

The Minister for Scientific Research, Dr. G. Stoltenberg, who sent the letter of intent from the Federal Republic of Germany, photographed (centre) during his visit to CERN in April, 1966. On the left is Professor V. Weisskopf and on the right, the Director General, Professor B. Gregory.

Mr. G. Medici, Italian Minister of Foreign Affairs (centre, wearing hat) photographed on the site of the intersecting storage rings during his visit to CERN on 6 September.

sure that the project is completed within the agreed price estimates. In the context of the limited financial resources of the Member States, priorities need to be established among the various programmes of CERN. The German government is also concerned about the participation of industry in the new project.

Now that a letter of intent from CERN's biggest contributor has been received (the Federal Republic of Germany contributes 23.3% of CERN's present budget) it is expected that other countries who have been awaiting the views of the major partners, will now be able to take their decisions. The next steps forward will be clarified at the Council Meeting which begins on 2 October.

Go forth and proliferate

On 6 September, the Italian Minister of Foreign Affairs, Mr. G. Medici, visited CERN. With him was Ambassador G. Smoquina, Head of the Italian permanent mission to the international organizations in Geneva who represents his country on the CERN Council. In the absence of the Director General, the Minister was welcomed by three Directors (Professor G. Cocconi, Dr. M. G. N. Hine, and Dr. K. Johnsen) and by Professor E. Amaldi, Chairman of the European Committee for Future Accelerators, ECFA.

The Minister toured the site and talked to many CERN staff. He was in Geneva for a Conference on the non-proliferation of nuclear weapons and at the end of his visit to CERN he linked the two, saying: 'I am quite convinced of the significance of this enterprise (CERN) in the framework of our general policy for peace and progress. This initiative is extremely important at a moment when we are supporting the Treaty for the non-proliferation of nuclear weapons. We do not like to proliferate bombs; we do believe, however, it is very important to proliferate scientific initiative. This is the positive policy of the Italian Government'.

Computer shut down

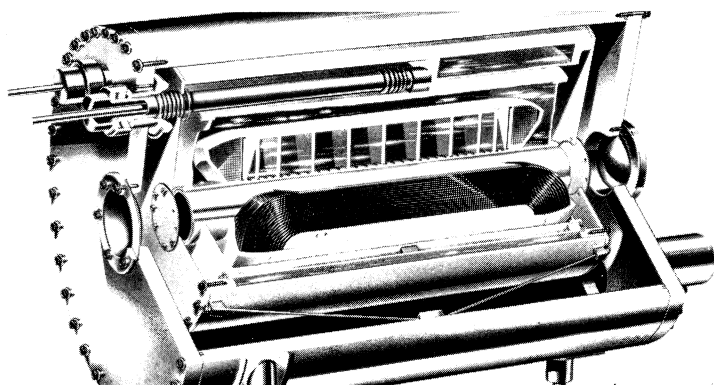
At the beginning of September, CERN's main computer — the CDC 6600 — was shut down to carry out some additions and modifications.



CERN/PI 33.4.66

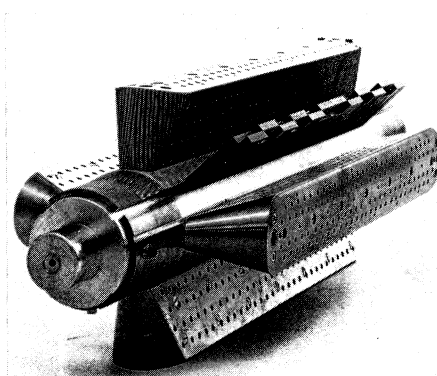


CERN/PI 64.9.68



1.

CMP 68-584



2.

CERN/PI 217.2.68



3.

CERN/PI 105.9.67

It was agreed in March 1966 with Control Data that the CERN machine, which was the third of its type to be produced, would be brought into line with the later production models. Among other things, this will ensure that the logic, the structure of the main chassis and the wiring is identical to the standard machines, so that all the detailed improvements which are constantly being made can be easily applied at CERN by the CDC engineers. This had become increasingly difficult on a non-standard machine.

The major change concerns the modification of the memory access logic and the addition of memory instruction decoding logic which CDC introduced to allow the use of extended core store (ECS) with the 6000 series computers. The use of an ECS would greatly increase the effective memory capacity of the computer and detailed studies are now going on at CERN to estimate what increase in through-put of programmes could be expected with an ECS. Such an addition has already been made to the CDC 6600 complex at Brookhaven National Laboratory.

However, ECS is only one of several alternative ways of improving the central computing facilities and a careful examination is being made of these alternative steps to find the optimum way of increasing the computing capacity at CERN. Some way of increasing the capacity will be needed to cope with the relentless increase in demand, through to such time as the next generation of computers has evolved. An examination of the future situation has started both in terms of an analysis of the need and of a preliminary consultation with a variety of computer manufacturers as to what the feasible parameters of the next generation of machines might be.

The CDC 6600 is scheduled to be back in full service at the beginning of November. In the meantime, the CDC 6400 and 3800 remain in operation and some computing time is being used on a 6500 computer outside the Laboratory at Zurich.

Quadrupole success

On 22 August, the first tests were carried out on a completed pole of the superconducting quadrupole being built for

CERN at the Oxford Instrument Company, U.K. The tests went very well and indicate that the design specifications for the quadrupole will be easily exceeded.

As reported in CERN COURIER vol. 8, page 24, the project involves CERN and Culham Laboratory in addition to the manufacturers. CERN (group led by A. Asner) designed the uniform current density superconducting quadrupole with the nominal parameters — 10 cm diameter, 70 cm long, field gradient 5.7 kG/cm, maximum field at coil 50 kG, overall current density 110 A/mm². Culham (group led by D.N. Cornish) have been particularly concerned with the cryogenic aspects. Oxford Instrument Company (work led by J. Williams) received a contract from the Ministry of Technology to construct the quadrupole to gain experience of superconductivity techniques, using niobium-titanium composite superconductor (sixteen Nb-Ti wires embedded in 1.5 x 4 mm² copper strip) produced by Imperial Metal Industries.

The quadrupole will come to CERN on long-term loan to be used on an external

1. A drawing of the superconducting quadrupole being built at the Oxford Instrument Company for use at CERN. (Photo Culham Laboratory)

2. The four pole cores which were sent from CERN to be used in the construction of the superconducting quadrupole.

3. A full-scale copper-wound model of a pole produced at CERN to develop the coil winding technique.

proton beam or a secondary particle beam as part of a superconducting lens doublet. The second lens, probably using niobium-tin superconductor is being designed at CERN.

Construction of the quadrupole began in March 1968 and a full-scale copper wound pole produced at CERN was sent to Oxford to be used as a model in the winding of the first pole. This is now complete and tests began on 22 August. A current of 1000 A was passed through the coil (compared with the design figure of 825 A) without difficulty and without causing any quenching. This indicates that currents of 900 to 950 A will be feasible in the completed quadrupole, leading to field gradients up to 6.5 kG/cm with current densities of about 125 A/mm².

Following this success, the remaining poles will be wound in the next three months and at the beginning of 1969 the quadrupole will arrive at CERN for final tests in the cryogenics laboratory of the Track Chambers Division.

Professor Amaldi Professor Weisskopf Birthday greetings

It is a pleasure to extend our good wishes to two physicists celebrating their sixtieth birthdays this month — Professor Edoardo Amaldi on 5 September and Professor Victor Weisskopf on 19 September. Both have played a major part in the life of CERN.

Professor Amaldi was born at Piacenza in Italy. He received his Doctorate in physics in 1929 and did research at a variety of centres in Europe and the USA before settling in 1950 to direct the Institute of Physics at the University of Rome. In 1952, he became the first Secretary General of CERN, when it existed as an interim organization, until 1954 and was Deputy Director General until the middle of 1955. He is a regular member of the Italian delegation to the CERN Council and a member of the Scientific Policy Committee.

In recent years, Professor Amaldi has been prominent in evolving the plans for the future of high-energy physics in Europe. He was Chairman of the first

European Committee for Future Accelerators, ECFA, which presented in 1963 the report (popularly known as the Amaldi Report) recommending the construction of a 300 GeV accelerator. He also chaired the revised ECFA which reiterated this recommendation in 1967.

Professor Amaldi's energy and youthful thinking are such that the news that he has reached 60 years is generally received with astonishment.

Professor Weisskopf was born at Vienna in Austria. He achieved his Doctorate in 1931 having studied at that hot-bed of physics at that time — the University of Göttingen. He then did some outstanding research in theoretical physics at centres in Europe, USA and USSR. He became Professor at the University of Rochester in 1937, moving in 1945 to Massachusetts Institute of Technology.

He returned to Europe and became the fourth Director General of CERN in 1961. His status as a physicist and his sensitive grasp of human affairs were an invaluable asset in those days when CERN changed from constructing its big machines to doing research. It was during his period of office, until the end of 1965, that the broad lines of policy which underlie CERN's present activities were largely worked out.

Professor Weisskopf took up his position at MIT again in 1966 becoming Head of the Physics Department. He also chairs an advisory panel on high-energy physics set up by the US Atomic Energy Commission. In addition to his physics and administration, he is also giving a great deal of time and energy to public relations on behalf of pure science. In the prevailing atmosphere with regard to pure research he sees this as a vital task. It is one which he is well equipped to undertake for his sincerity and fluency as a speaker and a writer are exceptional.

CERN still sees Professor Weisskopf often and holds him in special affection. He is a member of the Scientific Policy Committee and works at CERN for some time each summer. During his latest stay, he lectured on the theory of superconductivity and was received by a packed auditorium with a warmth reserved perhaps for no other person.

Recently, Professor Weisskopf's health has not been good and we add to our birthday greetings our wishes for a quick recovery to full health.

To both Edoardo Amaldi and Victor Weisskopf we wish many more years of active and happy life in physics — for themselves and for us, because we still need them.

Housing more power

(This information is extracted from an article prepared by M. van Aerschoot.)

To cope with the ever increasing demands and to prepare for the coming into operation of the equipment on the intersecting storage rings site, the 'Power House' at CERN is undergoing extensive modification and enlargement.

The Power House, operated by the Technical Services and Buildings Division, is not, in fact, an electric power station, as its name would imply. From the early days of planning the CERN site, it was designed to house:

- boilers to provide heating for all buildings
- the stand-by diesel engine to ensure electric power in the event of mains failure
- compressors to supply compressed air
- the sub-stations to distribute the normal 18 kV power and the emergency power.

The demand for these supplies has grown steadily since those early days and now has come the major expansion of the site into France. All the general power supply installations have had to keep pace and a considerable enlargement has become necessary to serve the ISR, the large European Bubble Chamber, etc...

It was a fortunate choice which originally located the Power House close to the frontier so that now it stands virtually equidistant from the eastern, western and southern boundaries of the site.

Figure 1 shows the Power House as it has become in 1968. The area it occupies has increased by some 150 % in ten years, from about 2 000 m² to about 5 000 m². The plan of the Power House complex (Figure 2) gives an idea of the arrangement of the building. Now follows a brief description of the Production and

Figure 1 : The Power House in August, 1968,
photographed from the Geneva-Lyon
road. (CERN/PI 257.8.68)

Distribution Station and the Electrical
Power Distribution Station.

Production and Distribution Station

Boilers

The boilers feed the heating and hot water systems in all the CERN buildings. The saturated steam generated is converted into superheated water and pumped to all parts of the site.

To keep up with the demand, the power of the equipment has been increased, in the way shown in Figure 3, up to 33 Mkal/h for 1968 (approximately equivalent to a power of 40 MW).

With the boilers now installed, it is estimated that further increases will not be necessary for another ten years or so. Nevertheless, space has been reserved in the extension to the Power House for one additional boiler, which would bring the total number to eight. The maximum heating power available on the site is governed by the heat-exchange capacity of the steam-water transformer, which has a ceiling of 55 Mkal/h, equivalent to about 65 MW.

Diesel engines

A diesel-powered emergency generator intended to supply electricity to critical points if the mains power failed was installed at the end of 1956. At that time it was intended to operate also during periods of peak demand if this were likely to give any appreciable saving. Its power was based on estimates made by the various Divisions and a diesel engine to give an effective power of 1520 HP at a speed of 300 rpm, with a 1320 kVA three-phase alternator, was selected.

The emergency power needed has increased and, after ten years, this generator set was inadequate to meet the requirements. In 1966, therefore, the problem was reconsidered. Selection was difficult in view of the wide variety of power sources, including low-speed or high-speed diesel engines, gas turbines, steam turbines and floating-piston generators, combined with the intention of possibly using the set continuously at peak periods. Finally, mainly for reasons of economy, low-speed diesel engines burning oil, generating a constant supply of power were chosen.

By the end of 1968, two new sets will be in service each consisting of a four-stroke diesel engine delivering 3500 effective HP at a speed of 428 rpm, with a 3080 kVA synchronous three-phase alternator with a nominal voltage of 6300 V. These two units will operate in parallel with the existing one so that the Power House will be capable of supplying a total power of some 7500 kVA.

Compressors

As soon as the first laboratories and workshops were set up, it was essential to have a supply of compressed air available. Consumption has rapidly increased. There was a particularly large increase in 1961 when the 2 m hydrogen bubble chamber building was equipped with two thirty-ton cranes, whose motors operate on compressed air to ensure safe operation in a hydrogen atmosphere. Two compressors were brought into service in 1957. A third was added in 1961 and by 1965, four were in operation. In view of the probable increase in compressed-air consumption, it is intended to add even more powerful units in the future. The compressed-air

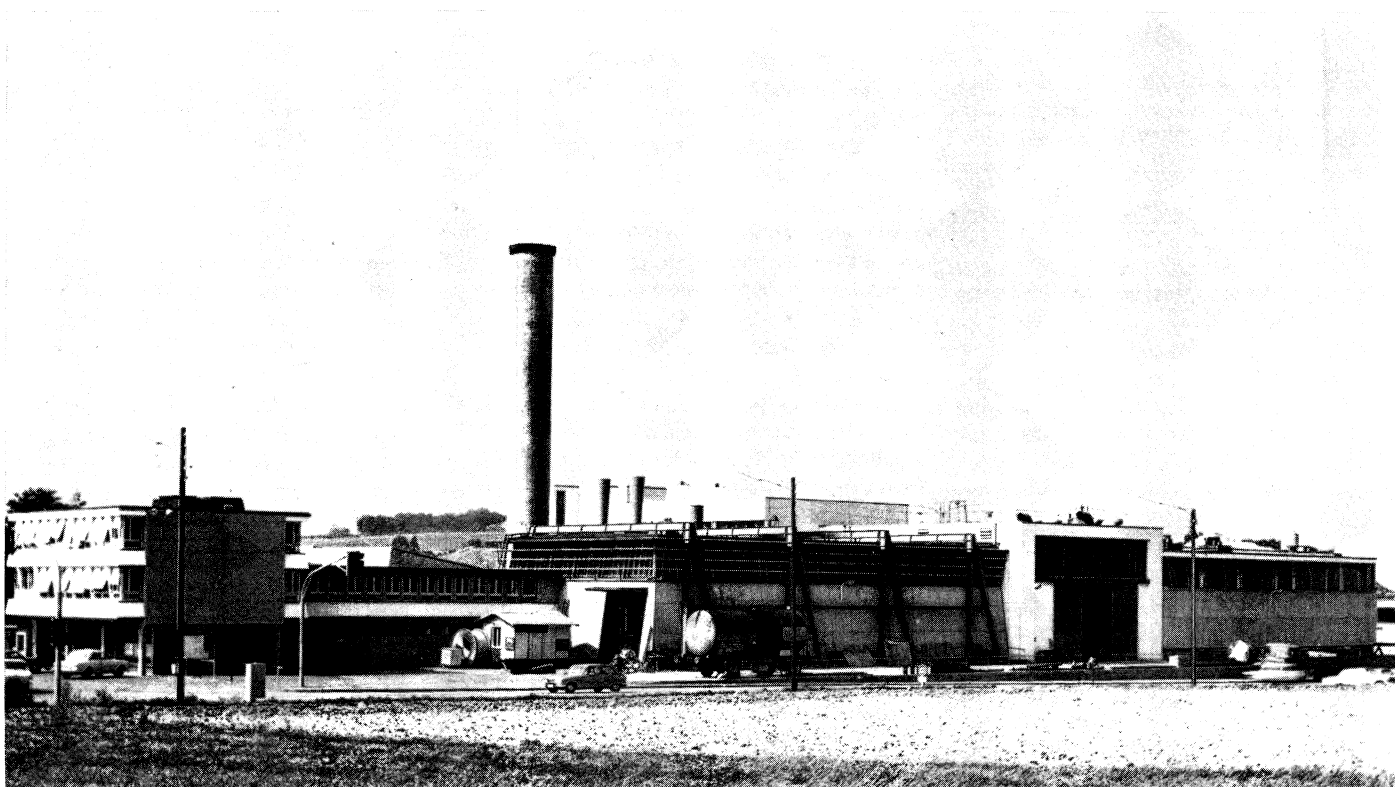


Figure 1

Figure 2 : Plan of the Power House and its main components

- A : Previous production and distribution station
- B : Previous electrical distribution sub-station
- C : Extension to the production and distribution station
- D : Extension to the electrical distribution sub-station
- 1-7 : Boilers
- 8-9 : Steam-water transformers
- 10-12 : Diesel engines
- 13-16 : Air compressors
- 17-19 : Heavy-oil storage reservoirs

generating set will then consist of four 700 m³/h units, with a total power at the shaft of 360 HP, and two units, each of 1700 m³/h, with a total power at the shaft of about 550 HP.

Electrical Distribution Station

The annual consumption of electricity at CERN has increased virtually steadily, the only break having been in 1966, when the proton synchrotron was shut down for some considerable time. For example, the consumption for 1960 was 23 565 049 kWh, and for 1967 was 118 152 000 kWh. In 1967, the electric power consumed at CERN came to more than 11 % of the power taken by the whole of the Canton of Geneva.

However, it is not simply the increase in total consumption that constitutes the problem facing the local electricity authority, the Services Industriels de Genève (SIG) and those responsible at CERN, so much as the increase in the maximum power required. Figure 4 shows the increase in maximum power since 1956.

Until 1966, this power came from a three-

phase supply at a voltage of 18 kV from the SIG Station de la Renfile. It was limited to a maximum of 24 MVA but the demand exceeded this limit during 1965.

With the completion in the autumn of 1965, of the SIG 130/18 kV transformer sub-station at CERN and of the CERN 18 kV main station, both located close together at the eastern end of the site, CERN had a reliable 130 kV supply from the Verbois 130 kV distribution station on the right bank of the Rhône beside the Verbois hydroelectric station. The 130/18 kV transformer sub-station is arranged to take three 30 MVA transformers, two of which are now in service. The third should be installed and ready within a few months.

At present, all electricity consumed at CERN also passes through Station I, known as the Salève 18 kV distribution station, installed in the building marked B on Figure 2. Since the equipment in the Salève station is incapable of redistributing a power higher than 45 MVA and since there are no further output cells available at this station, construction of a new 18 kV

distribution station called the 'Jura 18 kV distribution station' was considered in 1963. Its purpose was to distribute all the electrical power, 90 MVA, from the main 18 kV station and also the power from the three generator sets referred to earlier. The power provided by the generator sets, at a voltage of 380/220 V in the case of the first one and 6300 V in the case of the two new ones, will be increased to 18 kV in transformers arranged in cells attached to the Jura station, indicated by the letter D on Figure 2.

This station is housed in a three storey building. The basement contains input cables and sets of transfer bars enabling any one of the twenty-four output cells to be fed by any one of the six input cells, the latter corresponding to six 15 MVA connections with the main 18 kV station.

The ground floor is taken up entirely by high-voltage cells distributing the 'normal' power supplied by the SIG and the 'emergency' power supplied by the generator sets. A coupling line enables current to pass from the normal cells to the emergency cells and, if necessary, vice-versa.

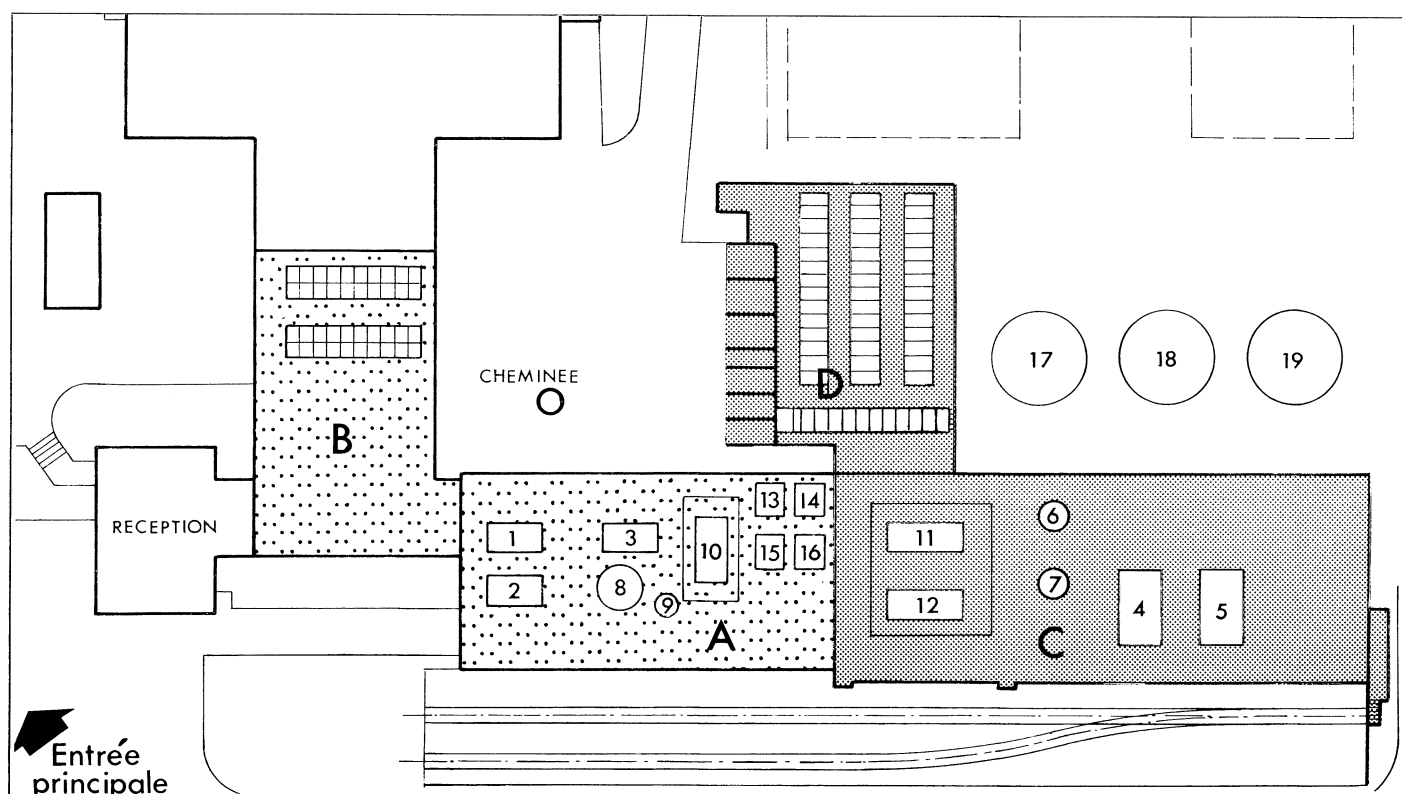


Figure 2

Figure 3 : Increase in the total heating power since 1956

Figure 4 : Increase in highest peak period use of electricity since 1956.

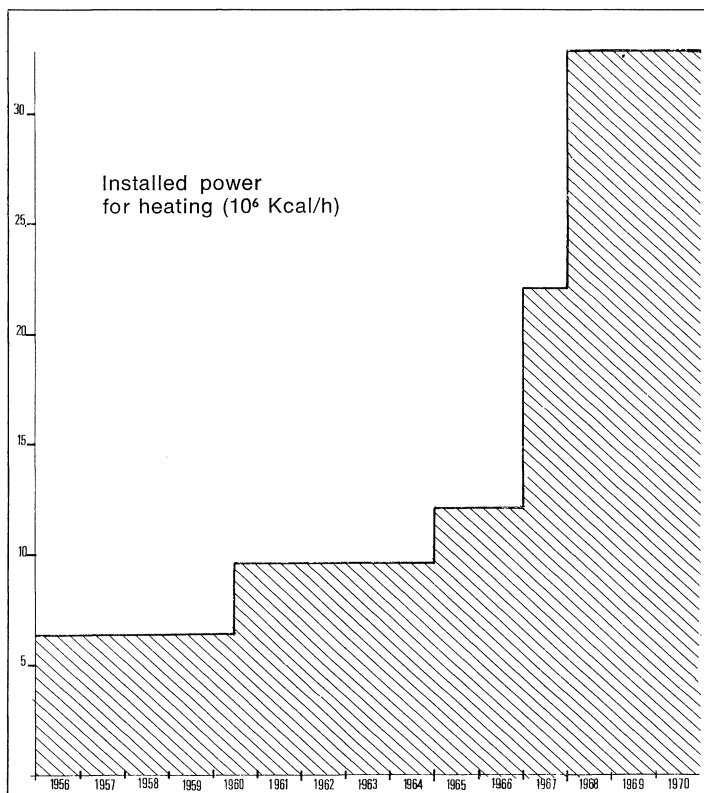


Figure 3

The auxiliary equipment for the station is installed on the first floor where there is also the chassis carrying the high-voltage equipment protection, control, and checking and signaling relays connecting the control room to the high-voltage cells of the Jura, Salève and CERN main 18 kV stations and the SIG 130/18 kV transformer sub-station, and also to the various installations in the Power House.

The second floor of the building is the Control Room, which replaces the one at

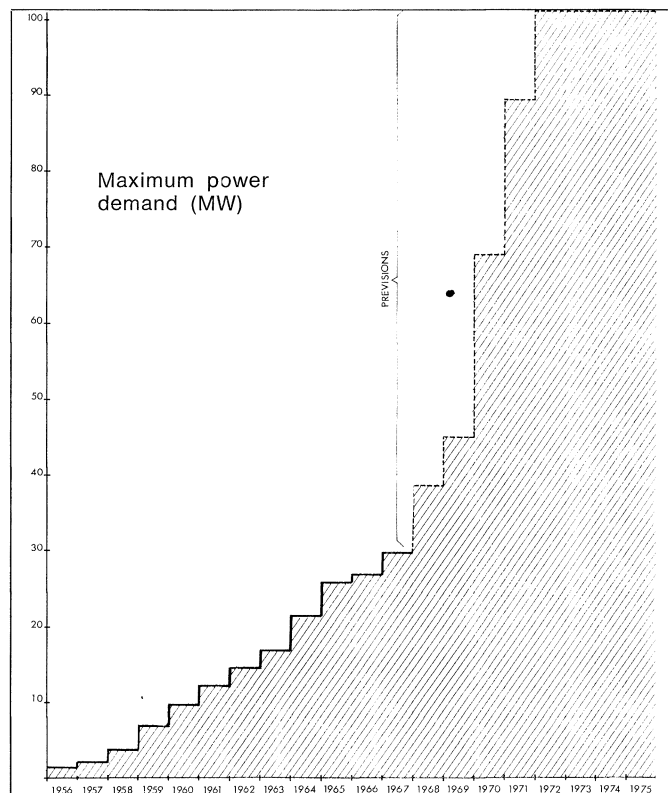


Figure 4

present housed in the building marked B on Figure 2. The essential equipment of this room will be a row of control and supervision desks for the electricity generating and distributing plant and a row of panels for the supervision and control of the production and/or distribution of the various fluids, i.e. drinking water, industrial water, oil, superheated water, gas and lighting and compressed air. This floor will also contain the Station Operations Manager's office and the rooms for the duty team.

The Power House revised and renovated in this way, will become operational before the end of the year and will be ready in good time to provide the heat, electricity and compressed air required on the ISR site.

It is appropriate to round off this survey by indicating how the contracts for the work involved have been awarded to companies from several of the Member States. The Power House constitutes a fine example of European technical co-operation.

Société Aixoise de Construction, Aix-en-Provence
Firma Muller, Offenburg
Termotecnica Industriale, Milan
Kloeckner-Homboldt-Deutz AG, Cologne
Siemens AG, Erlangen
Société Lyonnaise d'entreprises, Lyon
Sprecher & Schuh, Aarau
Merlin Gerin S.A., Grenoble
Société de Construction Electrique A.M.S., Grenoble
Nordon Fruhinholz Biebold, Villeurbanne
Haelg & Co, St. Gallen
Ceretti & Tanfani, Milan

France
Federal Republic of Germany
Italy
Federal Republic of Germany
Federal Republic of Germany
France
Switzerland
France
France
France
Switzerland
Italy

civil engineering
metalwork
steam boilers
diesel engines
synchronous alternators
engineering in the relay and control rooms
equipment for the relay and control rooms
high-voltage cells
lighting and power installations
pipework
pipework
crane

Biological effects of radiation

The number of people in contact with artificially-produced ionizing radiation is rapidly increasing. The time when only a few isolated research workers were subject to its effects is now long past. Atomic fission has become accepted almost as part of everyday life. In the medical field, radiation is becoming an essential tool in such work as radiology, the study of the metabolism and functioning of glands, and possibly in reducing rejection reactions to grafts. Its use is increasing also in biology (most of the recent knowledge of life processes has been gained using radiation), mechanics, metallurgy, hydrology, food preservation, etc...

This growing range of useful applications has made it more important to recognize the other side to the coin — the dangers inherent in the exposure of living matter to radiation. The early atomic scientists and radiologists were, to their cost, the first to become acquainted with 'radiation sickness'. But, as the knowledge of the properties of radiation and its biological effects has increased, it has become possible to take precautions against the dangers. The more accurate this knowledge of the risks becomes, the more thorough the precautions that can be taken.

How radiation acts

The action of radiation on living matter originates in the ionization produced by the particles of the radiation as they pass through matter. The ionization liberates active radicals which, in turn, bring about a chemical imbalance. This imbalance can result in a wide variety of biological effects.

Unlike light, ionizing radiation does not stop at the surface. It can penetrate deep into matter and can, in certain cases, be even more biologically active at a great depth than at the surface. As the energy of the particles increases, the ionization can be accompanied by the creation of secondary particles with a very complex ionization range.

Around accelerators generating very high-energy particles, the protection provided in the form of shielding, etc... is based on an extrapolation of the known effects of radiation, allowing a wide margin of safety. There is a danger, however, that these conventional safety measures may lose their effectiveness as energies increase and the interaction between the high-energy particles and matter becomes more complex. Hence the need to examine in advance any new effects that might result from exposure to very high-energy radiation.

The very exhaustive studies already carried out in the field of dosimetry, analysing the entire physical side of radiation, needs to be supplemented by biological studies. In order to understand radiation sickness the intermediate processes in its development (see diagram) have to be studied.

The most sensitive part of the cell is the nucleus, containing the chromosomes, which consist essentially of DNA (deoxyribonucleic acid). The effects, depending on the degree of irradiation of the cell, are as follows :

- 1) slight disturbance to the metabolism of the cell, which can be repaired
- 2) abnormal cell reproduction
- 3) inhibition of cell division (reproduction)
- 4) destruction of the cell.

Cells which are in the process of division are the most vulnerable, and a relatively small dose is enough to destroy them. For example, the cells of the reproductive organs, those of the hematopoietic system (the production of blood in the bone marrow) and cancerous cells are very sensitive to radiation because of their high rate of reproduction. On the other hand, the cells of the nervous system which do not renew themselves, are much less sensitive to radiation.

The changes produced in the cells by irradiation, affect the organism in a complex way, depending on the nature of the organ which has received the dose and on the type of radiation. The phenomena affecting the organism itself are called somatic, and those affecting heredity are called genetic. Effects produced by sub-

lethal doses may appear soon or after very long periods.

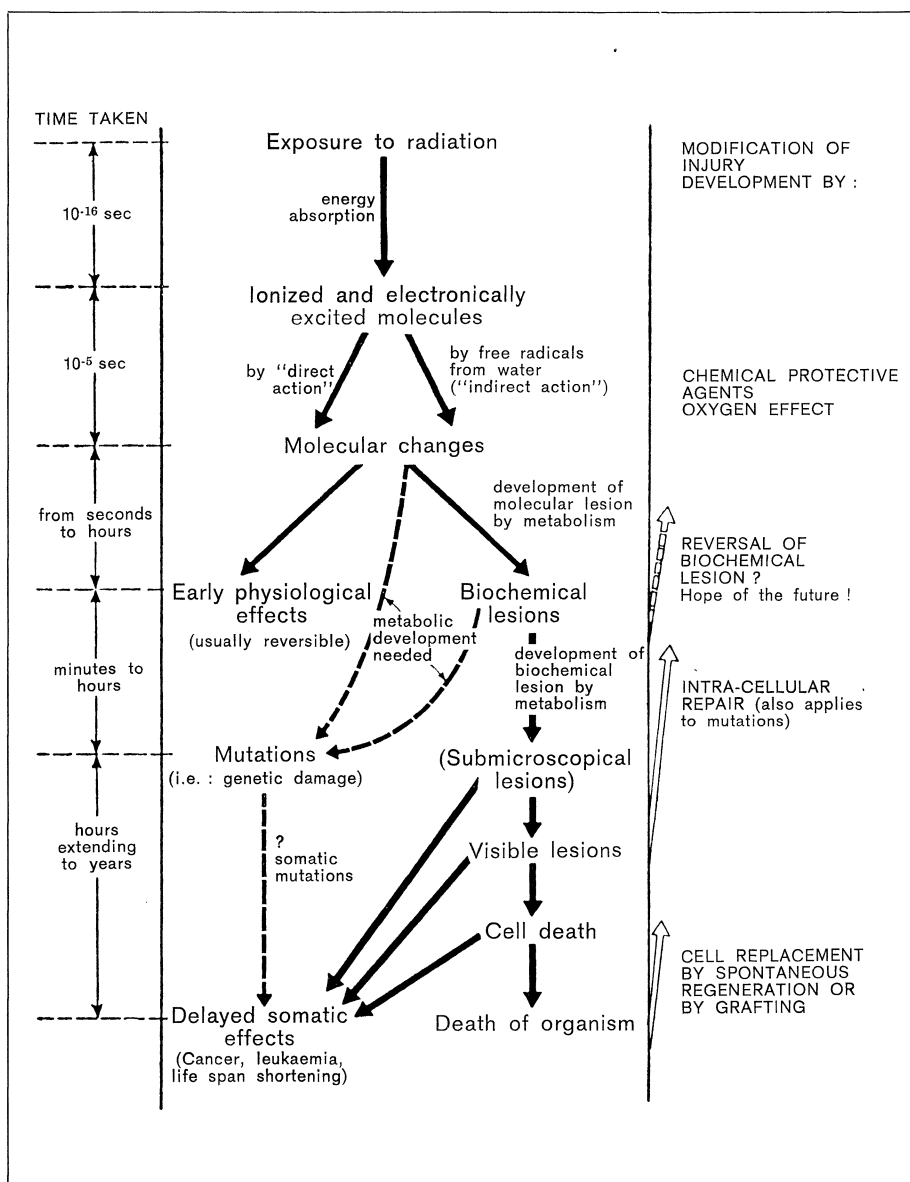
It is difficult to understand all the mechanisms involved in an organism as highly developed as that of a mammal, and the work done in physics and chemistry has to be corroborated by the experimental study of the complex reactions taking place in complete organisms.

A great deal of research has already been done on the induction of cancer, changes in the blood, skin reactions, mutations, metabolic disturbances and effects on micro-organisms and plants. Interest is now being directed towards the study of the effects of small doses and the special features of high-energy ionizing radiation, the action of the environment, separation mechanisms at cell level (repairable and irreparable effects), immunology, calculations on the distribution of ionization in sensitive points in the cell, and the new problems in the field of protection.

Biological research makes it possible to evaluate the maximum permissible doses, to be applied in protection with a considerable safety margin, to prevent artificial radiation from causing more mutations than are brought about spontaneously in nature.

The concept of biological effect

The dose of radiation received, i.e. the energy absorbed per unit volume of tissue is proportional to the ionization produced, and is measured in *rads* (100 erg/cm²). For equal doses, however, not all radiation has the same biological effect, since the latter is a function, in particular, of the distribution of the ionization inside the cells (i.e. the linear energy transfer — LET). In order to take into account the way in which the ionization is distributed, a coefficient called the *quality factor*, QF, is applied to the energy absorbed and the number of rads multiplied by the quality factor equals the number of *rems*. However, the rem unit system does not necessarily take account of the features of the biological system itself and it is necessary to define yet another factor, the *relative biological efficiency*, RBE. This takes into account the action of radiation at the biological level.



Scheme from Z.-M. Bacq and P. Alexander

Research programmes

Only quite recently has it become possible to carry out biological and medical research using high-energy particles generated by accelerators. CERN participates in this research in close collaboration with laboratories in Member States. The work is coordinated by the Advisory Committee on Radiobiology set up by CERN in 1964. In general, it is CERN which provides the irradiation facilities (predominantly, up to now, at the 600 MeV synchro-cyclotron)

and dosimetry, while the biological evaluation is carried out in the Member States. In the context of this overall programme, a series of biological assessments, has been undertaken over the past two years at CERN, by a visiting scientist, G. Buhner of the University of Geneva, working in the Health Physics Group.

The work of the Group, the majority of whose members are engaged on research as well as on protection systems, is directly related to the requirements of the high-energy physics field, that is to say to

protons and neutrons of high energy as well as sub-nuclear particles.

The biological research carried out by Buhner at the synchro-cyclotron used protons and neutrons. Using protons with an energy of 600 MeV, the research has provided a clearer picture of their relative biological effect which, up to now, has been a subject of dispute. It has also helped to fill gaps in the knowledge of their genetic action and to provide fresh information on the close relationship between high-energy protons and 'conventional' radiation.

Using neutrons with an energy of 400 MeV, work on plant chromosomes and the reproductive organs of mice has just been completed. One of the main results is a measure of the relative biological effect in relation to the depth of tissue penetrated.

Other research needs to be done on the action of beams of several types of particle over a range of energies on various biological systems. The emphasis will be laid on the formation of nuclear stars resulting from the explosion of the nuclei. This phenomenon can be produced only at high energies, and its effects cannot yet be foreseen.

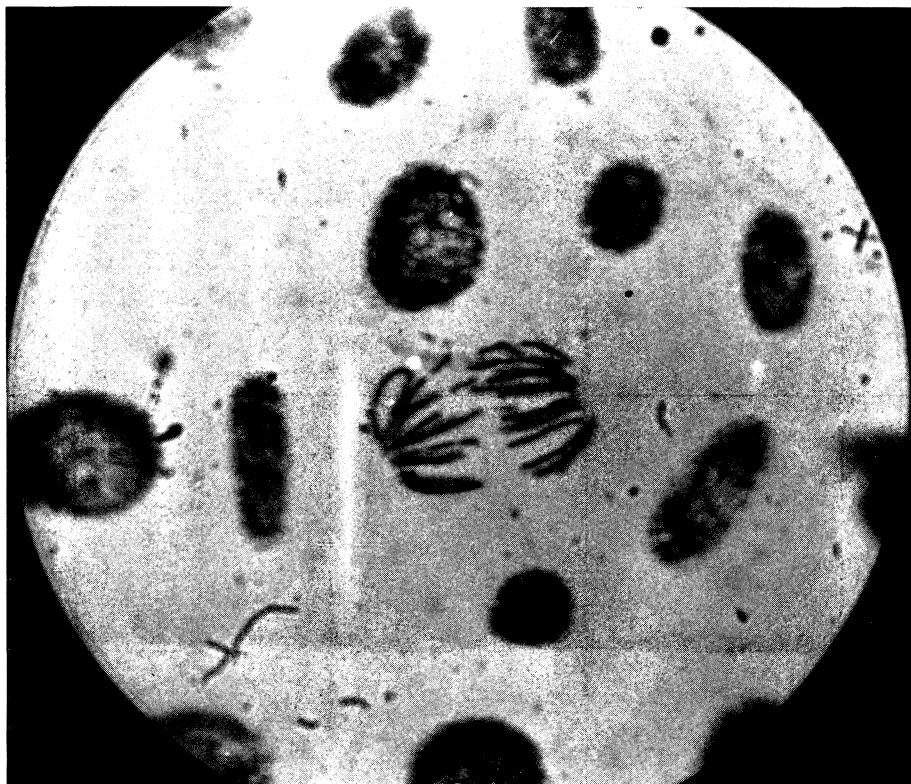
Conclusion

In addition to the uses of radiation which were mentioned at the beginning of the article, the time has arrived when astronauts and pilots flying at high altitude are subjected to high levels of ionizing radiation of cosmic origin. This has particular relevance to the work around accelerators since the radiation at high altitude has substantially the same composition as can be produced at the accelerators. It is therefore very important to know precisely the biological effects of the radiation; at present, this knowledge can be obtained only by work around accelerators. (It is significant that the USA space agency, NASA, have built a synchro-cyclotron specifically for this purpose.)

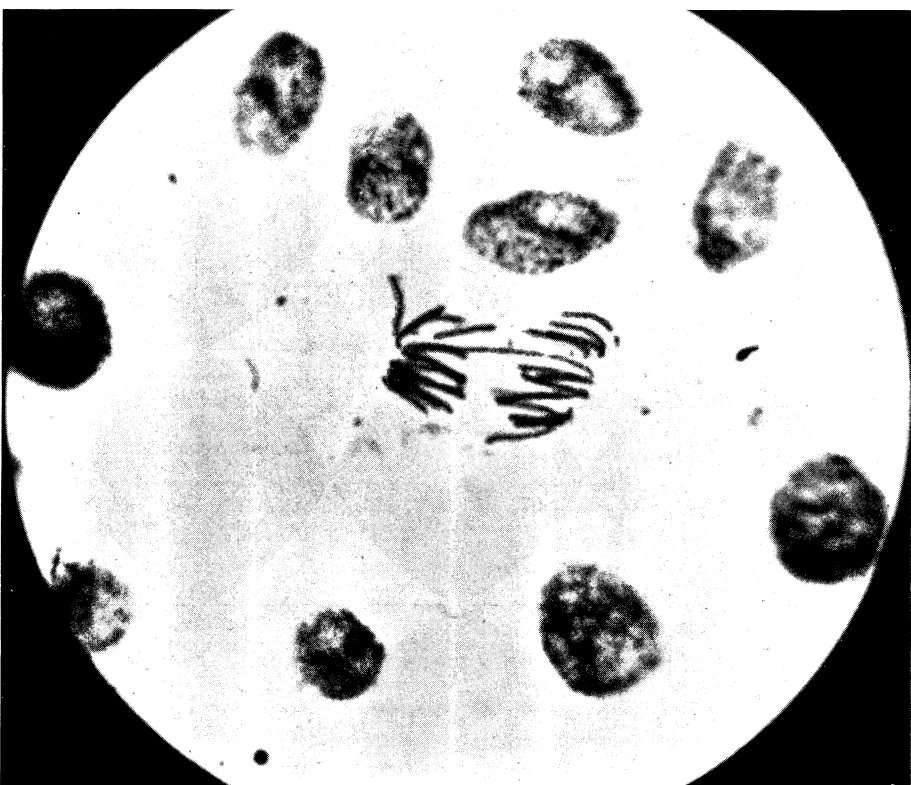
The research done in this field has already cleared away a lot of misconceptions. The information obtained has made it possible to improve the methods of protection

against radiation, to develop more effective medical treatment, and to reduce the danger of genetic damage to persons exposed to small doses. Furthermore, it has now been found that the organism can, to a certain extent, spontaneously repair somatic and genetic lesions, since some of the DNA contained in the chromosomes can be restored by a repair mechanism inside the cell which eliminates the damaged part. It has even been possible to demonstrate that animals previously exposed to a sub-lethal dose acquire some immunity to 'lethal' doses. In some cases very small doses can even prolong life, whereas, in general, exposure to radiation shortens life.

The research work already carried out has helped to remove certain superstitions which followed the tragic and spectacular manner in which humanity first came face-to-face with nuclear armements. Further increases in our knowledge, even if they do not remove the danger completely, will at least enable it to be estimated correctly.



1.



2.

Photographs from an experiment done at CERN on the irradiation of plant tissue (*vicia faba*) by a high-energy neutron beam (400 MeV).

1. At the centre can be seen an irradiated cell in the course of division. The chromosomes show signs of lesions, mainly in the form of breaks.
2. At the centre there is another cell in the process of division which has also been injured by radiation. Some broken chromosomes are visible, but the main effect of the radiation here is the presence of a bridge of an abnormal type joining the two sets of chromosomes and inhibiting the normal development of the cell. The other cells, in the compact state, which can be seen in both photographs, are not in the process of division.