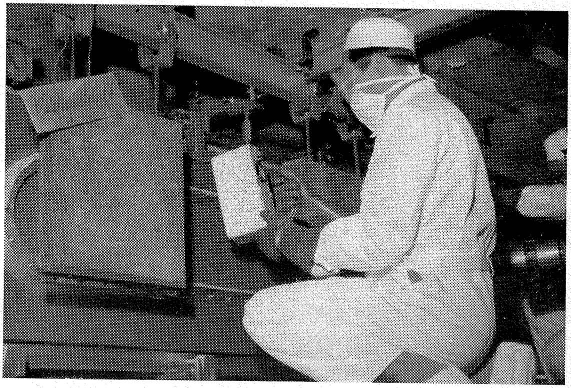
CERN COURIER



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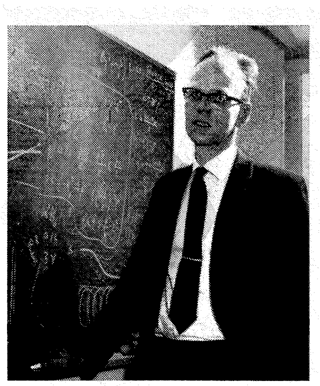
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

WHO'S WHO IN CERN

Léon VAN HOVE

Director, Theoretical Studies Division



Léon Van Hove was born in Brussels on 10 February 1924, not far from the University—l'Université Libre de Bruxelles —where he matriculated in 1941... but soon found his course interrupted. There was a war on and the University closed down on 24 November of that year.

Like many others, Léon Van Hove attended lectures secretly; one of the students would act as host to a professor and a group of fellow students. He completed his academic education in this way. This did not stop him from obtaining a degree in mathematics in 1945 and a doctorate in the following year with his thesis on the calculus of variations.

Henceforward his interests changed : from pure mathematics he turned to theoretical physics. Why ? According to Prof. Van Hove "very probably because it so happened that I was in very close contact with physicists from 1945 onwards".

In 1945, he was appointed Assistant to Prof. J. Géhéniau at the Brussels University. Officially he occupied this post until 1952, but in 1947 he spent a few very useful weeks at the Institute of Theoretical Physics in Copenhagen, and returned there for six months in 1948 to work with Prof. Niels Bohr.

Then in 1949, Léon Van Hove crossed the Atlantic, having been invited to spend a year at the Institute for Advanced Study at Princeton, the famous centre of advanced research in mathematics, mathematical physics and history.

It was there that he finally abandoned pure mathematics for theoretical physics ; his last publications on purely mathematical subjects date from that time : from then onwards his publications were devoted to physics (so far they number about fifty).

In 1952, he relinquished his appointment as assistant at Brussels. Georges Placzek whom he had met in the United States asked him to come back to the Institute for Advanced Study. Léon Van Hove therefore returned to New Jersey as a "member of the School of Mathematics", a school specializing among other things in studying the problems of theoretical physics. With Placzek, Van Hove concentrated on studying the theory of the scattering of neutrons in matter.

In 1954, the University of Utrecht offered him the chair of theoretical physics. It was there that Prof. Bakker approached him with a view to succeeding Markus Fierz as Director of the Theoretical Studies Division at CERN. At Utrecht, Prof. Van Hove studied the quantum field theory and the many body problem.

For these studies and for all his scientific work in theoretical physics, in 1958 Prof. Van Hove received the prize awarded annually by the Francqui Foundation to a Belgian scientist. The following year, he was made a member of the Netherlands Academy of Science.

Léon Van Hove arrived at CERN on 5 September as a visiting professor and Director of the Theoretical Studies Division. He will divide his time between Geneva and Utrecht during the present academic year. From the summer of 1961 onwards he will become full-time Director of the theoretical studies of the Organization.

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«CERN COURIER»

was founded in 1959 at the instigation of Prof. C.J. Bakker (†). It is published monthly for the staff of the European Organization for Nuclear Research and distributed free of charge to members of the Organization, scientific correspondents and anyone interested in problems connected with the exploitation of particle accelerators or in the progress of nuclear physics in general.

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The cover photograph shows the large 28 000 MeV synchrotron in the foreground of some CERN facilities (ATP Photo). **The inset picture** was taken behind the vacuum chamber of the synchro-cyclotron while a technician was checking the radioactivity level after an experiment (ILO photo).

Last month at CERN

The "CERN COURIER" is one year old. When our modest **publication** was started in August 1959 it was originally intended only for the members of CERN to associate them more closely to the life of the Organization by keeping them better informed. To-day, the "CERN COURIER" goes to all parts of the world to give news of our activities. The number of copies printed in the two official languages, French and English, has increased from 1000 to a total of 2500.

On the occasion of this first anniversary, we should like to thank all those who help to keep the "CERN COURIER" going : typists, translators, photographers, draughtsmen, printers, proofreaders and especially those who, with great patience, tell us about their work, give us their time or their advice, or whose signature lends distinction to our periodical.

A month never seems to go by without news from the **PS "Machine Group"** of an increase in the intensity of the accelerated proton current. The latest figure is 3.1 x 10^{11} protons per pulse, and this speaks for itself. The quarterly shut-down for maintenance work on the machine took place from 14 September to 2 October.

The most important of the recent **experiments on the PS** is certainly that which confirmed that the impact of 25 GeV protons on the nuclei of light targets produced not only the hydrogen 2 nuclei (deuterons) already observed, but also hydrogen 3 nuclei (tritons) and helium 3 nuclei. The discovery of nuclei of **light elements** in the products of high

They left CERN

The CERN staff is constantly changing. This is because the Organization wants to put its experimental equipment at the disposal of the greatest possible number of physicists and allow universities and national institutions to benefit from its experience.

CERN does this by leaving the door open to a continual stream of scientists. This ensures a constant renewal of ideas, but it also means that CERN has to part with some of those responsible for its operation, its development or even its creation. In the last few weeks CERN has thus recorded the departure of three of those who have played a considerable part in the life of the Organization :

● **William Gibson** came to CERN on 1 October 1957 to head the SC "Nuclear Emulsion Group" ; he left the Organization on 9 September. Under the direction of Prof. C. F. Powell of Bristol University, he will become leader of the group using photographic emulsions with accelerators. From Bristol, the Mecca of photographic technique with nuclear emulsions, W. Gibson will often have to work in co-operation with his former colleagues, the CERN physicists.

● **Hans Horisberger** left CERN on 31 August, for a factory manufacturing printing machinery. He came to Geneva in June 1954, in the early days of the Organization when there were only about twenty people in the PS Division ; in co-operation with A. Achermann, he established and organized a drawing office for the whole Division.

● **Bernard M. Wheatley** returned to the United Kingdom at the end of August. At the Nuclear Research Laboratory at Berkeley, in Gloucestershire, doing work on the operation of power reactors, he will be in charge of protection against radiation. He will therefore occupy a similar position to that which he had held at CERN since February 1957: Head of the Health Physics Section.

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energy reactions continue to intrigue the theoreticians, who are trying to explain this phenomenon.

At the **synchro-cyclotron**, many experimental teams continue their work with the accelerator. The g-2 Group has nearly completed preparations for an experiment which is eagerly awaited in the world of physics. By measuring the anomaly of the magnetic moment of the mu meson, this experiment will perhaps explain why two fundamental particles, the electron and the mu meson, have identical properties, except for mass.

The **Finance Office** in September was engaged in a very important task : drawing up of the draft budget for the financial year 1961, to be submitted to the Council for approval at the beginning of December.

The **Rochester Conference** on high energy physics closed on 1 September. Fifteen CERN physicists attended, and a dozen others went to Berkeley in the middle of the month for a meeting of experts on high energy physics instruments. Finally, at the beginning of September, there was a conference in **Copenhagen** on the use of radio-isotopes in the paper on geophysics entitled "The Radiation Age of Meteorites" ●

The CERN Health Physics Group

by Bernard M. WHEATLEY

"Health Physics" started in CERN in February 1957, as one of the groups of Dr. Kowarski's Division of Scientific and Technical Services.

At that time the accelerators were still being constructed and only very few of the 430 staff members had proper buildings to work in. So, the first headquarters of the Health Physics group was a room in one of the wooden barracks at the edge of the airport although, work proceeded at a lively pace at Meyrin. After a short time, Health Physics had a room of its own in one of the "temporary" wooden huts, between the synchro-cyclotron (SC) and the hydrogen liquifier.

FIRST MONTHS

The early months were very busy ones. The protection problems of the accelerators were studied, instruments were ordered, and a film badge service was set up. Such work is standard procedure when starting any health physics group, but CERN had many novel problems. As an international laboratory it had to devise its own rules and procedures without any precedents as a guide. Indeed, even the terms of reference of the health physics group, and the definition of its relationships within CERN itself needed to be discussed and agreed. Questions of insurance of staff and property against radiation risks were resolved, working relationships with the Safety Committee and with local authorities were established, and the future needs for people and money were made known.

When the synchro-cyclotron started work in August 1957, the Health Physics group was sufficiently well equipped to make the radiation surveys, and to take part in framing the local rules regulating work on the radio-activated components of the machine. At that time the SC Nuclear Chemistry laboratories were being planned, and the Health Physics group was able to advise on some aspects of the design, and to recommend the installation of delay tanks for liquid waste from the laboratories. Samples from these tanks are evaporated to dryness and measured for radioactivity before the tanks are emptied from the site.

GROWTH

Since 1957, the group has grown in order to keep pace with the demands upon it but without any major change of policy. Some of the technical problems, especially those of handling mildly radioactive material, are conventional, but the problems of measuring extremely

Continued on page 4.

Sven Larson measuring the level of radio-activity on the mound covering the PS, by means of the apparatus installed in the mobile laboratory belonging to the "Health Physics" Group.

high energy radiation in biologically meaningful units are very unusual. The group has kept in very close touch with other accelerator centres by exchanging visits, by correspondence, and by taking part in conferences. As a result CERN has health physics instruments as good as any in the world. The very intimate relationships between the Health Physics Group and the experimenters has meant that the CERN accelerators are surveyed extremely thoroughly : **personal exposures are very low and we have never had a radiation accident.**

Sometimes the group is asked about the protection of people who do not work on the accelerators, and this may be a good opportunity of saying something about the general radiation pattern of CERN.

RADIATION EXPOSURE

Firstly, the accelerators themselves are very well shielded, and only people working very near them can be exposed at all. The Health Physics group makes measurements to ensure that people working in offices cannot receive any significant exposure. Areas where there is any possibility of exposure are barricaded off, and access is very strictly controlled so that no-one can inadvertently walk into a potentially dangerous area. The radiation levels off the site are measured, and are quite negligible. Most of the radiation at CERN is from the accelerators and when they are switched off the radiation stops. There is **no possibility of widespread contamination as the result of an accident.** This is a significant difference from reactors as mechanical damage at CERN would stop the accelerators — and consequently their radiation — whereas with a reactor it may cause the release of radioactive materials which continue to emit radiation after the reactor has stopped working.

INTERNATIONAL STAFF

The Health Physics group is quite international ! When this report was written it comprised ten people from seven countries. The deputy group leader, who will run the group until this writer's successor is appointed, is **Pierre Guillot,** who came to CERN in 1959 after preparing a Dr. ès Sc. thesis at the Pasteur Institute in Paris. His main interests are in fast neutron dosimetry and spectrometry of stray radiation fields. These problems are complicated enough in laboratory conditions, but the methods have to be developed to the stage where the apparatus can be transported around the accelerators and results produced quickly and reliably. The senior technician, **Sven Larson,** is a Swede who joined the group at the end of 1957, having previously worked with the Jungfraujoch group in CERN's early days. He is helped in running the instrument services by **Piet Varekamp** a Dutch transistor circuit expert, **Klaus Klein** a skilled mechanic from Germany and **Jean Wiesmann,** a Frenchman, who is in charge of repairs, calibrations and wiring. Ra-

Continued on page 8.

The PS in 1960

by Pierre GERMAIN
Leader of the „Machine Group",
Division of the Synchrotron

We shall soon be celebrating the first anniversary of the commissioning of the machine. On 24 November 1959, the PS reached an energy of 25 GeV. What has happened since then ?

The position at the end of last year was as follows. From 2 to 3.10^{10} protons were accelerated during each cycle up to an energy of 25 GeV (¹). The trapping efficiency was 25 %, which means that out of four particles injected by the linear accelerator into the synchrotron vacuum chamber, one was actually accelerated.

Generally speaking, the PS worked remarkably well from the start and immediately gave a higher current than had been hoped for a few years before. The PS "Machine Group" therefore took over a potentially excellent accelerator and this greatly simplified its task because the group could immediately concentrate on developing the equipment and exploiting the accelerator.

The PS "Machine Group"

The "Machine Group" was created to take charge of the operation, maintenance and development of the machine. It originated in 1959 in a Committee called the Machine Operation Committee headed by C. J. Zilverschoon, who had the difficult task of working out the structure and organization of the present group.

The programme of our group for 1960 is as follows :

a) Creation of a staff of operators and engineers-in-charge with all the necessary auxiliary organization : setting-up and operating routines, theoretical and practical training, protection of the staff and users, etc.

b) Rapid development of the minimum facilities which are essential for the exploitation of the machine by physicists.

c) Completion of the machine installations and ancillary equipment, eliminating temporary installations. Extension of the machine facilities for experimentalists.

d) Study of the behaviour of the machine, mainly that of the proton beam. This is obviously essential if subsequent performance is to be improved.

e) Detection and improvement of the inevitable weak points in the equipment of a machine as original and complicated as the PS.

The "Machine Group" has been greatly helped in its work by the advice and assistance of many colleagues who after taking part in the construction and commissioning of the accelerator have now joined other groups. It is extremely gratifying to record that this valuable co-operation is still most effective nearly a year after the commissioning of the machine. Such co-operation is rare enough to deserve special mention. In this connection I should like to thank (hoping not to forget anyone) P. Bramham, M. Geiger, H. G. Hereward, K. Johnsen, P. Lapostolle, B. Montague, C. Schmelzer, W. Schnell, and in fact the whole PS Parameter Committee. I do not mention M. G. N. Hine because, fortunately for us, he joined the group during the year.

The "Machine Group" is only one of the groups in charge of the development of equipment which the experimentalists need in order to exploit the machine.

Beam transport, the ejection system, and electrostatic separators come under C. A. Ramm's "Propane Chamber Group". It is F. Grütter's "Engineering Group" which is responsible for the completion of the generator and cooling system for the beam transport equipment and the bubble chambers and the generator building. Finally the radio-frequency separators are being designed by A. Schoch's "Accelerator Research Group ".

The PS at 1 September 1960

It would be tedious for the reader to have a detailed account of the work done this year on the machine. Those interested can find particulars of these improvements in the quarterly reports issued by the group. Two reports covering the period from January to June 1960 have so far been published (²).

I propose to mention only the most important results directly connected with the exploitation of the machine by the experimentalists. Obviously the other work, although less spectacular, is quite as important.

From the point of view of the research work which it is hoped to do with the accelerator, an important parameter is the current supplied or, in other words, the number of particles the machine accelerates to maximum energy during each cycle. At present this number is regularly between 2 and 3.10^{11} which is more than tenfold what it was at the end of last year. This high intensity means that at present the PS is one of the synchrotrons producing the highest number of particles per second, apart from the fact that its energy is greater than all but one of other accelerators in existence.

(¹) The maximum energy of the PS is about 28 GeV. However, this energy is rarely used because it entails an interval of 5 seconds between two accelerating cycles whereas this interval is only 3 seconds for an energy of 25 GeV.

(²) CERN 60-23 and 60-29 : "Quarterly Reports N^{os} 1 and 2".

The higher current has been obtained partly by increasing the output intensity of the ion source which produces the protons, and partly as a result of the installation of a particle buncher at the input end of the first tank of the linear accelerator—which increases the intensity by a factor of about two—and finally by an improvement of the same order in the trapping efficiency of the synchrotron itself. At the end of last year, out of four particles injected into the synchroton by the linear accelerator, one was accelerated, but now the figure has improved to about two out of three. The trapping efficiency is, therefore, about 65 % instead of 25 %.

However, the experimentalists do not make direct use of the primary beam circulating in the machine. A target is used which is very frequently no more than a piece of aluminium or beryllium placed, at the end of the cycle, in the path of the primary high energy proton beam circulating in the machine. The interaction of the protons with this target gives the secondary beams.

A small proportion of the protons crossing the target are deflected and leave the machine. They go through the wall of the vacuum chamber and produce in the experimental hall a proton beam of about the same energy as that of the primary beam and of sufficient intensity for the bubble chambers, the photographic emulsions and even for some experiments with counters.

The great majority of the protons hitting the target interact with the nuclei of the target itself, and these interactions give rise to secondary particles (pi + and pi— mesons, K + and K — mesons, protons and antiprotons, deuterons, etc.) It is the behaviour of these secondary particles which is studied by the experimental teams. By and large, the experimentalists call for two kinds of secondary particle pulses. We are now able to provide these pulses under satisfactory and reliable conditions, which was not the case at the end of last year.

The first type of pulse is a **long pulse of high intensity** used for the counters : the greatest possible number of the primary protons circulating in the machine are made to act on the target and produce secondary particles for a few hundredths of a second, fairly regularly.

The second type of pulse is a **short pulse of low intensity** : a small fraction of the primary protons act on the target and produce secondary particles for about ten thousandths of a second. This type of short pulse is used for bubble chamber experiments. It is now possible for us to supply the two kinds of pulses during the same accelerating cycle, part of the protons being used to give a short pulse and the rest to give the long pulse. It is obvious that to produce particles at different stages of the cycle and in different parts of the machine is of the greatest advantage. In this case it becomes possible to use the machine simultaneously for several experiments : for instance a bubble chamber and a counter group may use two different targets. In this field we have made enough progress to be able to solve simple problems of simultaneity.

Exploitation of the machine in 1960

It is not intended to list the experimental programmes at present being carried out : this should be done by another writer.

It must, however, be recalled that until now, mainly because the accelerator came into operation more rapidly and possibly more satisfactorily than expected, "beam transport" has been on a small scale. Beam transport refers to the system of electro-magnets, magnetic lenses, power supply generators and electrical connections which produce a given secondary particle beam with specific properties in the experimental hall. In spite of this we are beginning to know something about the nature and intensity of the secondary particles as function of their energy and angle of production. Measurements of the cross-section of these particles have been made in liquid hydrogen. Two bubble chambers, Charles Peyrou's 32 cm liquid hydrogen chamber and A. Lagarrigue's 1 m propane chamber, were placed in secondary beams and took a few tens of thousands of photographs. In addition, nuclear emulsions have been exposed in different beams and at different energies.

From 1 January to 1 September 1960, a period of eight months, the accelerator or parts of it operated for about 1600 hours. About 780 hours of this time were devoted to high energy beam production and the rest was used for running in and especially for the study of the machine or parts of the machine.

From next year onwards the machine will probably work 100 hours per week.

During the same eight-month period the efficiency of the accelerator, namely the ratio between the actual accelerating time and the planned accelerating time was on an average between 75 and 80 % which is satisfactory efficiency level for such a "new" and complex machine.

To conclude this paragraph on the exploitation of the machine it is proposed to describe briefly the method so far used to fix the programme for exploiting the machine.

A general programme allocating machine time to the various experimentalists is fixed about every three months by the research co-ordinator.

A detailed programme for each week is settled on the Thursday of the previous week at a schedule meeting organized by the "Machine Group". The exact arrangement of the beams, the exact target requirements and the safety measures to be taken are discussed and settled with the experimental groups concerned.

This schedule meeting leads to the publication of the weekly PS programme which is widely distributed in CERN and gives full information about the hours of operation, the users and conditions of access to the machine.

It is impossible to quote the names of all the members of the "Machine Group" who this year have contributed not only to running the PS to the satisfaction of the experimentalists but also to planning the future improvements of its performance.

I would like to take this opportunity of expressing my appreciation for their valuable work, which I know is very often a thankless task. The best way to include them all in this acknowledgement is probably through the Machine Group Committee whose present members are H. von Ballmoos, F. Bonaudi, G. Brianti, A. Decae, H. Fischer, J. Y. Freeman, J. A. Geibel, M. Georgijevic, J. Gervaise, M. G. N. Hine, U. Jacob, G. L. Munday, K. H. Reich, P. H. Standley, C. S. Taylor and B. Vosicki ●

The synchro-cyclotron

Derived from the cyclotron, which it resembles from outside, the synchro-cyclotron — or SC — gives the accelerated particles a curved trajectory. It forces them repeatedly to cross an accelerating electrode, called a "Dee" because of its shape. The particles are injected 54 times per second from a source in the middle of the vacuum tank. Each accelerating push increases the speed of the proton which, owing to centrifugal force, has a trajectory in the shape of a growing spiral.

The accelerating process lasts a few milliseconds, during which the particles make 150 000 turns in the vacuum tank, covering about 2 500 km, and reach 80 % of the velocity of light ! When the pulsed proton beam reaches the energy at which it is used — a maximum of 600 MeV — i.e. at the circumference of the vacuum tank, there are two ways of using it. The proton beam can be extracted as it is and directed towards the experimental apparatus, or the beam may strike a target inside the vacuum tank ; in this way, a source of secondary particles —neutrons or pi mesons—is created and they in turn are directed towards the experimental apparatus.

The big photograph shows the inner sanctum of the SC, the machine room, which no one may enter when the machine is operating.

There one can see the huge structure of the 2500-ton **electro-magnet.** Its horizontal yoke consists of 18 magnetic steel plates, 11 m long, 1.5 m high and 36 cm thick. The electro-magnet is excited by two enormous coils. One is clearly visible on the photograph : its aluminium cover can be seen shining at the top of the photograph. The other is placed symmetrically to it but is in the shadow and does not show up so clearly. Each of the coils weighs 55 tons, measures 7.2 m in diameter and consists of 9 pancakes of aluminium conductors measuring 19 cm^2 in cross section. There is a 3 cm^2 hole in the centre of the conductor for the circulation of 30 000 litres/hour of demineralized cooling water. This is necessary as the exciting current is 1750 amperes d.c. at 400 volts. It was a considerable undertaking to bring these two coils from the factory where they were made in Belgium, by barge up the Rhine and on a special trailer through Switzerland.

The **magnetic field** set up by the electro-magnet is constant : 18 500 gauss. For the sake of comparison the magnetic field of the earth is 1 gauss, the strongest field which the best anti-magnetic watches can stand is 1000 gauss. The 18 500 gauss field is applied across the vacuum tank between the 5 m diameter poles of the electro-magnet—which were forged at Rotterdam and machined at Le Creusot. It "focuses" the accelerated particles on their spiral orbit in the vacuum tank.

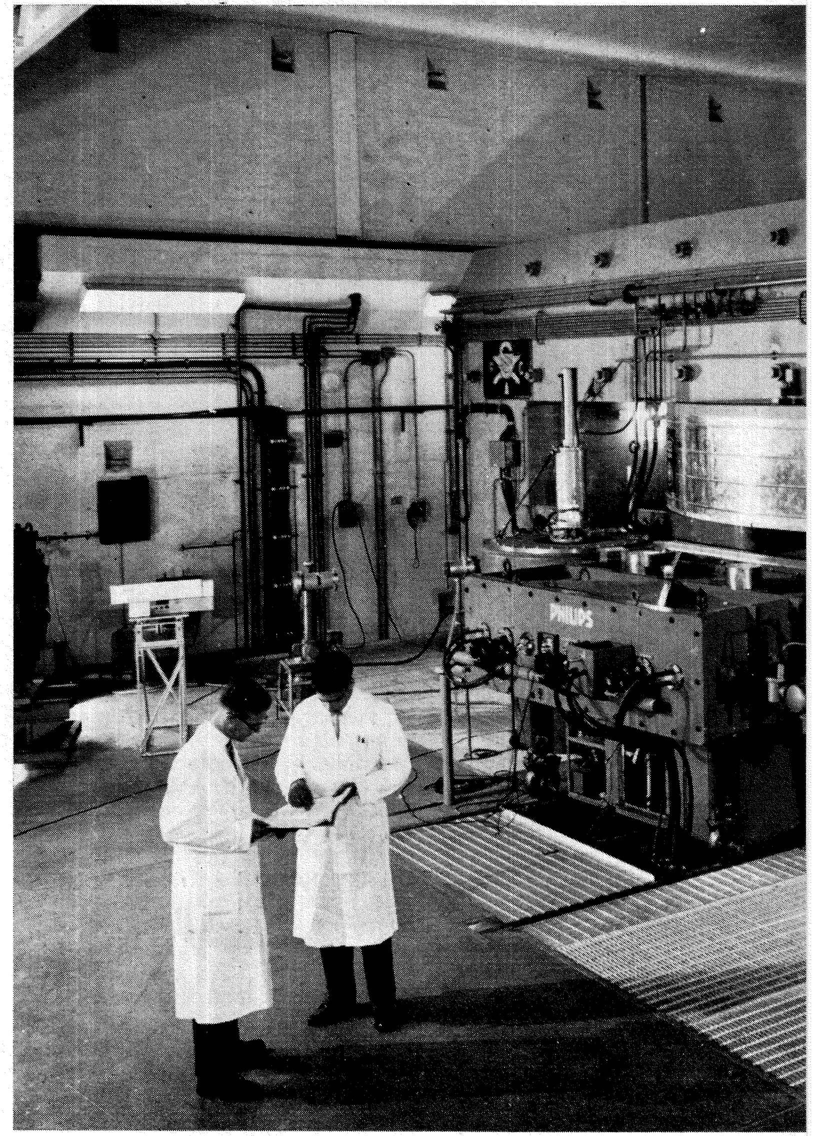
The **vacuum tank,** in which the protons turn, has a cubic capacity of 23 m^3 and its stainless steel walls are 60 mm thick. The vacuum in this tank is better than 10^{-5} mm of mercury, in other words the pressure is 76 million times less than that of the earth's atmosphere. This vacuum is created and maintained by two large vacuum pumps, one of which is clearly visible in the foreground of the photograph.

The **radio-frequency system** generates the alternating electric field which accelerates the particles. The frequency decreases from 29.3 to 16.4 Mc/s (millions of cycles per second) as the velocity and mass of the particles increase. The most spectacular part of the system is perhaps the modulator in the shape of a tuning fork, 0.5 m long and 2 m wide, housed in the bulge in the vacuum tank which can be seen to the left of the pump.

The concrete **building** in which the SC operates is intended to stop radiation. The walls which box in the SC are up to 5.8 m thick and are fitted with two 200-ton doors, which slide slowly into position to block the entrances. The total weight of concrete—standard or with baryte added—is 22 000 tons.

The **cost** of the synchro-cyclotron ? About twenty-four million Swiss francs, including the buildings. The **staff** in charge of maintenance, operation and technical development, totals 26, excluding the experimental physicists.

What place does the SC occupy in the world of accelerators ? Out of the 18 synchro-cyclotrons now operating, the CERN SC comes **third** in respect of energy (600 MeV), after the 730 MeV SC at Berkeley in California and the 680 MeV machine at Dubna, in Russia ●



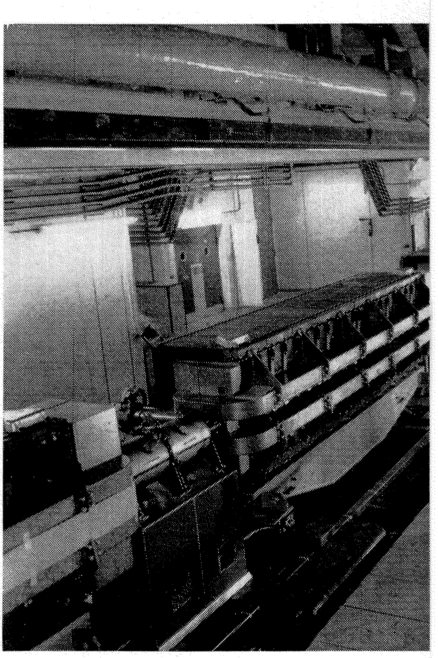
A COMP

The two particle accelerators built at CERN for studying the structure of matter are called the *synchro-cylotron* and the *synchrotron* What similarity and what difference is there between this two machines ?

All accelerators have certain *points in common :*

- — a source of particles to accelerate ;
- — a vacuum tank in which the particles can move without being slowed down too much by air molecules, and
- — a target, internal or external.

Like all accelerators, the CERN machines both

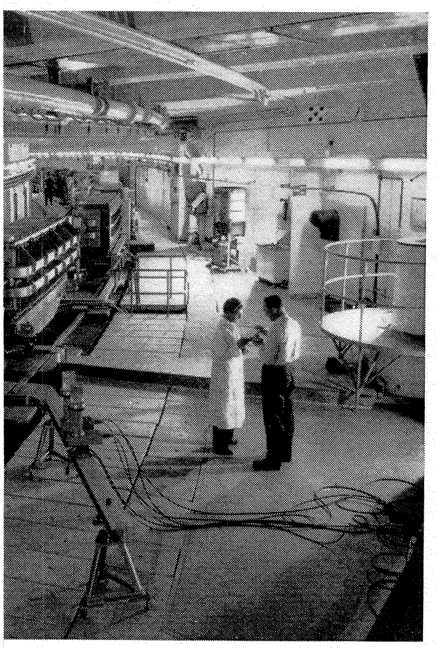


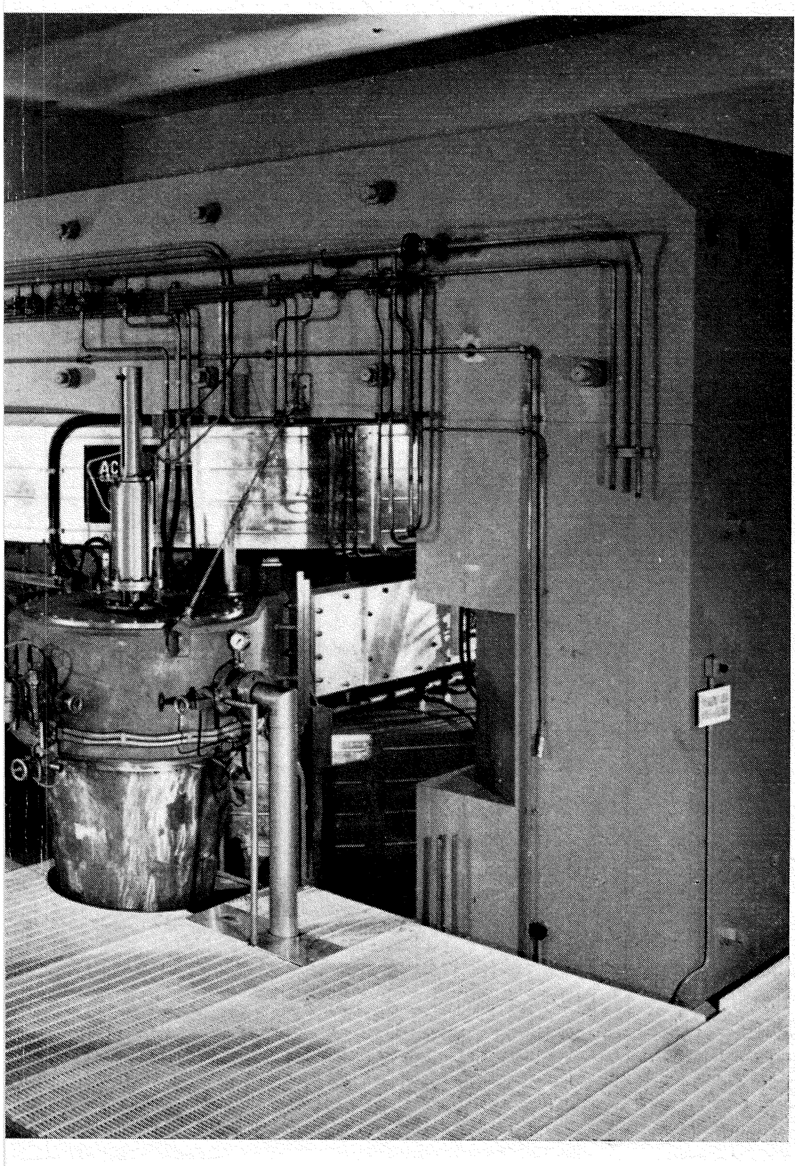
ARISON

use electrical phenomena for "pushing" the particles, and a magnetic field to keep them on an almost circular orbit.

The synchro-cyclotron and the synchrotron are "circular accelerators" also called "orbital accelerators". The particles move along curved trajectories. In both CERN machines these particles are protons or nuclei of the hydrogen atom.

By and large, the resemblance can be said to end here. There are basic differences in the design of the two machines and in the kinetic energy—or acceleration—which they can impart to the nuclear projectiles.





The synchrotron

The synchrotron looks quite different from the SC. It is as extensive as the SC is massive and squat.

The PS also curves the trajectory of the particles it accelerates, but the fixed radius of curvature is about 100 m. The protons go through 16 accelerating units, placed at intervals round the 628 m circumference. They are generally injected into the big accelerator's vacuum tank, once every three seconds, after having gone through a pre-accelerator and a linear accelerator. When they enter the 200 m diameter ring, the particles already have an initial kinetic energy of 50 million electronvolts (MeV). Every time the protons pass through one of the 16 accelerating cavities, their velocity is increased, while a growing magnetic field keeps their trajectory on an orbit of constant radius.

In the PS the acceleration process lasts one second. During this time the particles make some 450 000 turns in the vacuum tank, covering about 300 000 km and reaching 99.94 % of the velocity of light.

Once maximum energy — 25 or 28 thousand million electronvolts (GeV—has been reached, the bunches of particles strike a target in the vacuum tank itself. This produces secondary beams of particles and antiparticles. In 1961, it will be possible to extract the primary proton beam and make use of it; at present, only a small proportion of the protons scattered by the nuclei of the target cross the wall of the vacuum tank and can be used as a high energy proton beam for experiments.

The photograph at the top of the page was taken in the tunnel — the 200 m diameter ring in which the synchrotron is installed. Of course, nobody is allowed in the ring when the machine is operating, because of the radiation danger.

The **electro-magnet** consists of 100 separate units placed right round the circumference. Each unit weighs 28.7 tons net and consists of ten C-shaped blocks made up of laminations 1.5 mm thick. Each of the 100 units is excited by two coils placed longitudinally on the pole pieces of the units. Each coil consists of two pancakes, each which 5 windings of aluminium conductor 21 cm^2 in cross-section ; this conductor is hollow to let cooling water through since the current can reach 6400 amperes at 5400 volts.

The **magnetic field** produced varies from 147 gauss when the particles are injected into the synchrotron to 12 000 or 14 000 gauss when they have been fully accelerated. The magnetic field is applied across the **vacuum tank,** a long elliptical tube with a cross-section of 14 x 7 cm, curving round the 628 m circumference of the machine between the poles of the 100 magnet units. The walls of the tank are made of stainless steel, in order to be unaffected by the magnetic field and are only 2 mm thick. A vacuum better than 10^{-5} mm of mercury is maintained in the tank by 66 pumps on the outer edge of the ring and 5 others in the injection system.

In each accelerating cavity, the **radio-frequency system** creates the alternating electric field which accelerates the protons. As we have seen in the SC, the applied radio-frequency has to decrease in order to keep in step with particles which take more and more time to go round as the orbit expands ; in the PS, on the other hand, the orbit is constant and the ever-increasing velocity of the particles calls for an increase in frequency from 2.9 to 9.55 M c/s.

The ring-shaped concrete **building** which contains the PS is buried underground as an additional protection against gamma and fast neutron radiation : the 40 cm of concrete walls are covered with more than 3 m of earth and stones.

There are no gigantic doors here as in the SC : a zig-zag passage is used to stop radiation, while giving access to the machine when it is not operating. When it is in operation, a whole network of electric connections would stop the accelerator if anyone, regardless of the danger, tried to gain access to it by forcing one of the locked doors. The level of radio-activity is probably more intense between the two experimental halls—north and south—because of the presence of the targets. There the ceiling of the tunnel is made of 2 m of special baryte concrete with a density of 3.5 t/m^3. There is a series of movable blocks in the walls so that openings can be made as required for admitting the beams into the experimental halls.

The synchrotron cost **120 million Swiss francs :** ten

Continued on page 8.

A COMPARISON

Continued from page 7.

The synchrotron (cont.)

cigarettes for each of the 220 million inhabitants of CERN's twelve Member States.

The **"Machine Group"** in charge of exploiting and developing the PS is a team of 139. The actual running of the machine needs ten operators.

As for the **position** of the PS with respect to other accelerators, the CERN synchrotron comes second in the world with 28 GeV, after the 31 GeV synchrotron commissioned at Brookhaven on 30 July ●

Comparison between the CERN accelerators

	SC (Synchro-cyclotron)	PS (Synchrotron)
Basic data		
● particles accelerated	protons	protons
● maximum kinetic energy	600 MeV	28 000 MeV
● ion source situated	in the middle of the vacuum tank	on the input side of a linear accelerator
● cost	24 million Swiss Frs	120 million Swiss Frs
Magnets and excitation		
● magnetic field (gauss)	constant : 18 500	variable between 147 and 14 000
● weight of magnet	1 x 2500 t	100 x 28.7 t
● weight of exciting coils	2 x 55 t	100 x 1.2 t
● maximum power supplied the magnet	700 kW	32 000 kW
● magnet gap	45 cm	10 cm
Accelerating radio-frequency		
● system	a Dee	16 cavities
● frequency in Mc/s	decreasing from 29.3 to 16.4	increasing from 2.9 to 9.55
● energy increase per turn	4 keV	54 keV
● number of turns	150 000	450 000
● velocity of particles at maximum energy (as a percentage of the velocity of light)	80 %	99.94 %
● pulse repetition rate	54 per second	1 per 3 seconds (at 25 GeV) or 1 per 5 seconds (at 28 GeV)
● duration of accelerating cycle	9 milliseconds	1 second
Vacuum system		
● vacuum tank	cubic 23 m^3	toroidal cross section 14 x 7 cm, length 628 m
● wall thickness	up to 60 mm	2 mm
● material	stainless steel	stainless steel
● pumps	2	66 + 5
● acceptable vacuum	10^{-5} mm Hg	10^{-5} mm Hg

An index for the «CERN COURIER»

The contents of all issues of the CERN COURIER since August 1959 will be listed in the December 1960 number. It seemed better to publish an index at the end of the year than after the first twelve issues ●

Health Physics Group

Continued from page 4.

diation surveys are looked after by **Leo Haemers** who joined us from the Amsterdam cyclotron. The administrative work of the group is shared : record keeping is looked after by **Jenifer Shaw** (United Kingdom), and correspondence is taken care of by **Gabriéle Andreossi** (Switzerland) in the STS Secretariat. The neutron film badge service is operated by **Maria Schuler** who is also Swiss. The group has had a summer student, **Dietrich Zawischa**, who continued studies of neutron dosimetry by means of foil activation, work in which he is engaged in his home town, Vienna.

The group has a wide range of **interests, from** administration to fast electronics but the most stimulating part of its work is certainly its underlying human interest ●

Other People's Atoms

This is the last of a series of articles on high energy physics in the United States. The activities of "MURA" in 1959 are described and a table lists the prices of accelerators operating or under construction in the United States at the end of 1959.

MIDWESTERN UNIVERSITIES RESEARCH ASSOCIATION (MURA)

In an attempt to arrive at new types of accelerators, hopefully encompassing higher energies and intensities, the Midwestern Universities Research Association (MURA), a cooperative organization for research in high energy physics with headquarters in Madison, Wis. and with a membership of 15 midwestern universities(*), has been working for several years on design and development of various devices for high energy acceleration of charged particles.

MURA's solution to the problem of obtaining high intensity ion currents is based on the so-called Fixed Field Alternating Gradient Principle (FFAG). An accelerator embodying this principle differs from the conventional high energy accelerator in that a magnetic field constant in time is used to guide the accelerated particles in their circular paths. The magnet pole pieces would be so shaped that the field strength would increase rapidly from the inner to the outer edge of the doughnut-shaped chamber. Because the field is steady, particles can be injected continuously, or in rapid successive pulses, instead of at intervals as is necessary with the pulsed magnetic field used in a conventional synchrotron field. Alternating gradient focusing, the application of a succession of alternate focusing and defocusing magnetic fields to a charged particle rotating in an orbit, would stabilize the particle orbits and prevent them from flying out of the machine either vertically or radially.

This focusing is being studied both theoretically and through the use of small electron models in two different geometries : Radial Sector, in which the magnet sectors are pie-shaped, and Spiral Ridge, in which the magnetic sectors spiral out from the inside.

The Spiral Ridge geometry is essentially a MURA development and several low energy accelerators are currently being built at various sites in the country, using this approach to obtain high intensity beams.

In their efforts to extend the parameters of high energy accelerators, nuclear physicists for several years have been studying the possibilities of having two high energy beams intersect and collide. In this way, the energy available for reactions can be very substantially increased. For example, the energy available for the creation of matter in a head-on collision between two 15 BeV protons would be equivalent to that of a 540 BeV proton striking a stationary proton as in a conventional accelerator.

The difficulty of realizing this effect lies in the fact that high energy accelerators, such as synchrotrons, operate in pulses, and the particle currents are very small. Therefore, collisions among the particles in two such intersecting beams would be rare. With two high-intensity particle beams circulating in opposite directions, from two FFAG accelerators, the number of very high energy collisions could however be large enough to lead to significant results.

It has been determined that it is not necessary to have two separate accelerators ; under certain conditions two beams moving in opposite directions can be maintained in a single machine. A new model two-way Radial Sector accelerator was completed at MURA late in 1959 which will be able to accelerate currents of electrons of the order of 50 amperes to an energy of 50 MeV, and in which it will be possible to accelerate simultaneously beams of electrons travelling in opposite directions. This model will provide design information for a full-scale proton accelerator. It has been estimated that a 15 BeV "clashing-beam" proton machine together with associated laboratory and service facilities would cost over $ 200 million (860 million Swiss francs) ●

(*) The Universities of Chicago, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Wisconsin; Iowa State College; Michigan State, Northwestern, Notre Dame, Ohio State, Purdue and Washington (St. Louis, Mo.) Universities.

Costs of some U.S. high energy accelerators

(One billion electronvolt or greater)
(dollar amounts are in millions)

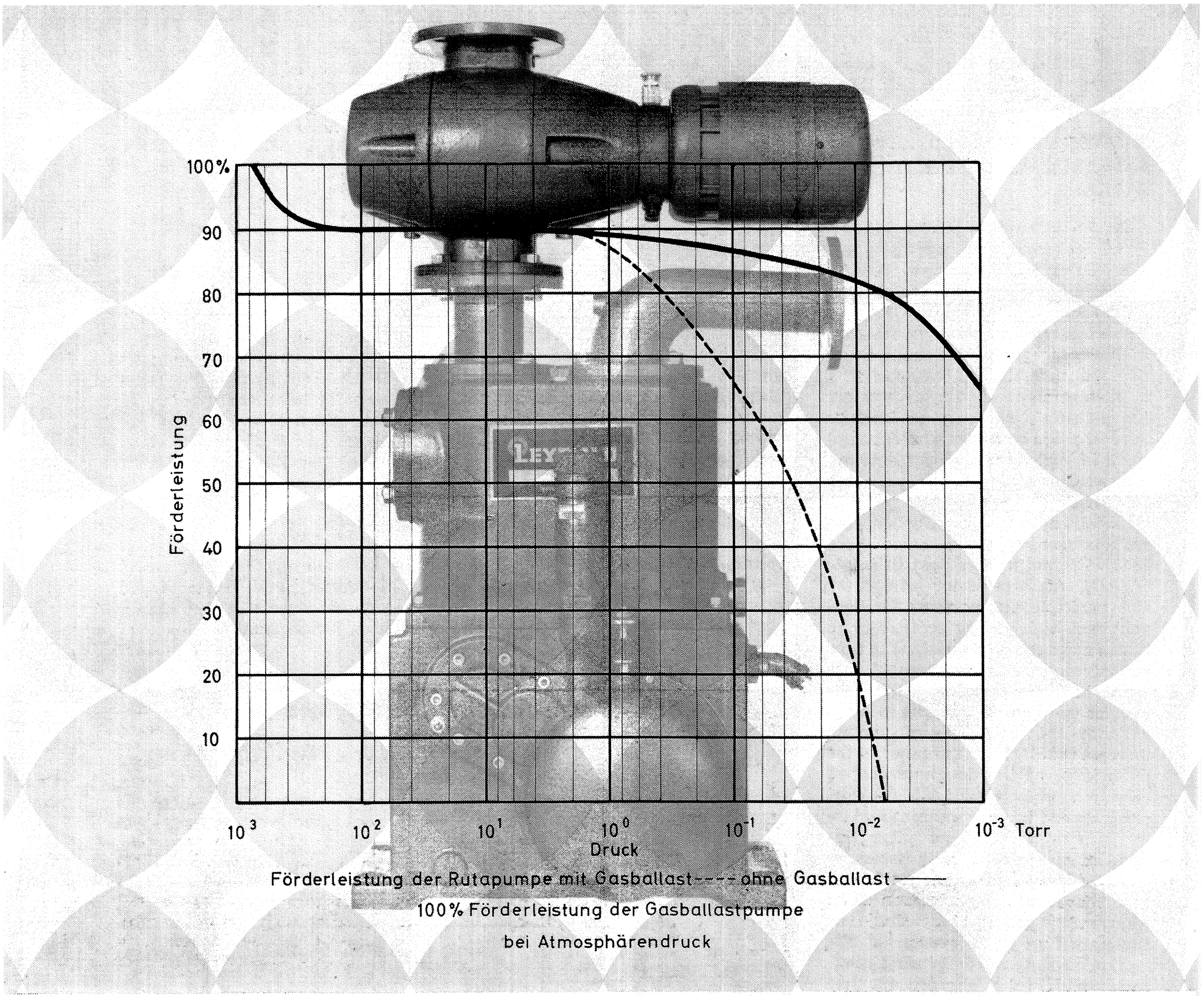
IN OPERATION

	Lawrence Radiation Laboratory (Bevatron)	Brookhaven National Laboratory (Cosmotron)	California Institute of Technology (CIT)	Cornell University
Particle	Proton	Proton	Electron	Electron
Energy	6.2 BeV	3.2 BeV	1.2 BeV	1.2 BeV
Start-up	1953	1952	1953	1953
Plant and equipment at 30 June, 1959 :				
Original cost	$ 9.7	$ 9.3	$ 1.3	(1)
Modifications :				
Completed	3.4	—	0.3	—
Not completed . . .	0.8	3.7	—	—
Fiscal year 1959 operating cost :				
Cost of operations . .	1.9	(2)	0.2	0.2
Research and development	3.1	3.5 (3)	0.4	—

(1) Owned by the Office of Naval Research, cost not available at time of writing.
(2) Shut down for repairs in fiscal year 1959.
(3) Includes cost of repairs.

UNDER CONSTRUCTION

	Brookhaven Nat'l Lab. (AGS)	Argonne Nat'l Lab. (ZGS)	Harvard U. and MIT (CEA)	Princeton U. and Univ. of Pa. (PPA)
Particle	Proton	Proton	Electron	Proton
Energy	25-30 BeV	12.5 BeV	6 BeV	3 BeV
Start-up	1960	1962	1961	1961
Estimated cost of plant and equipment . . .	$ 31.0	$ 29.0	$ 11.6	$ 11.2
Estimated annual operating costs :				
Operating	3.0	3.7	1.9	1.4
Research and development	3.4	3.8	2.8	2.3



Förderleistungsverhältnis 1 : 1

Pumpenkombinationen sind seit Jahren bekannt. RUTA-Pumpen, eine LEYBOLD-Neuentwicklung, verbinden erstmalig schnellaufende Rootspumpen mit normalen Gasballastpumpen bei einer Förderleistung beider Stufen im Verhältnis 1 : 1.

Diese Anordnung bietet eine Reihe wesentlicher Vorteile.

Günstige Förderleistungscharakteristik, auch bei niedrigen Drücken;

Ein Überdruckventil ist nicht erforderlich;

Ohne Verwendung eines Zwischenkondensors verträgt die RUTA-Pumpe Wasserdampfteildrücke bis zu 30 Torr;

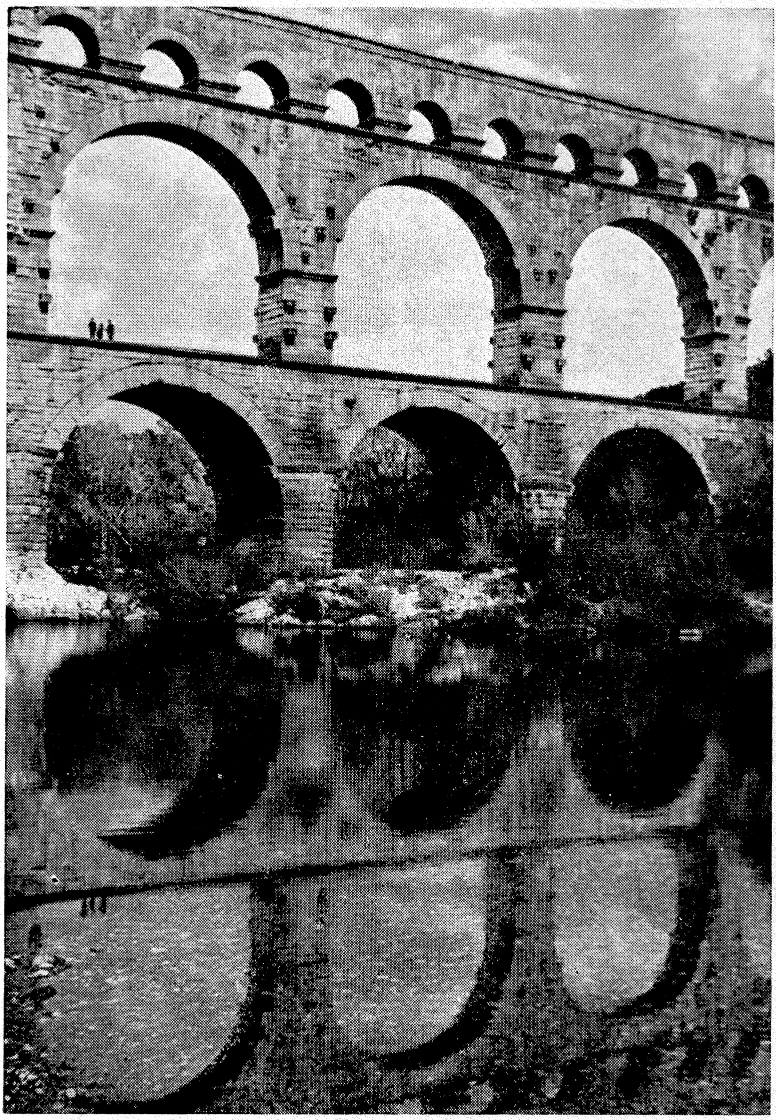
Die Energieaufnahme ist auch im Grobvakuumbereich nahezu gleichbleibend. Es ist daher bei allen Drücken Dauerbetrieb ohne Einschränkung möglich;

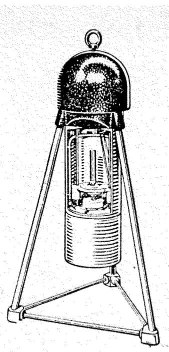
RUTA-Pumpen laufen erschütterungsfrei und geräuscharm; Ihr Raumbedarf ist minimal.

Welche Vakuumprobleme Sie auch haben – LEYBOLD berät Sie zu Ihrem Vorteil.

LEYBOLD

E. LEYBOLD'S NACHFOLGER · KÖLN - BAYENTAL





water - source of life

From time immemorial man has laboured on the provision of his drinking water, a fact strikingly demonstrated by the still existing aquaducts built by the Romans 2000 years ago.
To-day the degree of care demanded by the need for good quality water is steadily growing. Increasing use of radioactive isotopes and the putting into operation of nuclear reactors necessitate regular checking of the radioactive content of water, not only for human consumption but for the promotion of animal and plant life as well.

Radiation levels encountered in daily practice are low: tolerance level of contamination, as accepted by the I.C.R.P.*), has been defined to 10^{-7} μC per cm^3 of water. A further reduction of this standard might be expected in the future.

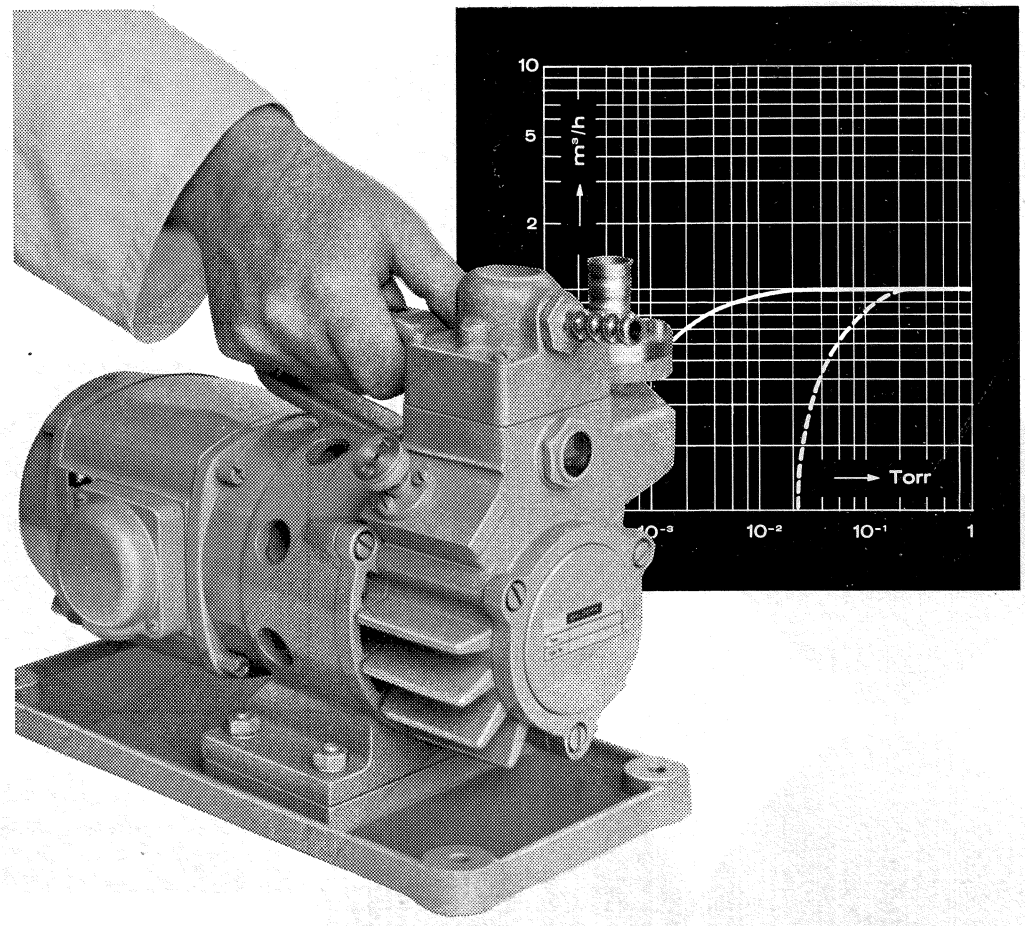
Measurement of these low activities calls for cumbersome and complicated equipment - if use is still made of conventional apparatus. However, Philips low-level beta counting assembly, type PW 4127, represents a remarkable solution.
With a background count rate of only 1 c.p.m., the measurement of low intensity samples is reduced to short duration testing on a routine basis, yet with a definite accuracy:
Beta contamination of 15×10^{-9} $\mu C/cm^3$ of drinking water is determined in one hour with a probable error of 12% (or in 30 minutes with a probable error of 17%) when measuring the sediment of 300 cm^3. This is less than 1/7th of the I.C.R.P. tolerance level.

*) I.C.R.P. = International Commission on Radiological Protection.

N.V. PHILIPS' GLOEILAMPENFABRIEKEN - EINDHOVEN - HOLLAND

PHILIPS
nuclear equipment

Particle accelerators ● Reactor control instrumentation ● Health protection and monitoring equipment ● Radiation measuring and detection equipment ● Geiger counter tubes ● Photomultipliers ● Radio-active isotopes ● Vacuum measuring equipment ● Air and gas liquefiers.


10
5
2
m³/h
Torr
10⁻³
10⁻²
10⁻¹
1