanian (Tata Institute, Bombay) presented evidence for the production of groups of collimated pions in the interactions of pions of energy 30 GeV and above in carbon. His multiplate cloud chamber, plus air Cherenkov counter defining the primary particle, was operated at 2300 metres above sea level at the Ootacumund high-altitude research station in South India. He interprets these events (about 20 per cent. of all inelastic pion-carbon collisions) as evidence for the single and multiple production of 'ABC' particles. Such events were not observed in the collisions of nucleons with carbon.

A controversial paper on **meson production at high energies** and the propagation of cosmic rays through the atmosphere was presented by Yash Pal (Tata Institute, Bombay) and Peters (Copenhagen). They assume that the average incident extra-terrestrial nucleon, in its passage through the atmosphere, is repeatedly excited by collisions with atomic nuclei of the air to one of the low-lying levels of the pion-nucleon system and that it decays between successive excitations by the emission of several mesons. They showed how the particle distribution in the atmosphere in the energy range between a few times 10^9 eV to about 10^{12} eV could be understood and calculated accurately in terms of such decay products and their progeny, other processes of meson production playing only a minor role. The average mass of the excited baryon system turns out to be at least 2200 MeV, and the number of pions emitted per decay is 3.5 ± 0.5. Excited baryons of such high mass have not yet been found by accelerator workers in the energy region up to 30 GeV (3×10^{10} eV), but the high-energy jet studies to be carried out using the 1.5-metre British hydrogen bubble chamber at CERN, and further counter experiments, should give more data on excited nucleon production than is presently available.

Intensity measurement of **cosmic rays deep underground** were reported by Ramana Murthy (Bombay). The observations made by the Bombay group extend to a depth of 8400 metres water equivalent (about 2800 metres below sea level). At this depth (in the Kolar gold mines in South India) no counts were recorded in 3 square metres of detector during 60 days of operation. The significance of this result for neutrino physics and for cosmic-ray neutrino experiments was discussed by Menon (Bombay). For example, the results so far available from the CERN neutrino experiment suggest that the cross-section for inelastic neutrino events might increase with the square of the neutrino energy, but the absence of counts in the underground experiment indicates that this could not be true above 60 GeV. Experiments to detect interactions of cosmic-ray neutrinos deep underground should enable better numerical answers to be given to this and related questions. One such experimental arrangement now being planned by Reines, to be carried out in a South African gold mine 3200 metres deep, was briefly described by Crouch (Case Institute of Technology). It consists essentially of two rails of liquid scintillator, each 70 metres long by 2 metres high by 12.5 centimetres wide, laid horizontally 2 metres apart in a tunnel.



The Prime Minister of India, Mr. Nehru, spoke to many of the participants at the dinner which concluded the conference. Beside him in this picture is Prof. C. F. Powell.

The conference concluded with a dinner given by Prof. H. J. Bhabha, Chairman of the Indian Atomic Energy Commission, at which the guest of honour was the Prime Minister, Jawaharlal Nehru. Mr. Nehru spoke after dinner to the assembled delegates. Prof. C.F. Powell, retiring Chairman of the Cosmic Ray Commission of I.U.P.A.P., and other members of the Commission expressed their thanks to the Government of India and the Department of Atomic Energy for inviting the Conference to India and for the hospitality extended to all the participants.

After the conference a small group of people (including myself) travelled to South India to visit the high-altitude research station at Ootacumund and the Kolar gold mines. At Ootacumund an elaborate array to detect extensive air showers has been in operation for the past few years, as has the apparatus to investigate high-energy nuclear interactions described at the conference by Subramanian. It is now planned to move the extensive-air-shower array to Kolar (which is near Bangalore) and to combine it with muon detectors which will be placed at different depths underground, below the counters on the surface. This will enable studies to be made of the muon component of extensive air showers. It is also planned to continue the intensity measurements underground at Kolar, and in particular to use visual detectors rather than counters. Consideration is also being given to carrying out neutrino studies very deep underground. However, at 3200 metres below ground (the deepest point) the rock temperature is such that one cannot touch the walls for more than a few seconds, and the air conditioning cannot be compared with that which exists at the CERN PS ! ●

News from abroad

National Synchrotron Study Group formed in France

" Whilst the existing machines throughout the world have led to the discovery of many more phenomena than could have been imagined in the realm of the so-called ' elementary particles ', fundamental research requires ever higher energies so as to be able to probe ever further into the physics of the infinitely small ; to uncover the structure that might exist and the laws that are obeyed in the very heart of these particles. Since the design and construction of a large accelerator takes some six to eight years, French physicists believe that it is now time to begin the study of a large national accelerator, which they think should produce energies of sixty-thousand-million electronvolts (60 GeV).

Advised by its Committee for Large Accelerators, the Office of the Delegate-General for Scientific Research has requested the Commissariat à l'Énergie Atomique (Atomic Energy Commission) to undertake such a study, and a research agreement has been concluded to that effect, receiving the approval of the Minister of State for Scientific Research and Atomic and Space Questions on 9 July last.

To carry out the task thus assigned to it, the Commissariat à l'Énergie Atomique has set up under its Physics Directorate a ' Groupement d'Études du Synchrotron National ' (National Synchrotron Study Group), which has already started work. The study group will be able to call upon valuable outside assistance, notably from high-energy laboratories independent of the Commissariat and from the National Geographic Institute, on questions of geodesy. It aims to produce a report, together with a preliminary design, in the shortest possible time, so that the Government can be in full possession of the facts to enable it to decide whether the project for the construction of the large machine should be included in the next quinquennial plan. "

Extract translated from the ' Notes d'Information ' of the Commissariat à l'Énergie Atomique, 15 Oct. - 1 Nov. 1963.

Last month at CERN (cont.)

periodic records by operating continuously for three weeks instead of two. Actual running time was from 2 p.m. on Wednesday 4 December until 6 a.m. on Sunday 22 December, and for most of this period the **Saclay/École Polytechnique 81-cm hydrogen bubble chamber** was also in operation, in the m_3 beam in the South hall. The beam was adjusted to give in turn antiprotons of momentum 5.7 GeV/c, positive kaons of 3 GeV/c and 3.5 GeV/c, and negative kaons of 3 GeV/c. Altogether some 480 000 photographs were obtained to study the interactions of these various particles with the protons of the liquid hydrogen.

It is of interest to note here that during 1963 some **2.5 million bubble-chamber photographs** (each consisting of three stereoscopic views of the same event) were obtained at CERN. This brings the total to more than six million since work with bubble chambers started here in 1960.

In the fourth week of January, there were altogether **nine experiments** in various stages of operation around the synchrotron, the highest number so far achieved. The machine was run to give a final proton momentum of 18.1 GeV/c, with one pulse every two seconds and a ' flat top ' (during which the protons circulate with their final energy) of 300 milliseconds. Four targets were in use : some 65 per cent. of the protons in each pulse struck target no. 1, and in every fourth pulse the remaining 35 per cent. struck target M60, on the special target assembly fitted between the poles of one of the synchrotron magnets ; in the remaining three out of four pulses, 25 per cent. of the total beam struck target no. 6 in the South area, and 10 per cent. target no. 61, in the East area.

From target no. 1, four beams provided secondary particles for five experiments in the South hall. Of these, the g_1 beam (pions) was used for the continued investigation of the beta decay of the lambda particle. The m_3 beam (shortened by the removal of one electrostatic separator) was set to give antiprotons for a development of the former ' Papep ' experiment, now designed to detect pairs of muons as well as electrons from antiproton annihilation and therefore renamed ' Paplep ' (proton-antiproton annihilation into lepton pairs). Stretching right across the hall was the d_{15} beam, being used again for the experiment on the production of gamma rays in the ' peripheral ' collisions of pions with protons, and its extension, $d_{15}a$, for tests on the possibility of indirectly detecting and identifying neutral particles by means of spark chambers in the magnet from the Wilson cloud chamber. The s_3 beam was used by the emulsion group for tests on track distortion in folded emulsions at low temperatures. Target no. 6 marked the beginning of a pion beam in the North experimental hall, in use for a new experiment set up to search for a possible ' diproton ', formed in the interaction of a pion with a deuteron.

In the East area, target no. M60 was producing particles for the o_4 beam, serving the 81-cm hydrogen bubble chamber which had been transferred to the East hall, near the bubble chamber building. The o_4 beam is, in fact, a branch of the long o_2 beam, now containing three of CERN's 10-metre electrostatic separators, which was set up for experiments with the British 150-cm bubble chamber. Owing to a number of ' teething troubles ', this chamber was still not able to start experiments in January, so the Saclay chamber was moved in to take its place in the schedule. At the end of the month, photographs of 8-GeV/c positive pions and 10-GeV/c protons were taken for the 'High-energy collaboration' (Aachen, Berlin, Cambridge, CERN, Hamburg, Krakow, Prague, Stockholm, Vienna and Warsaw). Also from the M60 target, a monitor beam (61) was being used in preliminary tests for an experiment on the charge exchange of pions. Target no. 61 provided scattered protons for the c_8 beam, to test apparatus being set up to measure proton-proton scattering at small angles.

At the **synchro-cyclotron**, the Christmas shutdown, beginning at 7 a.m. on 23 December, was continued through January and into February. During this time the work was mainly concerned with preparations for the installation of the polarized proton source later this year. A great deal of the cabling for the accelerator was renewed and some modifications were made to the vacuum system. The supporting straps for the tuning fork (which controls the frequency of the oscillatory accelerating voltage) were also renewed. We hope to give further details in the next issue of *CERN COURIER* ●

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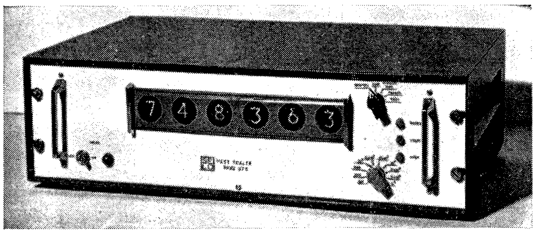

ST 6

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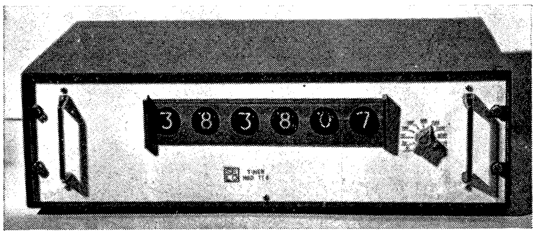

TT 6

6 decade timer.
time base operated from mains frequency
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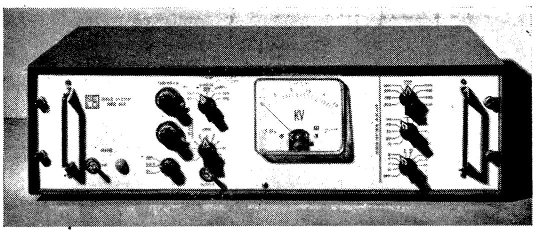
pre-set time operation.



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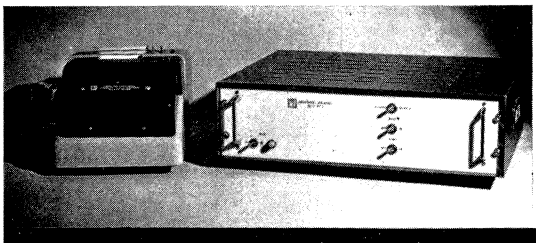

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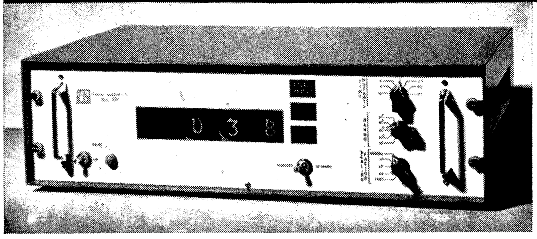

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