EUROPEAN ORGANIZATION
FOR
NUCLEAR RESEARCH
SECOND ANNUAL REPORT
CERN
1956
In accordance with the provisions of the Convention, the publication of the following report for 1956 is approved.

B. Lockspeiser
President of the Council
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- Supporting bridge of the three Linac tanks
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INTRODUCTION

The Second Annual Report of CERN is a straightforward account of developments during the course of 1956.

Work is progressing rapidly and according to plan.

Several years of intensive scientific and technical work will however be needed before CERN is really in a position to play the part for which it is intended and before it comes into full operation as Europe's great joint laboratory for advanced nuclear research.

[Signature]

Director-General
PROGRESS AND STRUCTURE OF CERN

1. General activities

At the end of 1955, apart from cosmic ray research on the Jungfraujoch and the work of the Theoretical Study Division in Copenhagen, CERN's activities were entirely directed towards the construction of its two accelerators, the 600 MeV Synchrocyclotron and the 25 GeV Proton Synchrotron, on the Meyrin site near Geneva.

During 1956 the work of construction advanced considerably, in accordance with the programme: the synchro-cyclotron is practically complete, with the exception of the high frequency system; as regards the proton synchrotron, the buildings are nearing completion, the specifications for all main components of the machine have been drafted in their final form and orders have been placed for most of them. The Meyrin site bears witness to an impressive record of progress which is also illustrated by the photographs inserted in the chapters devoted to the respective Divisions.

CERN is entering a new phase of research and measures have been taken to anticipate the use of the synchro-cyclotron which is to come into operation in 1957. A programme of experiments has been established and studies have been made in the internal organization necessary to carry this programme out. Means and methods have been suggested whereby graduates, either individually or in teams, from Member States can be enabled to make the best use of the machine and CERN's facilities.

The problems involved have been examined by the Scientific Policy Committee, whose recommendations will be considered by the Council during the first half of 1957, when it is expected that final decisions will be taken.

The recruitment of the Theoretical Group at Meyrin, which is to take over from the Division in Copenhagen in October 1957, is proceeding.

In the field of equipment, the set of two cloud chambers has been successfully completed by the Scientific and Technical Services Division and will be used for experiments on K-mesons.

CERN has an important part to play in international science and CERN delegations led by the Director-General went to Rochester (U.S.A.) in April and to Moscow in May.

CERN itself organized a Symposium in June 1956 on high energy accelerators and pion physics, which was held at Geneva. Over three hundred scientists from twenty-two countries attended that gathering. Fifty American scientists and fifty Russian scientists, who had all been invited by CERN, were able for the first time to exchange information freely and compare ideas. Highly interesting papers dealing in particular with new principles for the acceleration of particles and with pion physics were read and discussed during the course of the conference. The records of the Symposium in two large volumes were published and put on sale by 1st November.

The success of that gathering has encouraged CERN to make plans for a similar one in 1958, and it is hoped that it will then be possible to welcome participants in the new main building at Meyrin.

Advances in research revealed at the Symposium on new principles for the acceleration of particles, particularly in the United States and the Soviet Union, prompted the decision to set up within the Proton Synchrotron Division a new section to carry out its own research in this field.

The CERN staff has increased from 260 on 31st December 1955 to 396 on 31st December 1956, to which should be added, 8 half-time workers, 14 consultants, 22 fellows.

2. Progress during 1956

The origins, aims and structure of the Organization were briefly described in the First Annual Report.

In February 1956 the agreement between Denmark and CERN on the legal status of the Theoretical Study Division in Copenhagen was signed by Mr. H. C. Hansen, Prime Minister of Denmark, and the Director-General.

At its 43rd session, the Executive Council of UNESCO authorized the Director-General of that Organization to sign the draft agreement on scientific co-operation with CERN, which had been
The conversations that had been initiated in 1955 through Mr. Willems, Chairman of the Finance Committee, with Ford Foundation executives, resulted in a grant to CERN of four hundred thousand dollars to be spent over a period of 5 years. This grant is intended in particular to give fellowships to scientists from non-Member States.

With a view to showing the progress of work at CERN to the authorities of the countries that give the Organization both moral and financial support, the Council decided to invite a number of distinguished persons from Member States to visit the site at Meyrin. In response to that invitation a large number of Ministers, members of legislative assemblies and senior civil servants came to Geneva in September 1956 to see for themselves the progress that had been achieved in the construction of the two accelerators and the general way in which CERN puts in practice the ideals of international scientific co-operation on which it is based.

At its second session in February 1955, the Council had decided to adjourn until January 1957, namely the time when the first accelerator would be completed, the examination of applications by States for admission to membership of the Organization.

Since then no country has formally applied for admission. The Director-General has however been approached by several European countries for information concerning the conditions under which they could join the Organization.

3. Council, Committees and internal structure

No major change has taken place in the internal structure of the Organization during 1956.

As has already been mentioned, however, the Proton Synchrotron Division has been selected to carry out research on new principles for the acceleration of particles.

The Synchro-cyclotron Division on the other hand has concentrated on the preparation of the experiments that are due to begin in 1957.

Finally, the Scientific and Technical Services Division has been given the additional tasks of installing and operating an electronic computer, producing liquid hydrogen, organizing a health physics service and taking charge of the main workshop.

The organizational chart below has been brought up to date and is similar to that included in the Annual Report for 1955.
LIST OF MEMBER STATES

AND SCALE OF

PERCENTAGE CONTRIBUTIONS

APPLICABLE DURING THE PERIOD TO DECEMBER 31 1956

<table>
<thead>
<tr>
<th>Member State</th>
<th>Contribution %/</th>
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<tbody>
<tr>
<td>Belgium</td>
<td>4.88</td>
</tr>
<tr>
<td>Denmark</td>
<td>2.48</td>
</tr>
<tr>
<td>France</td>
<td>23.84</td>
</tr>
<tr>
<td>German Federal Republic</td>
<td>17.70</td>
</tr>
<tr>
<td>Greece</td>
<td>0.97</td>
</tr>
<tr>
<td>Italy</td>
<td>10.20</td>
</tr>
<tr>
<td>Netherlands</td>
<td>3.68</td>
</tr>
<tr>
<td>Norway</td>
<td>1.79</td>
</tr>
<tr>
<td>Sweden</td>
<td>4.98</td>
</tr>
<tr>
<td>Switzerland</td>
<td>3.71</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>23.84</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>1.93</td>
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## COUNCIL OF THE ORGANIZATION

### STRUCTURE AND MEMBERSHIP

**OFFICERS OF THE COUNCIL**
- **President**: Sir Ben Lockspeiser (United Kingdom)
- **Vice-Presidents**: M. J. de Bourbon-Busset (France)
  Professor I. Waller (Sweden)

### DELEGATIONS (Two delegates from each Member State)

<table>
<thead>
<tr>
<th>Belgium</th>
<th>Denmark</th>
<th>France</th>
<th>German Federal Republic</th>
<th>Greece</th>
<th>Italy</th>
<th>Netherlands</th>
<th>Norway</th>
<th>Sweden</th>
<th>Switzerland</th>
<th>United Kingdom of Great Britain and Northern Ireland</th>
<th>Yugoslavia</th>
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<td>M. J. Willems</td>
<td>Professor J. K. Böggild M. O. Obling</td>
<td>M. F. de Rose Professor F. Perrin</td>
<td>Professor H. Koppermann Dr. A. Hocker</td>
<td>Professor N. Emirekos M. G. Bensis</td>
<td>Dr. A. Pennetta Professor F. Ippolito</td>
<td>Mr. J. H. Banner Professor J. de Boer</td>
<td>Professor E. Hyllebaas Professor H. Wergeland</td>
<td>Professor I. Waller Dr. G. Funke</td>
<td>Professor P. Scherrer M. A. Picot</td>
<td>Sir Ben Lockspeiser Mr. D. W. Fry</td>
<td>M. S. Nakicenović I. Supek</td>
</tr>
</tbody>
</table>

### SCIENTIFIC POLICY COMMITTEE

- **Chairman**: Professor W. Heisenberg
- **Vice-Chairman**: Professor L. Leprince-Ringuet
- **Members**: Professor H. Algén, Professor G. Bernardini, Professor P. M. S. Blackett, Professor N. Bohr, Sir John Cockcroft, Professor P. Scherrer

### COMMITTEE OF THE COUNCIL

- **Chairman**: the President of the Council
- **Members**: the Vice-Presidents of the Council, the Chairman of the Finance Committee, the Chairman of the Scientific Policy Committee
- **Two members of the Council**: Sir Ben Lockspeiser

### FINANCE COMMITTEE

- **Chairman**: M. J. Willems (Belgium)
- **Members**: one delegate from each Member State

Sir Ben Lockspeiser
- M. J. de Bourbon-Busset (France)
- Professor I. Waller (Sweden)
- M. J. Willems (Belgium)
- Professor W. Heisenberg (German Federal Republic)
- Dr. A. Pennetta (Italy)
- Professor P. Scherrer (Switzerland)
INTERNAL ORGANIZATION AS OF DECEMBER 31, 1956

Director-General
Professor C. J. Bakker

Theory in Geneva
Cosmic rays

Proton Synchrotron
J. B. Adams

Construction of the Proton Synchrotron
Research on new principles for accelerating particles

Synchro-cyclotron
W. Gentner

Construction of the Synchro-cyclotron
Checking and testing equipment and putting it into operation
Planning of experimental work
Chemistry

Scientific and Technical Services
L. Kowarski

Instrumentation
Electronics
Track chambers
Electronic computer
Cryogenics
Health physics
Main workshop
Information

Site and Buildings
P. Preiswerk

Building and maintenance
Common services

Theoretical Study Division
C. Møller

Copenhagen
Liverpool
Uppsala

Administration
Jean Richemond

Finance
Personnel
Purchasing

* Present at one session of the Council:
  M. J. de Bourbon-Buset (France); M. A. Pompouras, M. J. Papayannis (Greece); Professor G. Colonnetti (Italy); Professor R. C. Extermann (Switzerland); M. M. Bucar (Yugoslovia).

** Vice-Presidents since December 1956:
  M. F. de Rose (France); Professor J. Holtsmark (Norway).

*** For 1957:
  Dr. A. Pennetta (Italy); Professor I. Supek (Yugoslavia).
1. General

The purpose of the Symposium organized by CERN in Geneva in June 1956 was to gather physicists from all parts of the world concerned with high energy problems and thus to enable CERN to start playing the part for which it is intended as an international centre for advanced nuclear research.

In response to CERN's invitation, 319 scientists from 22 countries, over 50 American scientists and an equal number of Russian scientists gathered for two weeks and, in an atmosphere of freedom and complete frankness, compared the results of their work on these problems.

The Symposium was held at the Institut de Physique of the University of Geneva where the Proton Synchrotron Division is still located. Most of the papers, including those submitted by the Russian scientists, had been pre-printed either in English or in French which involved the printing of 2,007 pages of typescript and 1,052 photographs or diagrams. Preprints were issued before the conference so that a fair amount of the time available during the meetings was devoted to discussing the papers.

In order that the results of these exchanges of views should be available to the greatest number of scientific workers as fully and rapidly as possible, CERN arranged for the discussions to be recorded and subsequently included with the main papers in the two volumes of the Proceedings of the Symposium (respectively 567 pages and 443 pages). The Proceedings were published and put on sale within 13 weeks after the Symposium.

The conference, which was a landmark in the history of CERN, proved so useful that it was decided to hold another similar Symposium in 1958. At its sixth session, the Council supported this decision, and it is hoped that on the next occasion the conference will be held in the Main Lecture Hall now being built on the Meyrin site, which has been designed to accommodate large gatherings of this kind.

The programme of the Symposium was divided into two distinct parts, one week being devoted to each of them.

During the first week the papers and discussions concerned the principles and the methods used in the construction of high energy accelerators, which are mostly the concern of the P.S. Division.

During the second week the papers and discussions dealt with particle detecting equipment and high energy nuclear experimental research, with special reference to research on pion physics, both subjects of special interest to the Synchro-cyclotron Division.

Appendix D gives a list of the papers presented by the two Divisions which have been published in the Proceedings of the Symposium.

2. First week

The topics discussed during the first week can be sub-divided into three groups:

a) Papers on new principles of accelerating nuclear particles;

b) Description of the accelerators now being planned or constructed;

c) Theoretical or technological problems relating to accelerators.

a) New principles

The most revolutionary new principle for the acceleration of particles was put forward by scientists from the Soviet Union. Their proposal consists of accelerating the particles (protons) in a toroidal plasma of high current density, in which the electrons have relativistic velocities. Their theoretical work predicts that due to the pinch effect, magnetic fields of the order of \(10^6\) gauss might be realizable. If such high fields were attained, protons in the plasma of an energy of 100 GeV could be held in an orbit of approximately three metres radius. Experiments are being carried out with high intensity toroidal electron beams, which later on will be neutralized by positive ions. If this new principle can be achieved in practice it will certainly offer attractive additions to the present types of accelerating machines. Since such machines involve the study of plasma physics there is some interlocking of interests between physicists working on these machines and those engaged in controlled thermonuclear research.
For machines designed to accelerate particles at high intensities, particularly in the 5 to 20 GeV energy range, papers on the principles of fixed field alternating gradient focusing were presented, mostly by American and English scientists.

The third principle considered was that of intersecting beam accelerators, which offer a way of producing in the laboratory reactions of very high energy, considerably higher than available even from the machines at present under construction. Up to now intersecting beam machines have not been practicable due to the low intensities available in the two beams, if these beams are generated in the present types of machines. The number of collisions has at least to be comparable with the background reactions due to either beam interacting with the gas atoms in the vacuum system. The new fixed field alternating gradient machines were proposed as being capable of realising sufficient intensity to make intersecting beam methods possible. Also systems of storing the high energy particles were discussed by which the beam intensity could be built up until sufficient particles would be accumulated and then allowed to react with an opposing beam of particles similarly stored.

An intersecting beam machine using two proton beams each of 25 GeV would give reactions equivalent to those given by a 1.25 TeV machine (one and a quarter million million electron volts), whose beam fell on a stationary target.

The new principles mentioned above open up new fields of development of particle accelerators, and the Symposium showed how keenly scientists are working on them in the biggest research centres in the world.

b) Description of accelerators in the course of planning or construction

Several papers were presented on the new accelerating machines at present under construction or being projected.

Though the Soviet Union is contemplating the building of an alternating gradient proton synchrotron of 50/60 GeV, the two highest energy machines under construction are the CERN and the Brookhaven alternating gradient proton synchrotrons of 25-30 GeV, which are both planned for completion in 1960.

c) Theoretical, technical and other problems of accelerating machines

The detailed problems of accelerators discussed during the Symposium can be summarized as follows:

- Problems concerning the transition energy occurring in alternating gradient focusing machines;
- Linear accelerators and injection of particles into high energy machines;
- Non-linear theory of betatron oscillations;
- Problems concerning the magnets of high energy accelerators;
- Problems of accelerating particles in high energy machines including methods of automatic beam control of the radio frequency and phase;
- Electron synchrotron machine problems including radiation from high energy circular electron accelerators;
- The use and efficient exploitation of accelerating machines.

The majority of the papers of the Symposium were concerned with these detailed questions and the wide scope of the papers submitted enabled physicists and engineers working in this field to appreciate the rapid advance in machine technology over the past few years.

3. Second week

The second week of the Symposium was devoted first of all to the measurement instruments and apparatus used with high energy accelerators and subsequently to the most recent results in certain fields of physics, that are now being explored with the help of these accelerators, particularly antiproton and pion physics.

Several papers dealt with bubble chambers and showed how rapid their development had been since the first chamber was constructed only four years ago. Thirty-cm. diameter bubble chambers are already in operation and a chamber 72 inches (183 cm.) in length is now being constructed at Berkeley.

Of all the liquids used in bubble chambers, liquid hydrogen is the most useful for work with high energy accelerators. But bubble chambers filled with helium or xenon, which were also described, present their own specific advantages.

Although the density of matter is greater in bubble chambers, which is a considerable advantage, and although these chambers can be re-cycled faster, the role of the conventional cloud chambers is by no means over. Several papers were read on the uses of cloud chambers with accelerators and on the modifications required to bring their performance nearer to that of bubble chambers.

In view of the large number of photographs of events now obtained with bubble chambers,
cloud chambers and nuclear emulsions in experiments carried out with the accelerators, it will be necessary in future to develop faster and more efficient means of analysing results than the ones so far used. Discussions took place concerning the various aspects of that problem. In particular, a description was given of an electronic scanner intended to count the number of parallel tracks produced by a homogeneous beam of particles in a nuclear emulsion.

Several papers dealt with the Čerenkov counter which has been very widely used in nuclear research during the last few years. There are two main types of Čerenkov counters, namely the selective Čerenkov counter, which is sensitive only to particles within a limited velocity region, and the total absorption Čerenkov counter normally using lead glass whose pulses are proportional to the energy of the incident gamma ray. Various Čerenkov counters of either type were described.

In order to take all possible advantage of the opportunities offered by these new counters, fast electronic techniques have also had to be developed. Several scientists dealt with that subject.

One meeting was devoted to the recent experiments carried out at Berkeley in co-operation with other laboratories, which led to the discovery of the antiproton and the study of its properties. A discussion took place on the technique used, and the theoretical consequences of the experimental results were explained.

Several reports described experiments made with the synchro-cyclotrons in the 100 to 600 MeV energy range.

During the meeting when nucleon-nucleon scattering was discussed, attention was mainly focused on the reports made by Russian physicists working on the Moscow synchro-cyclotron. Their experiments have extended our knowledge of elastic and inelastic nucleon scattering and of the polarization of nucleon beams at energies of several hundred MeV.

Several experiments on pion-nucleon scattering were described and research workers from various laboratories produced comparable results. Our experimental knowledge in that field has thus become considerably more accurate, and it is to be hoped that a satisfactory theory on the important problem of pion-nucleon interaction may be evolved on that basis.

Some papers dealt with experiments on the photo production of pions by gamma rays emitted as a rule by an electron synchrotron.

Discussions took place concerning the extremely interesting experiments carried out with the Stanford linear accelerator on the scattering of electrons against nuclei; these experiments make it possible to work out in detail the charge distribution in a nucleus and in particular in a proton.

Pion production in collisions between nucleons has been studied in the Liverpool, Birmingham and Moscow laboratories, and with the help of the Brookhaven cosmotron for higher energies.

Finally, one meeting was devoted to the study of mesic atoms (both \( \pi \) and \( \mu \)). The increasingly accurate experiments carried out in that field provide considerable additional information on the interaction between mesons and nucleons and on the electric field near nuclei.
RESEARCH ACTIVITIES CARRIED OUT UNDER AUTHORITY OF THE DIRECTOR-GENERAL

1. Theoretical work

The Theoretical Group in Geneva, which until 1st September consisted of two physicists, was progressively expanded from then onwards. At the end of the year it comprised 7 physicists.

The work of the Group concerned the following subjects:

a) Theoretical aspects of hyperon and heavy meson physics: classification of these particles, discovery of certain invariable characteristics of their strong interactions in relation to special transformations inside the isotopic spin, search for a suitable formalistic description of disintegrations.

b) Study of the binding energies of hyper-fragments.

c) Research on the Bohr and Mottelson model of the atomic nucleus. General form of the Hamiltonian of interaction, passage from individual to collective co-ordinates, validity of the model.

d) Theory of the production of mesons by meson-nucleon collisions at energies slightly higher than the production threshold. Computation of the total cross section, estimation of the angular distribution of the mesons produced.

Close contact was maintained between the Theoretical Group and the experimental staff of CERN as a whole. Joint discussions took place on the interpretation of experimental results and on plans for new experiments, in so far as they might contribute to an advance in theory. These discussions took place during joint colloquia and frequent exchanges of views between those concerned.

Some of the research subjects mentioned above were chosen because they might prove useful in interpreting the results of experiments which it will be possible to carry out with the first accelerator to come into operation at CERN, namely the synchro-cyclotron.

2. Cosmic rays

1) Geneva Group

The two multiplate cloud chambers constructed by the Scientific and Technical Services Division operated for the first time at the end of June. Adjustments to these chambers were completed in December, but the counter system for measuring the lifetime of K-mesons is still being adjusted.

The scientific programme of the Group is being considered carefully. The original plan of the experiment was devised more than two years ago and was to measure the lifetimes of K-mesons brought to rest in the plates of the lower cloud chamber. This problem is still of interest and the experiment will be continued for the present. However, a great deal has already been done by the workers with accelerators and it is well appreciated that the Geneva experiment may not lead to novel results. For this reason, other scientific problems are being considered as possible subjects for future research and the Group proposes to invite interested scientists from a number of European laboratories to a meeting in Geneva where work with multiplate cloud chambers will be discussed.

2) The Jungfraujoch Experiment

From July to December 1956, no work was possible at the Jungfraujoch as a new laboratory to house the CERN apparatus was under construction. The laboratory was completed at the end of December; the apparatus has been installed and will start to operate normally again in March 1957.

This enforced hiatus has been used to make more detailed studies of photographs taken previously. Some of the results are given below.

a) The Neutral Tau-meson

In April a single photograph of exceptional interest was obtained at the Jungfraujoch. It showed a four-pronged event in the gas of the cloud chamber (see page 15). Two of the prongs are due to a pair of positive and negative electrons and the other two resemble a normal neutral V-event.
This event is interpreted as the decay of a neutral $\pi^0$-meson into two charged $\pi^+$-mesons and a neutral $\pi^0$-meson. The neutral $\pi^0$-meson subsequently decays into an electron pair and a $\gamma$-ray.

The event is of interest since it is the first of its type to be observed and probably provides the best experimental evidence for the existence of the neutral $\pi^0$-meson. A detailed description of the photograph has been published.

b) Charged V-particles

A paper on charged V-particles was published at the beginning of the year. This paper reported observations of K-mesons in the cosmic radiation and compared the Jungfraujoch results with those from other experiments made both with cosmic rays and with machines. From this comparison it appeared that the relative frequencies of the different modes of decay of K-mesons could be the same in all the experiments considered. Moreover, the same proportions could hold for both positive and negative K-meson decays. This result is important since the decays of negative K-mesons have not yet been studied in machine experiments and cosmic-ray cloud chambers in a magnetic field are the only source of information about them.

To account for the small value of the positive excess among the observed charged K-mesons (3.5 : 1) it was suggested that, in cosmic-ray experiments, processes leading to the production of pairs of K-mesons were of comparable importance to the well-known processes in which a K-meson is produced with a hyperon.

c) Neutral V-particles

A considerable effort has been put into a careful comparison between the neutral V-particles produced in nuclear interactions in carbon and copper. This work is very nearly completed and the results are being prepared for publication. It is clear that there are very big differences between the energy spectra of the $\Lambda^0$-particles and the $K^0$-mesons. There is also an excess of $K^0$-mesons over $\Lambda^0$-particles among the V-particles produced in carbon. This excess could again be due to the production of pairs of K-mesons.

Two extremely simple nuclear interactions have been observed, each of which gives rise to two K-mesons. A short paper is being published on these events and it is suggested that they are examples of the production of true pairs of K-mesons (particle and anti-particle).

d) Future Work

After discussion it has been decided to change the direction of the work of the Group towards the study of high energy ($>25$ GeV) nuclear interactions. Some time will be spent in finding the best conditions for observing such interactions. When a reasonably large sample of photographs has been obtained and analysed it will be decided whether or not to propose a more elaborate experiment than is possible with the present apparatus.
The Decay of a Neutral Tau-Meson

The plate is an enlargement of part of a photograph taken at the Jungfrau-joch. The event shown is interpreted as the decay in flight of a neutral tau-meson travelling downwards. On this interpretation the tracks C and D are due to charged π-mesons. The tracks A and B are those of an electron-positron pair resulting from the decay of a neutral π-meson.
PROTON SYNCHROTRON

1. General

During 1956 the Proton Synchrotron Division has concentrated on getting the construction of the machine under way. The basic parameters for the machine have not been changed.

Final specifications were drawn up for the component parts of the machine and tenders were invited from European industry. Tenders were received in respect of the magnet blocks, the radio frequency accelerating units and the ferrite rings, and the magnet power generating equipment. After the adjudication of the contracts had been approved by the Finance Committee, contracts were negotiated and manufacture began under CERN's supervision. The same procedure is now being followed for the exciting coils, the cooling system, the vacuum plants, the magnet supporting girder structure, the correcting lenses and the pole face windings, and all the contracts will probably be placed during the first quarter of 1957.

The machine buildings (ring, experimental halls, linear accelerator), the laboratories and offices are nearing completion.

During the year the Proton Synchrotron Division also took part in the general organization of the CERN Symposium and of the first week in particular, which was devoted to the study of accelerators. The Division presented eleven papers at the Symposium and its members took an active part in the discussions.

Encouraged by the work done in the Soviet Union and the United States on new methods for accelerating particles, the Proton Synchrotron Division proposed to start a research group to study such new methods. On the recommendation of the Director-General, the Scientific Policy Committee endorsed the proposal to set up the group, which was finally approved by the Council at its sixth session. It is hoped that by 1958 an experimental research programme will be started on the basis of the results emerging from the initial studies during 1957. Preliminary contacts have already been made with a view to recruiting the necessary qualified staff.

The staff of the Division increased from 118 on 31st December 1955 to 143 on 31st December 1956.

2. Theory and analogue models

The analytical theory of non-linear betatron oscillations, developed earlier, has been applied to quantitative calculations of the possible effects of sub-resonances, i.e. of beating factors and build-up rates of amplitudes in practical cases. The tolerable fluctuations of non-linearities in the guiding field turn out to be rather small (less than $10^{-3}$ of the $n$-value at 4 cm. distance from the centre of the vacuum chamber). Stabilisation could be effected by octupole lenses producing a non-linearity exceeding the non-linear fluctuations by a factor of about twenty. Such a fixed stabilizing non-linearity may have unfavourable effects on the amplitude of the closed orbit, as a function of the momentum of the particle. This question has also been studied with the conclusion that a stabilizing non-linearity sufficient to suppress sub-resonances excited by fluctuations in $n$ would just be feasible.

The electromechanical analogue model for the study of betatron oscillations has been used to check the analytical theory, which proved fairly reliable not only qualitatively but also quantitatively.

The analogue model was briefly described in the Annual Report for 1955. A more detailed description of the model and accounts of the experimental results obtained with it can be found in the records of the Symposium. (See page 21, C)

There is still doubt as to the value of stabilizing non-linearity under "dynamic" conditions, when the $Q$ values are slowly moving inside the working diamond. A number of theoretical hypotheses concerning that problem are now being worked out and their validity will be tested by experiments with the analogue model.

Additional theoretical studies have also been made on the effect of the faults which unavoidably result from the construction and the alignment of the magnet units (errors due to transition between blocks, errors due to the use of straight blocks instead of curved blocks for the magnet units, etc.). The results of these studies helped in the final drafting of specifications for the magnet.
3. Magnet

Final specifications for the magnet blocks were drafted in May 1956. The final contract was placed only at the end of October. A large number of manufacturers and steel producers were invited to tender and it proved particularly difficult to select the final blockmaker and steelmaker, partly on account of the very stringent tolerances required.

The fluctuations of the magnetic properties of normal production steel are several times larger than can be tolerated. It had originally been intended to stack the blocks in accordance with some pre-arranged scheme after magnetic measurement. It turned out however that this plan was not as satisfactory as expected at first, because the number of blocks \( N = 1,000 \) is very small if many different variations have to be minimized by stacking. Care must be taken not only to avoid any repetition of systematic properties, such as the variations between laminations at the top and the bottom of the annealing furnace, but also to reduce to a minimum the effects of uneven ageing.

The problem must therefore be approached in a different manner. The present system is based on the fact that the total number of laminations in the magnet is 250,000 so that statistical uniformity can be obtained by suitably mixing the laminations. A scheme has been worked out for collecting and storing the steel plates and for feeding them to the manufacturing process.

The contract stipulates that block delivery will start in September 1957 and the 1,020th block will be at Meyrin before 15th May 1958; penalty clauses against late delivery have been included in the contract.

The first complete trial magnet unit made of full scale blocks has been delivered by the manufacturer, assembled in the workshop and is now being tested. Special mechanical devices have been constructed and put into operation in order to check the mechanical stability of the unit.

Sufficient power to excite the whole of the ten block unit will not be available until about next March, when the necessary equipment will be installed at Meyrin. However, the studies in progress will be sufficient to obtain the final data for the magnet blocks and will allow production to proceed as planned.

Tenders for the main magnet coils are under investigation. Specifications are now being drafted for other parts of the magnet system.

Trial sections of pole face windings have been made and measured and the proposed method of construction using copper conductors embedded in glass fibre and synthetic resin seems satisfactory.

Designs have been prepared for the correcting lenses and offers have been invited for a full scale model experimental lens.

4. Radio frequency

a) Accelerating units

Development work for the construction of the accelerating units involved measurements on a full scale model of one half cavity, model experiments with coupling and excitation systems for the final push-pull cavity resonators, and the design, construction and testing of wide-band high power amplifiers, AVC systems and phasemeters for the automatic tuning system. In addition, an extended programme of measurements on the tuning magnet and the cavity was undertaken to work out the design of the electronic part of the automatic tuning system. An automatic tuning system was designed on the basis of those measurements and constructed at the same time as the cavity model with which it was tested. The tests were successful at a tuning speed which was four times as high as necessary. An automatic tuning system for the full scale model was then designed and constructed and is at present ready for testing. (See page 21,B)

Tests carried out on the accelerating units, namely the cavities, their power amplifiers and the automatic tuning system, showed that the system designed by the Division is technically sound, and it was therefore possible to place the contract for those components in November.

At the same time as the above tests were being carried out, apparatus was designed and built to measure the electrical properties of the large ferrite rings under various conditions. Measurements were then taken on the sample rings sent in by the manufacturers tendering for the ferrite.

As a result of those measurements the contract for the supply of the rings was placed in October with the manufacturer whose rings had proved most satisfactory from a technical point of view.

b) Frequency control

A refined model of the Hall-computer has been constructed, which works successfully with closed servo loops. The model has been used mainly to study questions of static and dynamic behaviour
of the system, as well as accuracy and reproducibility.

A first version of a beat frequency spin generator using electron spin resonance has been built and tested. The short-time frequency stability agreed with expectations and is sufficient for our purpose. Long-time instabilities mainly due to inadequate mechanical stability were observed, however. A new type of Bloch-head was developed, which showed itself to be extremely stable and a second improved model for a beat frequency spin generator, using the new Bloch-head as well as a new design of tuning magnets, is under construction.

The problem of beam control was taken up temporarily in connection with a lecture presented by CERN at the June Symposium. It was shown that beam control presents several fundamental advantages over programmed frequency control. Detailed work on these problems is scheduled for 1957. In connection with this work and other problems associated with radio frequency acceleration, an electronic computer for phase oscillations in accelerators has been designed and, after successful experiments with a simple model, this computer is being constructed in its final form.

c) Timing

The special Electronics Section of the Radio Frequency Group has designed and constructed timing apparatus for the linear accelerator. Experiments to derive precise timing signals from the magnetic guiding field using either electron spin resonance or peaking strips are being carried out.

5. Injection linear accelerator

a) Accelerating structure

The first of the three cavities (10 metres long) was delivered at Meyrin at the end of the year. The other two cavities are being constructed.

b) Vacuum chamber

The vacuum envelope for the first cavity arrived at Meyrin in September. The pumps and ancillary components are now being made by the manufacturers.

c) R.F. supplies

Final tests were made in September on the valve and circuits. The prototype satisfactorily produced the required 2 Megawatts peak power, and the development contract with the manufacturers was therefore terminated. At the same time a new contract was placed with them for the supply of two circuits and three valves to be delivered in April 1957.

This is only part of our total requirements (4 valves and circuits, plus spares); it is intended to order the remainder when the tests now being carried out on the prototype valve and circuit in Geneva show whether modifications are desirable. The amplifiers have been tested at 400 kW output and are in use as driver stages for the prototype valve tests.

Work has been proceeding on a prototype 5 MW modulator for the valves, and this is complete with the exception of its pulse transformer.

d) Ion source and H.T. set

A pulsed R.F. ion source was completed in June and has been undergoing tests since, producing ion beams of 10 to 40 mA. A prototype 500 kV accelerating column has also been constructed and is being tested with the 500 kV D.C. generator.

e) Beam focusing between the source and the linear accelerator

A study was made of the problem involved in focusing the proton beams between the source and the linear accelerator. Since the focusing properties of the accelerating column are insufficient to offset the defocusing effect due to space charge, it will be necessary to make use of focusing lenses. Before the column, namely at 500 kV with respect to ground, it is proposed to use electrostatic lenses whose power consumption is negligible. Between the column and the linear accelerator it will be possible to put into operation a pulsed magnetic lens with a short focal distance. The problem then becomes one of carefully selecting the position of the lenses and their converging power. Though it is possible to obtain a very high degree of convergence with the magnetic lens, this is not so with the electrostatic lens. As the diameter of the beam is fairly large when the beam enters the column, owing to the high space charge at low voltage, the diaphragm of the electrostatic lens has to be large and the efficiency of the lens is thereby reduced. A detailed study of lenses with three electrodes has been undertaken with a view to determining the maximum degree of convergence obtainable.

f) Pulsed focusing magnets

Pulsed quadrupole focusing lenses for use in the drift tubes of the first tank have been tested and
found satisfactory. Prototypes of special drift-tubes to contain them are being made, and the development of suitable stabilized pulsers is proceeding.

Prototypes of many other items have been made or delivered during the course of the year, and are being tested: for example, the buncher, matching lenses, R.F. test gear, etc.

6. Engineering

a) Vacuum

It has finally been decided that fifty pumps would be necessary to obtain an efficient vacuum system. The type of pump to be used has not yet been decided, but the idea of using mercury vapour pumps for the circular vacuum chamber has been entirely rejected. The choice now lies between oil diffusion pumps and the new getter-ionisation pumps. Work on oil diffusion pumps is continuing but a great deal of consideration is being given to the getter-ionisation pumps which look promising for a system such as the vacuum chamber of the proton synchrotron. Owing to delays in delivery, no experiments have yet been made with the getter-ionisation pump, but an American model is due to be delivered in Geneva shortly and it will soon be possible to carry out tests. Various European manufacturers have been requested to take an interest in these pumps and they are now working actively on their development. Although these pumps have attractive advantages over oil diffusion pumps, both their manufacture and operation is likely to entail additional hazards, and it may therefore be expected that the standard oil diffusion pump design, which has already been put to the test, will finally be selected.

The vacuum chamber, which presents some unpleasant mechanical problems, as it has to be made in very thin-wall metal, is being studied. Two manufacturers are attempting to produce satisfactory prototypes using different methods and a third method is being tried by our own workshops.

b) Cooling

The magnet cooling systems will have aluminium pipes, for use in conjunction with the aluminium coils of the magnet units. The total power dissipation is 1,500 kW.

The general cooling system can be made of copper; the dissipation expected for that system is about 1,000 kW.

Specifications have been prepared for the two cooling systems and their pipe circuits and tenders for them will be submitted at the beginning of 1957.

c) Electrical

The motor-generator set for the magnet power supply was ordered in June; manufacturing was started immediately and delivery is expected at the end of 1957.

Specifications for the motor-generator set are as follows:

(1) The alternator will be of the turbo type and the MG set will run at a speed around 3,000 r.p.m. As compared with original estimates, a considerable reduction has been achieved in the dimensions and weights of the machines and the flywheel (the flywheel weighs 6 t. instead of 35 t.).

(2) The driving motor will be regulated by a Scherbius set which has marked advantages over "classical" regulating methods (resistors in the rotary circuit):
   - Load variations are smoothed out more easily during the pulsing process and this is done practically without losses.
   - The power factor in the supply line can be improved.
   - The set is easily adaptable to variable pulse programmes.

(3) There will be an intermediate transformer between the alternator and the power converter.

(4) Excitrons will be used instead of ignitrons.

(5) A wave filter will be used on the DC side. In order to avoid transients by charging and discharging the filter condensors, the filter is disconnected before the changeover from "rectify" to "invert" and connected again immediately after the start of a magnet pulse.

The planning of the P.S. main sub-station is now nearly completed. Orders were placed for 800 kVA transformers, the 18 kV switch gear and the 380/220 V. distribution gear. A contract is being negotiated for the 3 kV switch gear.

The general layout of the Power House, in which the greater part of the electrical equipment, the cooling devices and the computer for the R.F. system will be installed, has been decided upon and detailed plans are being drawn up by the architect.

d) Survey

1. Moraine study

Accurate geodetic measurements showed that elastic deformations of the moraine (top layer)
A. Scale model of a complete magnet unit.

B. Scale model of an accelerating cavity.

C. Analogical scale model.
A. Proton Synchrotron experimental hall, south side.

B. Western part of the great experimental hall.
SECTION OF LINAC

Section A+A

TANK II TANK I

A

H-T PLATFORM

H-T GENERATOR

ION SOURCE

ACC. COLUMN 500 K.V.

BUNCHER

FARADAY CAGE

S-SECTION OF LINAC

Section A-A

DRIFT TUBES

VALVE

R-F FEEDS

BAFFLES

MERCURY DIFFUSION PUMP
TUNNEL

SEXTUPOLE AND OCTUPOLE LENSES

EQUILIBRIUM ORBIT

QUADRUPOLE LENS

R-F FEEDS

DEBUNCHER

COOLING WATER PIPES

COIL

MAGNET

FERRITE

CROSS

TUNER DRIVES

FLOOR

TANK III

VACUUM PUMPS

R-F FEEDS
were of about 1 mm. amplitude per 100 m. length of ground, occurring chiefly after heavy rains but remaining also in dry periods, though smaller in amplitude.

Electrical measurements of the ground resistivity with buried electrodes at different depths show that the moraine undergoes physical changes after heavy rains, which can only be due to water soaking. This soaking with water probably causes a swelling of the superficial layers which causes part of the observed changes of linear dimensions.

2. Molasse study

The maximum amplitude of the rock movements amounts to about \( \frac{1}{5} \) of the maximum moraine movement, i.e. 0.3 mm. per 100 m. length.

The rains have no effect at all on the rock and the swelling occurs only in the moraine.

The deformations are not isotropic, being maximum in a S.W./N.E. direction (parallel to the Choully hill ridge), and almost unnoticeable in the perpendicular directions.

A systematic level survey of the whole length of the hill has been effected regularly through the summer in order to detect any "breathing" of the molasse due to subterranean waters which could have explained the observed superficial variations. It has been found that the hill retained exactly its shape (accuracy of the levelling, 1 mm. per km.), but that it was submitted as a whole to a periodic tilting (maximum amplitude 2.5 mm. per km. or \( \frac{1}{3} \) sexagesimal second; period a fortnight).

The systematic study of Neuchâtel and Besançon seismograms during the last twenty years has shown the abundance of small microseisms which could induce resonances in the magnet girder. To this effect it has been thought advisable to establish seismograph installations near the site when the machine is working to be able to detect microseisms, and preliminary contacts have been established with the Meteorologische Zentralanstalt in Zürich to have a seismographic station set up in Geneva.

c) Building work

By 31st December 1956 three-quarters of the ring building had been completed. Nearly half the foundation pillars had been built up and the first section of ring girder had been cast. If there are no further delays in the work the ring girder should be completed in the summer of 1957 and nearly six months settling time can be allowed before the magnet units are placed on the girder.

The south experimental hall was nearing completion. The roof over the two end-sections was finished and the heating tubes in the east end had been installed. Two 20 ton cranes and a 30 ton one had been delivered to the site and were being fitted. The roof of the central section of the south hall was being erected and when this work is finished temporary partitions will be put up so that the entire south hall can be used for experimental work by the Division. Some experimental work in this hall will start at the beginning of January 1957, as foreseen in the programme.

The shielding bridge between the north and south experimental halls had been cast and the prestressing cables tightened. The whole structure has been completed by the programmed date.

The linear accelerator building was about half finished from the structural point of view and the work was going according to plan.

The construction of the laboratory wings had been somewhat delayed and they will not now be ready until March 1957. The Division will only move into its final quarters in April.

The plans for the generator building had nearly been completed and construction work was due to begin on it early in 1957.
SYNCHRO-CYCLOTRON

1. General
Since the synchro-cyclotron is due to be ready for operation during the course of 1957, all the preliminary work connected with research has had to be undertaken as early as 1956.

2. Research programme
Consideration was first given to preparing the initial programme of experiments to be carried out on the machine.

For that purpose, the problems were very thoroughly discussed within the Division with the help of Professor Bernardini. Since the CERN Symposium had revealed that a fairly large number of valuable experiments had already been carried out in the field for which the synchro-cyclotron has been built, it was decided to concentrate mostly on experiments requiring a high degree of accuracy.

The programme thus evolved was approved by the Scientific Policy Committee and it will be kept under constant review.

It mostly consists of experiments with proton, neutron, polarized proton, pion and muon beams.

3. Recruiting
It is necessary to recruit a number of experienced physicists and fellows in order to carry out the experiments that have been planned. The number of scientists so required and the qualifications they should possess were determined and agreed to by the Scientific Policy Committee. Recruiting began in 1956 and will continue in 1957.

At the end of 1956, the Division numbered 10 physicists and 3 fellows, whereas at the end of 1957 it will include 20 physicists and 27 fellows.

4. Formation of teams
A number of experiments have been selected to be carried out by integrated CERN teams and, as they are recruited, scientists are joining the teams with which they are intended to work.

It should be mentioned that the setting up of a Theoretical Group in Geneva to take over from the Theoretical Study Division in Copenhagen will enable the teams to have the assistance of a number of theoretical scientists when discussing their problems.

5. National teams
As CERN is an organization in which several European countries jointly participate, research teams from the Member States should have the possibility of using the machines to carry out their own experiments.

The conditions in which those teams, or scientists operating on their own, could come and work at CERN have been thoroughly studied, not only with regard to the provision of all the necessary facilities and the sharing of expenses, but also from the point of view of fitting their proposed experiments into the general research programme and that of fixing time-tables. The results of this study were submitted to the Scientific Policy Committee.

The recommendations of the Committee are at present being examined with the delegations of Member States and final decisions on the question should be taken by the Council during the first half of 1957.

6. Characteristics of the beams
The proton beam circulating inside the machine is expected to reach an energy of about 600 MeV. With the present arrangements, it is hoped to obtain an average current of 0.2 µA.

A proton beam extraction system, similar to that used in the Liverpool and Chicago accelerators, will give a concentrated beam of high intensity and well defined energy outside the machine to facilitate experiments. Expected values are $10^9$ protons per pulse and 55 pulses per second.

Internally produced neutron beams in seven steps of 70 MeV each, rising from 110 MeV up to 600 MeV, will be available in an array of parallel channels cut through the shielding wall.

Internally produced negative pions will be available in a two-channel array. By proper adjustments of the focusing and deflecting devices it is expected to obtain a continuous spectrum from 100 MeV to 400 MeV.
One section is specialising in the study of the alterations to be made to the machine with a view to improving the quality of the beams and particularly their intensity. (See diagram of the various beams on page 37)

7. Miscellaneous apparatus and technical equipment

Specifications have been drawn up for the bending and focusing magnets required in the initial experiments and the magnets have been ordered.

The maximum power required for their operation will be 180 kVA.

As a general rule, the Scientific and Technical Services Division is responsible for designing and constructing the equipment required for experimental research. This Division is therefore co-operating with the Track Chambers Section (two members) and the Electronic Section (eight members) which have recently been set up and developed within the Synchro-cyclotron Division to meet the Division’s specific requirements.

A first experimental liquid hydrogen bubble chamber (10 cm. in diameter and 10 cm. in depth) is being constructed in the workshop jointly operated by the Synchro-cyclotron and the Scientific and Technical Services Divisions.

A second liquid hydrogen bubble chamber of larger size (30 cm. in diameter and 15 cm. in depth) is also being developed. It is hoped that it will be available for the first experiments.

The two chambers can be brought for momentum measurements of charged particles in a field of 16,000 gauss produced by a magnet consuming 1,000 kW. The power required will be supplied by a 1,000 kW generator fitted with a fly-wheel enabling it to pulse power up to 3,000 kW.

Work based on the Čerenkov effect and the use of fast pulse electronic devices has been carried out to develop the apparatus and techniques required for the detection of various particles.

A small Chemistry Section has been set up to carry out a number of high energy nuclear chemistry experiments.

II CONSTRUCTION OF THE ACCELERATOR AND LABORATORIES

1. General

The year 1956 was mainly devoted to the construction of the accelerator itself and of its subsidiary equipment.

Most of the equipment has been delivered, assembled, tested and accepted.

Thanks to the efforts of the manufacturers and in spite of certain alterations requested by the Division while the equipment was being manufactured, it has on the whole been possible to keep to the fairly stringent time-table laid down in the programme.

It should however be pointed out that the lifting system for the two concrete mobile platforms had to be altered when it was being assembled and that the development of the high frequency system has not yet been completed. All the buildings have been completed and fitted out, with the exception of the laboratories which are due for completion in the spring of 1957.

A number of figures, details and plans relating to various parts of the accelerator and buildings, which were included in the Annual Report for 1955, are not reprinted in the present Report.

2. Buildings

The shielding walls of the machine building are made of heavy baryte concrete.

There are two long slits in the walls separating the machine from the experimental rooms.

These two slits may be closed with a series of baryte concrete blocks weighing 2 tons each. These blocks will be placed in suitable positions to allow the beams to pass through appropriate channels.

In order to save manpower in the handling of the mobile blocks, the blocks will rest on two lifting platforms filled with baryte concrete, which can be raised to close the lower half of the slits in the shielding walls. The lower half of the slits will therefore be closed by the lifting platforms and the upper half by a series of mobile blocks suitably placed to leave the channels required for the beams to be brought out.

The total weight of the larger platform is two thousand tons. The lifting system will finally be hydraulically operated.

In order to keep the counting apparatus away from harmful radiations, the control room, around
which five counting rooms have been built for experimental workers, is connected to the machine building by a corridor fifty metres long.

In the control room the operator in charge will control all the machines used in the operation of the accelerator and will also be in direct contact with the experimental workers.

The counting rooms have been equipped with all the necessary facilities for electronic work and are connected by cables with every part of the building.

An electronic workshop has been built below the counting rooms and is linked to them by an elevator.

Specifications have been drawn up for the internal fittings in the laboratory wing, and the fittings have been ordered. The wing consists of a corridor, where all the cables and pipes are laid, and of floor space on either side of it, which can be subdivided according to requirements by means of movable partitions.

Specifications for these fittings were drawn up in agreement with all Divisions and will become the standard specifications for all the CERN laboratories.

3. Magnet

In spite of certain manufacturing and transport difficulties the steel for the magnet was delivered close on the specified date and the plates had been assembled by July 1956.

The magnet coils were delivered at the beginning of 1956 and were assembled together with the pole discs.

As soon as the generator had been installed tests based on the Hall effect were carried out in order to obtain an accurate and continuous record of the field-strength on both an azimuthal and a radial trajectory. The Hall plates used were of the indium phosphite type.

The measured field shape proved to be as predicted, the irregularities found being very small and of no practical importance. It was observed that the presence of the vertical uprights of the magnet frame produced a second harmonic of almost perfect symmetry, the field being greater near the uprights.

The stability is greater than 1/10,000 and the temperature coefficient is 7/10,000 per degree centigrade. The various field shapes are shown on the diagrams on page 36; these diagrams show clearly the fluctuations caused by the Hall sonde passing over the bolts which tie the pole plates together.

4. Vacuum system

The vacuum chamber, the three mechanical pumps and the two diffusion pumps were assembled and accepted by the date prescribed.

The performance of the vacuum system is well within the tolerances laid down. (See page 35)

5. High frequency

The Dee and its liner have been received and the liner has been mounted.

The high frequency equipment as a whole is expected to be delivered by the date prescribed.

The variable condenser, on the other hand, is still in its development stage. It had been decided to use a tuning-fork system, but by the end of 1956 this system had not come up to expectations. It was therefore decided to proceed at the same time with the construction of a rotating condenser system.

6. Power installation

All the equipment for the motor-generator, the transformers and the switchboard has been installed and is in working order.

Space has been reserved in the equipment room for several small motor-generators to feed the experimental equipment, as well as for a second motor-generator, the high frequency cubicles and the rectifier.

7. Control system

The heavy machines of the synchro-cyclotron are started up in the equipment room, in order to ascertain that they are functioning properly during the starting period.

The machines can be stopped either in the equipment room or by remote control from the panel in the control room.

All the equipment is fully protected against the faulty behaviour of any of its parts by means of suitable interlocks. An alarm system gives warning of any fault of this kind and enables the operator to locate the faulty part.

The operator in charge is not only able to check the reading of the instruments on his control panel, but he can also carry out a whole programme of operations to the order of experimental physicists, and operate, as well as control, a complete intercommunication system throughout the buildings.
8. Cooling system

The two cooling systems of the closed circuit type, namely one for the magnet and the other for the high frequency equipment and auxiliaries, have been assembled in the equipment room and are now in working order.

It should however be pointed out that originally some excessive gas circulation (hydrogen) had been observed; this difficulty has now been dealt with. (See page 33,C)

9. Ion source

The manufacture of the hot cathode arc type ion source has been completed in the workshop which is jointly operated by the Synchro-cyclotron Division and the Scientific and Technical services Division. It has been assembled and the first tests are due to be held in January 1957.

10. Workshops

A small mechanical workshop has been set up mainly for the maintenance of the machine and for miscellaneous repairs. Its total staff of six men will be sufficient to deal with the immediate requirements of the physicists.

All heavy mechanical work such as the construction of experimental equipment (deflecting magnets, track chambers, etc.) will be given to the Organization’s main workshop.

Finally, an electronic workshop has been set up with the help of the Scientific and Technical Services Division for the development of new techniques such as electronic work in the millimicrosecond range.

The Synchro-cyclotron Division which numbered 32 staff members on 31st December 1955, numbers 61 staff members on 31st December 1956.
A. Building and shielding blocks.

B. Control room.

C. Heat exchangers for the cooling systems.
A. Magnet and coils.

B. One of the coils being assembled.

C. Coils, vacuum tank and Dee.
Diffusion pumps.
FIELD SHAPE (RADIAL MEASUREMENTS)

FIELD IRREGULARITIES (AZIMUTHAL MEASUREMENTS)
1. General

In 1956, the activities of the Scientific and Technical Services Division progressed in the various directions which had been indicated in the Annual Report for 1955.

Efforts were mostly concentrated on the development and the initiation of various specialized techniques to contribute to research work with the accelerators. These techniques include cryogenics (mainly in connection with bubble chambers), electronic evaluation of experimental data, and health physics (as a means of protection against radiation).

Close collaboration was maintained with other CERN Divisions which make use of the apparatus produced by the STS Division (joint operation of mechanical and electronics workshops with the S.C. Division and the Division followed with interest the coordination of similar work in various European laboratories.

The staff of the Division increased from 41 to 61.

2. Double cloud chamber for the experiment on K mesons

The assembly of this important piece of equipment on which the Division concentrated most of its efforts from the point of view of mechanical and electronic development (see page 43), was completed at the end of June. After several months of testing and trial runs, the equipment now seems to be working satisfactorily and it has been handed over to the Cosmic Ray Group.

Page 42 gives an idea of the complexity of this installation. The decision to combine such completely different techniques in one single experimental unit was dictated mainly by the desire to develop the use of all these types of instruments at CERN with a view to future research with the accelerators. Owing to their very dimensions, these chambers, which are somewhat unusual and call for proportionally large ancillary installations, provide a basis for the development of even more powerful means of observation in the future.

3. Cryogenics

Since very low temperatures are used in nuclear research, it is necessary to apply advanced techniques concerning certain fluids such as liquid hydrogen and liquid helium.

The Scientific and Technical Services Division is studying these problems and developing the relevant techniques, since it is felt that the use of these little-known fluids, which is still hazardous, will soon be regarded as normal and become widespread throughout the laboratory.

It was decided to put up an initial plant for the production of liquid hydrogen. As a result of enquiries made in the leading European laboratories (Cambridge, Grenoble, Leyden, Oxford, Malvern), it was considered best to build a liquefier with a production capacity of 20 litres/hour, which could later be stepped up to 40 litres/hour. Leyden University was requested to construct the plant under the supervision of Professor Taconis. The building had been roofed by 31st December 1956, while the manufacture of the various components of the plant was well advanced. The production of liquid hydrogen is now expected to start at Meyrin during the summer of 1957.

Investigations and arrangements were made concerning the sources of supply of various basic products (liquid nitrogen, compressed hydrogen gas).

A number of experiments connected with the bubble chambers programme were carried out at Leyden on low temperature heat exchangers. A regulating device proposed by the STS design staff was tried and found satisfactory.

4. Bubble chambers

Since experiments on the synchro-cyclotron will soon be starting, it has been necessary to prepare and to implement a bubble chamber construction programme. Although this technique is quite different from the cloud chamber technique (and depends on cryogenics) it requires a similar type of staff for construction purposes, including physicists, experienced design engineers and laboratory technicians.

A physicist from the Division first of all collected background information on the various developments in that field during a stay in the United States, where he studied cryogenics, optics and the control
of bubble chambers at Columbia University as well as in various other American laboratories interested in this novel technique. Physicists from other Divisions spent some time at other laboratories where the technique is now being developed. Some interesting information on the subject also became available as a result of the June Symposium.

It was then decided that the Scientific and Technical Services Division and the Synchrocyclotron Division should jointly undertake the construction of a first experimental liquid hydrogen bubble chamber of 10 cm. diameter, and subsequently of a larger liquid hydrogen bubble chamber of 30 cm. diameter. An attempt has been made to improve on existing models of chambers, particularly with regard to thermal regulation.

Assembly of this chamber should begin during the spring of 1957. Work is already being organized with a view to constructing larger models, at a later date, taking into account the growing importance of the technique and future requirements for the proton synchrotron.

5. Electronic instrumentation

The various types of electronic instruments required for experimental research have been developed in close co-operation with the Synchrocyclotron Division in whose buildings an electronic workshop is jointly operated.

Preparations have been made for the routine production of large scintillation counters and the necessary machinery has been built.

Close co-operation with a view to standardizing certain characteristics of nucleonic instruments was established with the Atomic Energy Research Establishment, the Commissariat à l'Energie atomique and the Liverpool laboratory, and information is constantly being exchanged with them. The meetings are organized by CERN which provides secretarial facilities. Two engineers of the Scientific and Technical Services Division spent four months with the electronic groups at Harwell and Saclay.

6. Electronic computation

Following in the footsteps of Harwell and Saclay, and with a view to establishing interchangeable methods and means of computation with these two institutes, CERN ordered an electronic computer of a new type (Mercury) in May 1956. Because of unforeseen difficulties experienced by the producers of this machine, however, there will undoubtedly be some considerable delay in its delivery—originally expected for the spring of 1957—and it will not come into operation in the summer, as planned. Preliminary programming studies are jointly being continued by the various institutes concerned.

Two important problems are now being coded before the computer comes into service. Extensive computations are planned on design problems connected with the Proton Synchrotron (and the Division is already being helped by British laboratories for some of the work), and the reduction of photographic data from cloud chamber experiments.

An experienced mathematician-physicist has been recruited to run the future Computer Section. Further staff will eventually be recruited, but the Section will not be very large since electronic computation is bound to become a working tool not only for theoretical physics but also for experimental physics, and a growing number of experimental physicists will be trained in programming techniques, as is now being done in other physical laboratories.

7. Electronic analysis of photographs

Photographs of nuclear phenomena can be obtained at the rate of several dozen per minute, in bubble chambers for instance, but their analysis is becoming evermore an acute problem. Automation of part at least of the scanning and measuring operations should be possible, and new methods to that end are now being studied in several laboratories. The most promising methods are the ones which transcribe the information provided by photographs into codes and programmes for digital computers. The flexibility of the computer is such that it will be possible, for instance, to attempt a large number of different interpretations of the same plate almost simultaneously or to analyse again, from various new angles, data which have been previously examined.

The programme provides for the construction of two prototypes, the first one being comparatively simple, and the second one somewhat more refined. Both of them will increasingly reduce the part played by the observer. A number of new ideas are now being developed with a view to reducing human interpretation more and more, in the more distant future.

With the first prototype the operator will be able to move an indicator by hand to the various points of interest on the plate. Whenever satisfactory coincidence of the two pictures is obtained, the observer will start an automatic measuring device.
to transfer the indicator co-ordinates to the punched tape of the computer. All mechanical, optical and electronic parts of the first prototype have either been ordered or are now being assembled.

Programming studies have been started for the computer, taking our own cosmic ray experiments as a basis to begin with.

On the second apparatus the operator will move an electrically driven indicator along the track while readings of co-ordinates will be registered at a pre-determined rate. Optical or electronic devices will give the observer an enlarged picture of the track, and an apparatus, similar to a television camera, will enable him to examine controls which automatically move the indicator along the track selected by the operator.

Studies of most of the problems connected with the second prototype have only just begun. The electronic measuring and perforating device of the first one, however, is being built in such a manner as to be easily adapted to the more severe requirements of the second prototype.

Views have been exchanged with Saclay on this matter, and various series of examinations of stereoscopic plates, in particular, will be studied by both groups, and results of experience exchanged.

8. Main workshop

The Scientific and Technical Services Division was given the task of implementing the plans for the main workshop which it received in December 1955.

Half the building had been roofed by 31st December 1956; orders had been placed for the machine tools included in the first programme for 1957, and the staff was being built up around the original nucleus from the provisional Cointrin workshop. It is planned that the first move to Meyrin will take place in the spring of 1957.

9. Health physics

The services using the machines are responsible for the protection of their staff against radiation.

The Scientific and Technical Services Division has been given the task of preparing the necessary instructions and providing technical assistance, and it may have to develop current protection methods with a view to adapting them to novel conditions connected with the use of high frequency accelerators.

The head of this new section—an experienced specialist recruited for that purpose—will be taking up his duties early in 1957.

A number of preparations were made in 1956 to study and control the radiation risks near the injection linear accelerator, which is being tested by the Proton Synchrotron Division.

10. Scientific Information

The Scientific Information Service is in charge of the library and of its transfer to the new building under construction at Meyrin.

It is responsible for the publication and reproduction of documents and had to deal with a very considerable extra load of work on account of the June Symposium and the visits of representatives of Member States in September.

The 500 copies of the preprints of the June Symposium reproduced in off-set included over 2,000 pages of text, diagrams and photographs. As a result of exceptional efforts the printing of the proceedings was completed in record time, on 31st October, and the two volumes of 567 and 443 pages respectively are of a quality worthy of the Symposium’s world-wide importance.

It was decided about the middle of the year under review to transfer the CERN Public Relations Section under the direct authority of the Director-General’s office. This Section is responsible for the reception of the many visitors to the site, relations with the Press, exhibitions, the survey of the local and foreign Press and also for publishing and distributing photographic documents for general information purposes. The Scientific and Technical Services Division, which was previously in charge of Public Relations, was responsible for them until the end of the year.
PERSPECTIVE VIEW AND DIAGRAM
OF THE DOUBLE CLOUD CHAMBER
AND OF THE INSTRUMENTATION FOR THE
STUDY OF K MESONS
Double cloud chamber.
A. Čerenkov counter.

B. Electronics.
SITE AND BUILDINGS

1. General

1956 was a year of considerable activity on the Meyrin site during which the most difficult building tasks were either begun or completed (prestressed concrete bridge, proton synchrotron experimental halls, concrete ring girder for the proton synchrotron magnets).

The maximum number of workers engaged on the site on any one day was 608, employed by 49 firms, and the number of man-hours worked per week reached a maximum of 28,000. A total of 899,000 man-hours was worked on the site in 1956; 21,700 m³ of concrete was poured in building the proton synchrotron and 3,300 m³ in building other installations. Eighteen hundred tons of reinforcing steel for concrete were used for the proton synchrotron building and 300 tons were used for the other buildings.

The office of the architect and those of his consulting engineers prepared 1,537 new plans. The number of hours worked in these offices totalled 193,000, including the hours spent on checking the progress of work on the site; 1,200 contracts and orders for construction work and internal fittings were placed.

Owing to the general surfeit of orders on the European market, many of the firms approached either abstained from submitting tenders or quoted extremely late delivery dates. Shortages of local manpower also affected the site and the contractors had to recruit the majority of their workmen outside Switzerland. The progress of the work was considerably hampered by the exceptionally hard winter which was followed by a rainy summer.

In spite of these difficulties, it was possible to go on building at a comparatively fast rate, and, despite certain delays in the implementation of the programme, the rate of progress should be sufficient to ensure that the buildings are completed in time to house the equipment when it is delivered.

Although the total staff of CERN is appreciably larger than the original estimates, it has not yet been considered necessary to make provisions for an additional laboratory wing. Various parts of the buildings, however, had to be either enlarged or altered to meet the new requirements.

The general layout of the site was given in the Annual Report for 1955.

There has been a considerable expansion of both the technical services and the common services in the Site and Buildings Division during the course of 1956.

The additional duties the Division is called upon to perform have entailed a notable increase in its staff, from 17 on 1st January 1956, to 64 on 31st December 1956.

2. Synchro-cyclotron buildings

Finishing work on the main synchro-cyclotron building and on its internal fittings, including the experimental room and the equipment room, was practically completed during the course of the year.

Only the hydraulic lifting systems for the two lifting platforms and the concrete sliding walls are still in the course of assembly.

A proportion of the movable baryte concrete protection blocks has already been manufactured.

The control station and the adjoining counting rooms were completed in August.

The completion of the laboratory wing was delayed owing to certain alteration in the internal layout and to the designing of the standardized technical fittings required, and the wing will only be ready at the beginning of 1957.

During the course of the year, the Synchrocyclotron Division’s staff was temporarily accommodated in barracks near the machine.

3. Proton synchrotron buildings

Though the general difficulties mentioned earlier caused delays in certain sectors, considerable progress was made during 1956 in the construction of the proton synchrotron buildings as a whole.
a) Ring building

On 31st December 1956, the ring building was almost completed and had reached the linear accelerator building, which was also in the course of completion.

Thirty-nine of the 80 pillars supporting the concrete ring girder had been built up and nine further pits had been dug; concrete had been poured on the first of the 20 sections of 30 metres each into which the ring girder is subdivided.

The construction of the ring girder raises more delicate problems than any other building work at CERN.

First of all, in order to prevent the movement of pillars in the radial plane from causing local distortion in the girder, the latter has been connected to the pillars by means of elastic supports and it rests in fact on a series of steel rods, each 1.50 metres long and 18 millimetres in diameter.

The supports are so flexible that one man can make any of the 20 sections of the girder oscillate, though each of them weighs 240 tons. (See page 49)

In order to prevent distortions due to changes in temperature from affecting the various sections of the girder in a different manner, the concrete used must be of exactly the same quality throughout the length of the girder. This requirement has called for special precautions to be taken.

First of all, in order to ensure that the quality of the cement should be perfect and absolutely consistent, a check has been arranged at the cement works and samples of every batch are tested before use.

Four different types of gravel are used to make up the gravel mixture and the moisture content of the sand and gravel is kept constant by preliminary heating and by checking the electric resistance of the materials. The mixing water is very carefully gauged. Before it is poured, every batch of concrete is slump tested (by measuring the time taken by a pyramid of constant dimensions to collapse) and data are obtained concerning penetration and specific gravity. Thanks to these precautions concrete has been produced whose quality is not only excellent (crushing strength: 500 kg. per 1 cm², 28 days after setting), but also does not vary by more than 5%.

Finally, it is absolutely essential that the temperature of the girder should be constant, since a variation of 10⁴ centigrade in the average temperature of the concrete would make the radius vary by more than 1 mm.

The ring building will therefore have to be fully air conditioned, so that changes in temperature do not exceed 1° centigrade, and water at a constant temperature will also circulate in 16 pipes laid inside the girder itself and near its surface. The water is to be kept at a perfectly even temperature by 4 heat exchangers connected to the circuit.

The high specific heat of the concrete itself moreover helps in maintaining an even temperature. (See page 49,C)

Variations in temperature and its distribution throughout the mass of concrete have been studied by means of tests on electrical analogues in which an electrolyte replaces concrete for the measurement of heat conductivity, electrodes take the place of the water pipes, electric potentials are used instead of temperatures and the intensity of the current simulates the amounts of heat.

b) Experimental halls, laboratories and miscellaneous buildings

On 31st December 1956, the large outer experimental hall had been roofed, the three mobile cranes were being assembled and the lighting and heating systems were being installed. The outer shell of the small inner hall had almost been completed.

The outer shell of the linear accelerator building was nearing completion; the laboratory wings and the control station had been roofed.

The only buildings that were still at the planning or excavation stage were the generator room and the building at the centre of the ring as well as the adjoining channels and the junction between the ring and the eastern side of the experimental halls. It is however hoped that these buildings will be completed in time for the magnet units to be checked on delivery, tested and assembled as soon as they arrive on the site.

The most interesting part of the work as a whole has been the construction of the prestressed concrete bridge which will carry the mobile baryte concrete shielding blocks on the level of the experimental halls.

In order to carry out experiments in all parts of the halls, channels must be available to let the beams through at appropriate places and it must therefore be possible to move large or small sections of the shielding walls. The following system of construction has been chosen for this purpose:
the top of each of the two shielding walls consists of a horizontal girder, and these two girders constitute two 36.5 m. long single span twin bridges resting on 4 concrete pillars embedded in the molasse. About 750 baryte concrete blocks, each weighing approximately 2.4 tons, will be suspended from the girders by rails. Underneath these hanging blocks there will be a row of similar blocks resting on the floor of the halls. The layout is arranged to leave a slit 30 cm. wide between the upper and the lower rows of blocks at the level of the beam.

This layout has the advantage of reducing considerably the loads to be moved and of preventing any distortion of the ground when the channels are altered to suit the various experiments.

Owing to the unusually large size of the bridge a number of problems had to be solved in building it. The two horizontal girders weigh 5,100 tons, the suspended blocks weigh 1,800 tons and the movable sections placed on the top of the bridge weigh 1,200 tons. The total weight of the bridge and its components is about 17,000 tons.

With a full load the bending moment of the cantilever girder is 29,700 m.T. To meet this requirement the concrete for the girder had to be prestressed. The prestressing was carried out by the Freyssinet method with 304 stressing cables. Each cable consists of 12 strands of 7 mm. wire made of first class steel and housed inside a flexible sheet steel tube. The cables were inserted in the concrete and after the concrete had set they were stretched at both ends with 50 ton hydraulic presses; subsequently, they were anchored in the concrete. If losses due to friction are excluded, the total strength of the prestressing thus obtained is 13,500 tons. The degree of prestressing and the positioning of the cables have been so worked out as to avoid any tensile stress in the concrete due to deflection, regardless of the load. It should moreover be pointed out that some of the concrete is baryte concrete and that carefully planned methods of construction had to be used in order to obtain the required breaking strength of 300 kg/cm² for the prestressed concrete. (See pages 50, 51)

4. Miscellaneous buildings

On 31st December 1956 the library building had been roofed, whereas laboratories II and III for the Scientific and Technical Services Division and the Synchro-cyclotron Division had only just been started; one half of the roof on the main workshop had been completed and the building for the hydrogen plant, on which work started in July, had also reached the same stage of progress.

The power house was practically completed and much progress had also been made in fitting it out with internal equipment. The steam raising plant for central heating was in operation and the auxiliary Diesel generator of 1,300 kVA was being assembled. The final transformer station with a capacity of 21,000 kVA will be installed in 1957.

The final plans for the main administrative building have been agreed upon and the contract for the civil engineering part of the building has been placed; this building is expected to be completed in the middle of 1958 and it is hoped that it will be ready in time to be used for the next CERN Symposium.

5. Technical services and common services

Now that part of the technical installations have been brought into service the Site and Buildings Division has to keep them in working order, guard them and maintain them. This applies mostly to the electric power network, the water system and the heating and compressed air installations.

Electric power is still distributed by means of two temporary transformers. It is supplied by the "Services industriels" of the city of Geneva.

Water for ordinary use is taken from the Geneva mains.

Cooling water began to be supplied early in July when the pumping station at Peney on the bank of the Rhône, the 5 km. pipe line connecting the station with the CERN site and the 3,000 m³ water tank installed on the site had been completed. The "Service des Eaux" of the city of Geneva put up these installations at its own expense. At the same time, the internal equipment for the synchro-cyclotron cooling system was put into operation.

Two steam generators with a total capacity of 6 million calories per hour were brought into service at the beginning of November and supply the various buildings with superheated water for heating purposes.

Four shifts ensure that the boilers are in constant operation; an auxiliary Diesel generator and air
A. Elastic supports of circular girder.
B. Supporting mesh of circular girder.
C. Circular girder.
A. Prestressed concrete bridge: erection of four corner pillars.

B. Prestressed concrete bridge: angle pillar.
A. Prestressed concrete bridge: cable-laying for one of the two horizontal girders.

B. Prestressed concrete bridge: Northern horizontal girder; rails supporting shielding blocks.
Aerial view of the site (April 1956).
A. Central power station.

B. Entrance from ring into experimental hall.
1. General

During 1956 the Division carried on its work on the same lines as in 1955.

In February, an agreement between Denmark and CERN concerning the legal status of the Theoretical Study Division and of its members was signed in Copenhagen by the Prime Minister of Denmark, Mr. H. C. Hansen, and the Director-General.

There were no changes in the senior staff of the Division.

2. Activities in Copenhagen

On 31st December 1956, thirteen Fellows, including two Ford Fellows, were attached to the Division in Copenhagen.

During the course of 1956 the following physicists who visited Copenhagen gave lectures to members of the Division and took part in their discussions:

G. Alaga  
H. Alfvén  
E. Amaldi  
J. Bardeen  
G. Bernardini  
H. A. Bethe  
W. Brattain  
R. F. Christy  
R. J. Eden  
B. H. Flowers  
G. Uehling  
C. F. Wandel  
A. Winther  
S. Watanabe  
A. Wightman

The following members of the staff of the Institute for Theoretical Physics of Copenhagen University and guests of that Institute gave lectures for the Division:

P. Axel  
B. F. Bayman  
T. Bergström  
T. Bonner  
M. Cantwell  
R. Finkelstein  
S. Frankel  
H. Fulbright  
J. Goldstone  
T. Huus  
O. Koføed-Hansen  
A. Komar  
H. J. Lipkin  
P. Martin  
O. Nathan  
L. Rosenfeld  
D. Saxon  
H. Severiens  
L. Sliv  
T. Tamura

A list of the Division’s publications and preprints is given in Appendix A.

Appendix B also gives a list of the lectures and colloquia held in 1956.

3. Co-operation with other scientific institutes

The Department of Natural Philosophy of Glasgow University placed facilities at the disposal of CERN to enable some Fellows to work with its new big accelerator. So far one young scientist has been able to take advantage of this offer.

On 31st December 1956 four CERN Fellows were working at the Nuclear Physics Research Laboratory of the University of Liverpool.

Two CERN Fellows have been pursuing their research work in radio-chemistry at the Gustaf Werner Institute for Nuclear Chemistry, Uppsala.

Several members of the Division took part in a number of conferences, including the CERN Symposium, either as representatives of the Division or by personal invitation:

April: Rochester Conference on High Energy Nuclear Physics, Rochester, N.Y., U.S.A.

June: Gordon Conference on Nuclear Chemistry, Meridan, New Hampshire, U.S.A.


September: Congresso internazionale sulle costanti fondamentali della fisica, organized in Turin by the “Società Italiana di Fisica”.

International Conference on Theoretical Physics, Seattle, Washington, U.S.A.

Six staff members from Copenhagen and all the staff members detached to Glasgow, Liverpool
and Uppsala attended the CERN Symposium in June 1956. G. Källén was invited to give an introductory talk on quantum electro-dynamics at one of the meetings.

A. Bohr was invited to give a series of lectures in the Soviet Union (Leningrad, Moscow, Kharkov, Kiev). Moreover, B. Mottelson was invited to give several lectures in Paris at the Institut du Radium, the Ecole Normale and the Collège de France and also at a number of scientific institutes in the United States.

The following are the reference numbers of the CERN publications dealing with theoretical studies:

CERN 56 - 2 - 3 - 4 - 5 - 6 - 10 - 11 - 12 - 13 - 14 - 15 - 18 - 19 - 20 - 22 - 27 - 28 - 29 - 30 - 31. (See Appendix A)
ADMINISTRATION

1. General

In addition to its normal work, the Administration Division devoted special attention during 1956 to the following problems:

It was necessary to determine the patent policy CERN was to follow. Owing to the intricacy of the problem, the Finance Committee sought the opinion of a group of experts. Representatives of the National Research Development Corporation (United Kingdom), the Centre national de la Recherche scientifique (France), the Nederlandsche Centrale Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek (T.N.O., Netherlands), together with a counsellor of the United International Bureaux for the Protection of Industrial, Literary and Artistic Property (Berne), and CERN's consultant, Mr. S. A. ff. Dakin, met in Geneva, and, after a thorough examination of the problem, unanimously came to the conclusion that CERN should refrain from pursuing an active patent policy for the inventions which might be made as a result of construction, development or experimental work, mostly on the ground that CERN was intended to carry out fundamental research unconnected with commercial applications. Inventions were, on the contrary, to be made free to the world by early and complete publication. Since there might however arise an exceptional case when an invention proved to be of outstanding value, it seemed advisable to authorise the Director-General in such an event to take out patents in the name of CERN as a precautionary measure before referring the matter to the higher authorities of the Organization.

The patent policy thus evolved was approved by the Council at its sixth session, and the Staff Regulations were amended accordingly.

The First Annual Report of the Organization covering the period from October 1954 to the end of December 1955 was drafted and distributed by the Administration Division. It was widely circulated not only throughout the twelve Member States, but also in countries that are not members of CERN, and the National Committees of UNESCO took part in its distribution.

In September, the Division organized the visits to Geneva of distinguished persons representing Member States.

Since, at its fourth session, the Council had agreed in principle to the establishment of a staff insurance scheme and had voted the necessary appropriations in the 1956 Budget for the maintenance of the scheme, the Administration Division, and particularly the Finance Office, drafted the regulations for the scheme, which were adopted by the Council at its fifth session.

The Administration Division closely followed the discussions of the Symposium on the Direction of Research Establishments organized by the National Physical Laboratory at Teddington (England) and found them very profitable.

Increases in the staff of the Division are to some extent proportional to the successive increases in the staff of the Organization as a whole, as well as to the general development of construction work which will soon be followed by research work. The staff of the Division increased from 48 on 31st December 1955 to 60 on 31st December 1956.

2. Finance Office

The scale of contributions to be paid by Member States until the end of 1956 had been laid down in the financial Protocol attached to the Convention.

For every subsequent period of 3 years the scale will be "based on the average net national income at factor cost", requiring adoption by the Council by a two-thirds majority of all the Member States (Article VII of the Convention).

The new scale for the years 1957, 1958 and 1959 was prepared from figures provided by the United Nations Secretariat and was accepted by the Council at its sixth session.

The final accounts for the financial year 1956 which should be submitted to the Council at its seventh session in June 1957, show expenditure of Swiss francs 38'792'472.94 and receipts of Sw. Fr. 39'598'795.27 (See page 61). The sum of Sw. Fr. 806'322.33, corresponding to the excess of receipts over expenditure, will be carried forward to the next
financial year, thereby reducing by an equivalent amount the financial effort that will be required from Member States in 1957.

At its sixth session, the Council adopted the budget for 1957 which amounts to Sw. Fr. 61’825’800. Appropriations remain within the limits estimated in the Capital Investment Programme though they were based on the cost of living index, manufacturing prices and building costs prevailing in October 1956. It will be the highest budget in any of the years devoted to implementing the initial programme. (See page 62)

A new estimate of the Capital Investment Programme was worked out and submitted to the Council at its sixth session. The revised programme provides for a total expenditure of Sw. Fr. 219 millions during the construction period. It is based on a more realistic appraisal of research expenditure and takes into account the general tendency for the Organization to expand. It is based on economic data that were valid in the autumn of 1956. (See page 63)

With the help of two actuaries, the Finance Office drafted the Regulations for the Staff Insurance Scheme which, in accordance with the decisions taken by the Council at its fourth session, will be maintained by means of a deduction of 7½% on the basic salaries of staff members and by an additional contribution from CERN equal to 14% of the staff members’ basic salaries. The Regulations take into account the fact that CERN will consist of staff members having long term appointments and of temporary staff members, and both groups are to receive equivalent benefits.

The benefits cover old age and disability and also take the form of pensions to superannuated staff members, as well as to widows and orphans.

A savings fund has been created for Fellows and staff members who are not eligible to join the staff Insurance Scheme.

The Finance Office has initiated a simple form of analytical accounting which will enable it to obtain quite cheaply the information required concerning the cost of constructing machines and equipment, the maintenance and operating expenses of machines and workshops, and subsequently the cost of research.

3. Personnel Office

The main task of the Personnel Office has been to ensure the steady recruitment of qualified staff to meet the ever growing needs of the Organization.

In order to implement its programme, CERN makes a periodical assessment of its future staff requirements and it periodically notifies Member States of vacancies.

Owing to the continued demand for scientists and technicians throughout Europe, it has not always been easy to arouse the interest of highly qualified candidates. Publicity has therefore had to be intensified and advertisements have been inserted in the daily newspapers and periodicals of member countries in order to obtain suitable candidates.

Generally speaking the method of selection adopted has proved satisfactory and it has not been modified.

The average cost of appointing a staff member amounts to Sw. Fr. 540,—, which seems reasonable, taking into account the fact that staff is recruited from twelve different countries and that travel and other incidental expenses are reimbursed to all candidates interviewed by the selection boards.

In the course of 1956:

- 87 selection boards were held;
- 3,171 applications were received, bringing the total number of applicants to 9,484;
- 496 candidates were interviewed, and
- 129 appointments were made.

As the general increase in the cost of living only amounted to 1.9% in Geneva for 1956, the salary scales revised in January 1956, in accordance with decisions adopted by the Council at its fourth session, have been maintained.

It should be added, however, that the above-mentioned increase in the cost of living occurred mainly during the fourth quarter, and that there now is a general tendency for the cost of living to rise in the principal European countries.

The Personnel Office has kept up-to-date organizational charts for each Division, and has co-operated with the Staff Advisory Committee which examined staff requirements on behalf of the Council, as it had already done in 1955.

The table on page 59 gives details of the staff distribution by functions and divisions.

Co-ordination of all personnel matters is carried out satisfactorily within CERN by the Joint Committee with the Staff Association, by the Common Services Committee, and by direct contact with the administrative assistants appointed for each Division.
CERN STAFF AS AT 31st DECEMBER, 1956
Distribution by Functions and Divisions

<table>
<thead>
<tr>
<th>Division</th>
<th>Leading and Scientific</th>
<th>Technical</th>
<th>Administrative</th>
<th>Ancillary</th>
<th>Fellows</th>
<th>Total</th>
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<td>7</td>
<td>5</td>
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<td>61</td>
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<tr>
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<td>14</td>
<td>2</td>
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<td><strong>82</strong></td>
<td><strong>22</strong></td>
<td><strong>426</strong></td>
</tr>
</tbody>
</table>

The Personnel Office drew up conditions for Fellows in Geneva, a considerable number of whom will be recruited in 1957 to take part in research on the synchro-cyclotron as well as studies and research undertaken by the Proton Synchrotron and the Scientific and Technical Services Divisions and to form a Theoretical Group in Geneva, which is to take over from the Copenhagen Division in October 1957.

The Personnel Office is preparing, for the consideration of the Council, an important revision of the Staff Regulations with a view to the future recruiting of staff on a more permanent basis, while maintaining sufficiently flexible rules over appointments to secure a constant flow of arrivals and departures of research workers.

The Personnel Office is also considering a unified grade scale, including a detailed job description for each function. This new system is intended to prevent unequal grading between the Divisions. It should, however, be flexible enough to allow for promotion and to leave Divisional Directors the necessary authority in respect of their staff under the responsibility of the Director-General.

Similar systems are being examined by other international and European organizations. The Personnel Officer is taking part in these discussions as an observer.

4. Purchasing Office

A considerable increase took place in the activities of the Purchasing Office during 1956. Seven thousand nine hundred orders and contracts were placed, namely an increase of 76% over the previous year. (The orders and contracts placed total Sw. Fr. 29'500'000).

The Purchasing Office had to arrange for the supplies necessary for the construction of the synchro-cyclotron and for the intensive engineering work carried out on the Meyrin site.

The Office also took part in negotiating and settling the main contracts for the proton synchrotron, and particularly those for the magnet blocks, the magnet power generating equipment, the accelerating units and the ferrite rings. Moreover, tenders of considerable importance have been invited for the cooling system and the steel supporting girders for the magnet units.

Despite the reluctance of certain contractors all the contracts were negotiated at fixed prices. Penalty clauses for late delivery have been included in all the contracts, since strict compliance with the time limits laid down is essential.

Owing to the complexity of the equipment required and to the strict tolerances prescribed by the technical services, only a few of the many European firms approached have sometimes been in a position to submit tenders.

There have been considerable differences between the quotations given by the various tendering firms, and it has not always been possible to understand the reason for these.

As a rule, orders for special equipment, particularly for important equipment, were placed with firms of very high repute. These firms often proved extremely keen on gaining the high prestige of being purveyors to CERN.

Complicated problems sometimes arose in con-
nection with ordinary supplies and with all types of construction work, owing to the difficulties produced by boom conditions in Europe and to shortages.

In spite of these adverse conditions, orders were shared out as far as possible between Member States, including the furthest distant.

Standardization work continues in close cooperation with other institutions similar to CERN, whose experience is of value to the Organization.
## Breakdown of 1956 Expenditure

<table>
<thead>
<tr>
<th>Category</th>
<th>Budget 1956</th>
<th>Expenditure 1956</th>
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CAPITAL INVESTMENT PROGRAMME 1952-1960
(in 000's of Swiss francs)

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<th>Scientific and Techn. Services</th>
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<th>Administration</th>
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_of which_

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INVESTMENT PROGRAMME

Yearly Expenditure Chart

Probable annual expenditure

Yearly Expenditure Chart

Probable and maximum expenditure

Construction
Maintenance
Research


235 max.
219 prob.
178
166
150
100
50
0
CERN PUBLICATIONS

CERN 56-1 DEBRAINE, P., LAZANSKI, M. and BOYADJIAN, G. The design of the CERN Synchro-cyclotron control system.
CERN 56-8 LÜERS, G. On the influence of irregularities of magnetic field on betatron oscillations in an alternating gradient synchrotron.
CERN 56-20 STEINWEDEL, H. Particle orbits in circular accelerators.
CERN 56-21 ADAMS, J. B. The design of the foundations for the magnet of the CERN alternating gradient proton synchrotron.
Vol. 1 — Les accélérateurs de haute énergie./ High energy accelerators.  
Vol. 2 — La physique des mésons π./ Pion physics.  
(40 Fr.s./vol.)  

CERN 56-27 Petermann, A. Suppression of pair effects in double \( \pi \)-meson photoproduction at low energies.  

CERN 56-28 Kind, A. and Jess, L. On the real part of the complex potential well of the nucleus.  

CERN 56-29 Groenewold, H. J. Quasi-classical path integrals.  

CERN 56-30 Alder, K. and Winther, A. Tables of the classical orbital integrals in Coulomb excitation.  

CERN 56-31 Pauli, W. Continuous groups in quantum mechanics.
APPENDIX B

LIST OF LECTURES AND COLLOQUIA OF THE THEORETICAL STUDY DIVISION IN COPENHAGEN

A. Mesons and the Field Theory of Nuclear Forces.
W. Heisenberg (February 6th): General remarks on the theory of elementary particles.
F. Cerulus (February 16th): On the classification of fundamental particles.
H. Lehmann (February 27th): Remarks on the causality problem in the interaction of elementary particles.
A. Petermann (March 5th): Photoproduction of two \( \pi \)-mesons at low energies.
W. Heitler (March 16th): Self-stress problems and the limit of validity of the field theories.
W. Zimmermann (April 9th): Discussion on causality in field theories.
G. Källén (May 7th): Some impressions from the conference in Rochester.
B. Jouvet (June 4th): On Fermi coupling and the theory of bosons.
H. Lehmann (June 29th): On dispersion relations for the scattering of particles with rest-mass.
A. Wightman (October 2nd): Compatibility of the canonical commutation relations and Lorentzinvariance.
A. Wightman (October 8th): The use of analytic functions in field theory.
G. Källén (October 22nd): A model of an unstable particle.
B. Jouvet (November 7th): Fermi coupling and renormalization constants.
K. Baumann (November 12th): Quantum field theory as theory of distributions.

B. Quantum Electrodynamics
G. Källén: Weekly lectures on quantum electrodynamics.
G. Källén (May 9th): Quantum electrodynamics.
G. Källén (May 14th): Retarded functions of two variables.
K. Wildermuth (October 29th): Some remarks about the self acceleration of the electron.

C. Nuclear Constitution
A. Winther (January 21st): Theory of the Coulomb excitation process.
T. Huus (January 21st): Experimental methods and results.
A. Bohr (January 21st): Rotational excitations.
H. J. Lipkin (February 9th): Collective motion in the nuclear shell model.
L. Sliv (February 17th): K-shell internal conversion coefficients.
T. Bergström (February 20th): \( M4 \) transitions in the Pb-isotopes.
P. Axel (February 24th): Summary of photonuclear reactions.
O. Kofoed-Hansen (March 2nd): Coupling constants in \( \beta \)-decay.
L. Sliv (March 9th): Mono-energetic positrons.
L. Sliv (March 9th): Some problems of a \( \alpha \)-decay.
P. C. Martin (April 6th): The basis for the independent particle model of the nucleus.
R. J. Eden (April 9th and 16th): The Brueckner theory in nuclear structure.
B. H. Flowers (April 18th): Some recent calculations at Harwell on nuclear structure.
C. F. Wandel (May 25th): On the imaginary part of the potential in the complex potential model of the nucleus.
H. A. Bethe (May 28th and 29th): On the Brueckner theory of nuclear structure.
R. F. Christy (June 28th): The analysis of data on nuclear scattering of charged particles.
L. Rosenfeld (September 3rd): Nuclear mass distribution and average potential.
T. Bonner (October 5th): Some recent nuclear experiments at the Rice institute.
A. Bohr (October 19th): A little about nuclear physics in the U.S.S.R.
H. Fulbright (October 26th): Experiments with the new variable energy cyclotron at Rochester.
B. R. Mottelson (November 2nd): The State of the Union.
H. Severiens (November 9th): Life-time measurements by recoil.
G. Rakavy (November 16th): Rotational spectra in the region beyond \( 0^{16} \).
APPENDIX B

P. Martin (November 26th): Radiative capture of orbital electrons.

J. Goldstone (November 28th): Many-Fermion perturbation theory.

B. F. Bayman (November 30th): Configuration mixing and the $\beta$-decay of radium E.

O. Nathan (December 7th): Measurements on level schemes in even-even nuclei in the rare earth region.

S. Frankel (December 14th): Extra nuclear effects in angular correlation.

Weekly informal discussions on theoretical problems of nuclear structure.

D. General Topics

H. J. Groenewold (March 19th): Quasi-classical path integrals.

R. Jost (April 13th): Remarks on scattering theory.

J. A. Wheeler (May 2nd): Problems and properties of a universe built of fields of zero rest-mass.


S. Watanabe (September 4th): The concept of time in the Onsager principle.

J. M. Jauch (September 17th): A relation between phase shifts and bound states.

C. Möller (November 5th): On the possibility of terrestrial tests of the general theory of relativity.

A. Komar (November 19th): Singularities in gravitation theory.

E. High Energy Nuclear Physics and Accelerators.

W. Heisenberg (February 6th): Multiple production of mesons.

H. Alfvén (March 23rd): Cosmic radiation.

E. Amaldi (April 16th): On the anti-proton.

D. Judd (June 28th): Survey of research work going on at the radiation laboratory in Berkeley.


G. Bernardini (September 21st): Electromagnetic properties of the nucleons.

J. Hamilton (September 26th): Anti-proton annihilation.

S. Frankel (September 28th): Hypothesis concerning K-mesons and hyperons.

J. Hamilton (September 28th): Selection rules for anti-proton annihilation.

D. Saxon (October 12th): The optical model.

Z. Koba (December 3rd): Antiproton-proton interaction.

M. Cantwell (December 10th): Internal Bremsstrahlung accompanying $\mu$-meson capture.

D. Saxon (December 17th): High energy potential scattering.

F. Solid State and Molecular Physics.

I. Espe (April 20th): Electronic motion on the rotating hydrogen molecule.

E. A. Uehling (June 15th): Acoustic excitation of magnetic relaxation in crystals.

J. Bardeen and W. Brattain (December 3rd): Physics of transistors with demonstrations.
APPENDIX C

LIST OF COLLOQUIUM LECTURES

INSTITUTE OF PHYSICS

GENEVA

1956


J. P. BLASER (February 1) : Meson-Proton Scattering Experiments.

P. HUBER (February 15) : Neutron Scattering and Reactions in the MeV region.

C. C. BUTLER (February 22) : The Properties of Strange Particles.

B. d'ESPADAGAT (February 29) : Phenomenological Theory of Gell-Mann and Others.

B. HAHN (March 7) : Work at Stanford on Electron Scattering.

E. H. BELLAMY (March 14) : Recent Work with the Glasgow 300 MeV Synchrotron.

C. H. TOWNES (March 21) : Mesurage du temps par les méthodes spectroscopiques.

H. ELLIOT (April 18) : Astronomy and Cosmic Rays.


H. P. J. WUIN (May 2) : Physical Properties of Ferrites.

P. B. MOON (May 9) : Recent Work with the Birmingham 1 GeV Synchrotron.

A. GOZZINI (17 octobre) : Application des micro-ondes à quelques problèmes de la recherche physique.

W. J. HuisKAMP (October 24) : Nuclear Orientation at Low Temperatures.

E. BRUN (October 31) : Energy Level Schemes of Ga$^{69}$ and Cu$^{69}$.

F. JOLIOT (November 7) : Activité du Laboratoire de Physique et Chimie nucléaires et du Laboratoire de Synthèse atomique.

F. VILLARS (November 14) : Conservation Laws in Elementary Particle Physics.

P. CUER (November 28) : Étude de quelques résultats obtenus à Strasbourg.

S. D. WINTER (December 5) : The Saclay Proton Synchrotron.

W. B. THOMPSON (December 12) : Some Theoretical Aspects of Controlled Thermonuclear Reactions.

M. LÉVY (December 19) : Theoretical Considerations on the Interactions of Anti-Nucleons with Nuclear Matter.
APPENDIX D


BARBIER, M. A mechanical analogue for the study of betatron oscillations (p. 262-264, vol. 1).


HAGEDORN, R. Note on an instability on a difference resonance line (p. 293-294, vol. 1).


JOHNSON, K. and SCHMELZER, C. Beam controlled acceleration in synchrotrons (p. 395-403, vol. 1).

