CERN

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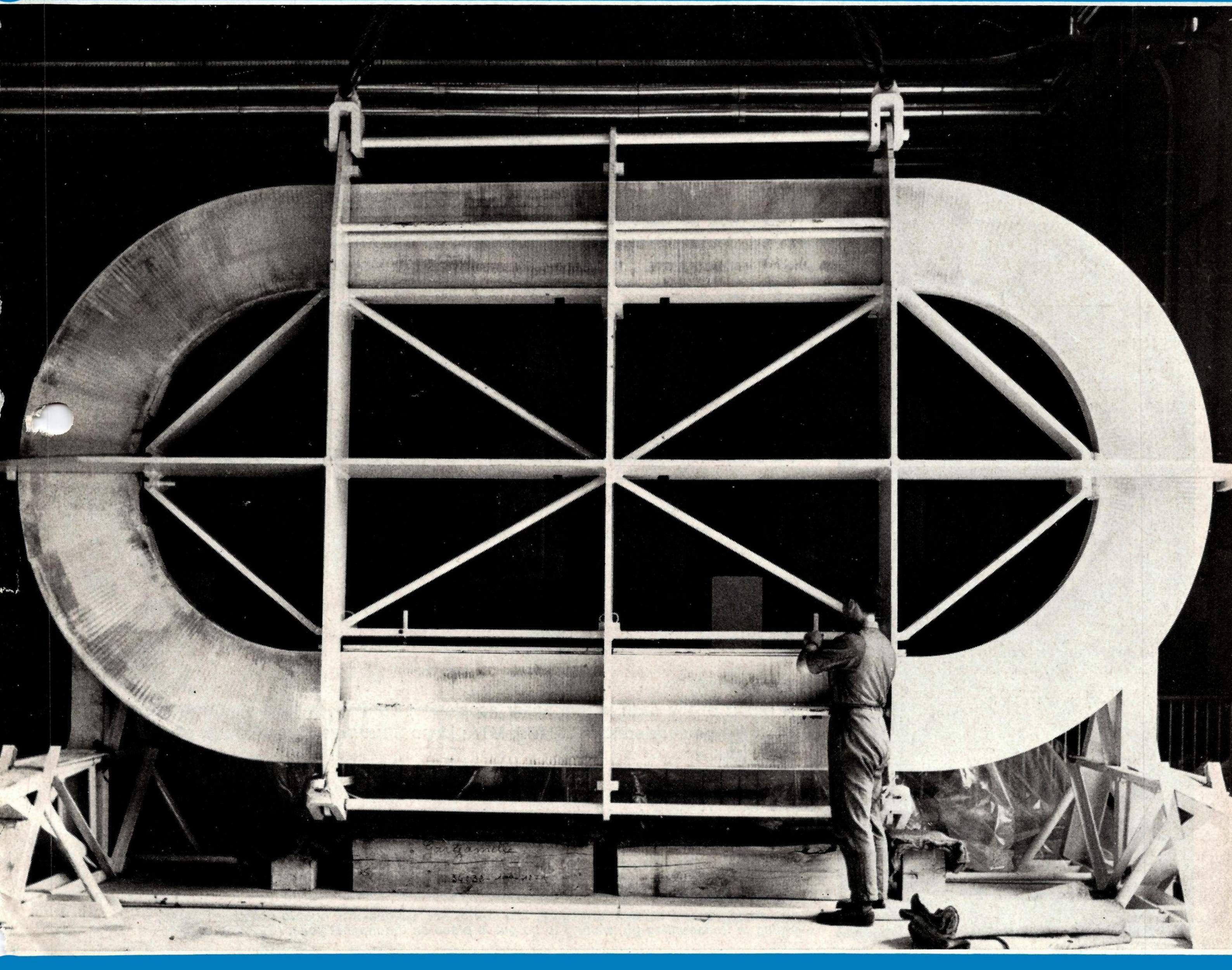

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientifice and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 700 physicists outside CERN are provided with their research material in this way.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2350 people and, in addition, there are over 400 Fellows and Visiting Scientists.

Thirteen European countries participate in the work of CERN, contributing to the cost of the basic programme, 197.5 million Swiss francs in 1968, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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Comment

The United Kingdom delegation announced at the Council Session on 20 June that their government has decided not to participate in the 300 GeV project.

There is no doubt that this decision from a major participant in CERN is a serious blow for European physics. It came as a surprise and a deep disappointment. But, far from abandoning hope, the Council rallied to the project and is trying to find ways and means of going ahead without introducing any new delay.

The Scientific Policy Committee has already considered the possibility of a major withdrawal of support and has gone a long way towards evolving a revised programme for the project which would reduce the annual budgets. A detailed analysis of the possibilities will be presented very soon. There is no question of considering a lesser machine; the basic parameters — a peak energy of 300 GeV, high proton beam intensity, and capability for extensive exploitation — would remain firmly in any revision. The loss could come in a longer time-scale to reach full exploitation.

There was no question in the UK decision of doubt concerning the technical and scientific merits of the project. The statement announcing the decision said 'the project is well conceived' and 'strong scientific views have been expressed in its favour'.

It was obvious also from the personal statements at the Council that the UK scientific community remains solidly behind the project and will fight for a reversal of the decision. They have given the 300 GeV top priority for some time, even while appreciating the painful implications that this could have on their national Laboratories. The programme of sub-nuclear physics that they are now left with is not the programme of the future.

However, the present decision of the government is unequivocal. One can only hope that the UK will be in a position to reverse it in a few years time and to buy themselves back into the project. For the immediate future, the ripples of the stone that has been dropped into the pool of European physics will have to die down before the true effect of the withdrawal of the UK can be assessed. Meanwhile, the Council has urged that work towards the project should continue and that the UK decision should not introduce any new hesitations for the governments of the other Member States.

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Cover photograph: A study in symmetry. The coil of the 'Gargamelle' bubble chamber magnet, standing in its mounting-jig, waiting to be put in place on the magnet yoke. (CERN/PI 86.6.68)

38^{th} Session of CERN Council

The 38th Session of the Council was held at CERN on 19-20 June under the chairmanship of Dr. G. Funke.

The Council opened with a report by the Director General, Professor B.P. Gregory, on the activities of CERN over the past six months. He picked out three topics for special mention — the experimental programme at the proton synchrotron, collaboration with Serpukhov, and preparation for experiments at the intersecting storage rings.

PS experimental programme

The proton synchrotron has just concluded a year's almost continuous operation. It has now been shut down for several months for extensive civil engineering work, for the connection of the new magnet power supply which will increase the repetition rate of the machine, and for rebuilding of the beam lines in the three experimental halls.

Just before the shut down there were twelve experiments using electronic techniques, set up around the machine. In addition, three bubble chambers were supplied with particles. The fact that the synchrotron was able to cope satisfactorily with the need to serve such an intense and complex programme reflected the skill of its operators, the calibre of the machine itself and the efficiency of the experimenters.

Nine of the electronics experiments finished collecting their data as scheduled. They included the 'g-2 experiment' which used the muon storage ring for a measurement of very high precision (20 times more accurate than that done at the synchro-cyclotron six years ago). The measurement could reveal some subtle difference between those mysteriously alike particles — the electron and the muon, or could indicate the limit to which the very successful theory of quantum electrodynamics is applicable. The result of the experiment together with many others from CERN is expected to be announced at the major high energy physics conference at Vienna in September.

Other notable achievements from the electronics experiments have been the work on proton-proton scattering which revealed an unexpected change in behaviour at an energy around 10 GeV, and the 'missing mass' experiment which, using a different experimental method, confirmed the strange observation first made at CERN of the splitting of the A2 resonance into two separate peaks.

The very efficient operation of the three bubble chambers made it a record year for bubble chamber output. The 81 cm hydrogen chamber recorded its ten millionth picture. The 2 m hydrogen chamber took three million pictures in the year and in terms of the number of particle interactions recorded has put at the disposal of the European physicists almost as much as had been collected in all the previous years. The heavy liquid bubble chamber, after completion of the successful neutrino experiments, was moved behind the 2 m chamber and it proved possible to use one particle beam to feed the two chambers simultaneously.

The participation of 'outside' physicists in the experimental programme is still growing. Other European Laboratories and the Universities have always been extensively involved in the bubble chamber experiments — this involvement has now grown to the extent that, of the 550 physicists basing their research on the CERN chambers, 500 are from outside CERN, 30 are fellows or visitors here for short periods, and only 20 are on the CERN staff. But outside participation has also grown in the experiments using electronic techniques. Twenty universities provide 70 % of the physicists and another 15 % are short term visitors.

To complete the picture — at the smaller CERN accelerator, the 600 MeV synchro-cyclotron, from about 80 physicists only 6 are on the CERN Staff.

Serpukhov and ISR

Collaboration with the Institute of High Energy Physics at Serpukhov, USSR, is fulfilling the highest hopes. The latest stage is that, at a meeting held at CERN at the beginning of June of the Joint Committee (which has six representatives from each Laboratory who are closely involved with the work in hand), details of the scheme for the fast ejection system to be provided by CERN were agreed. (This will be covered in the next issue of CERN COURIER.)

A CERN team are preparing to go to the 70 GeV accelerator Laboratory to join their Soviet colleagues for the first collaborative experiment (see page 128).

Performance of the accelerator itself is very promising. Protons have been accelerated to 76 GeV and energies even above this may prove possible. The linear injector has produced the remarkably high current of 100 mA at 100 MeV and the present machine intensity is 3×10^{11} particles per pulse.

Another example of collaboration, not tied specifically to the CERN-Serpukhov Agreement is a recent decision on the standardization of the size of bubble chamber film. Soviet and European bubble chamber designers have agreed to use the same type of 70 mm film — it involves the hydrogen chamber 'Mirabelle' and the heavy liquid chamber 'SCAT' for Serpukhov, and the large European hydrogen chamber and the heavy liquid chamber 'Gargamelle' for CERN. This agreement may seem rather trivial but it has taken a long time to achieve and means that experimental groups could now do experiments using different chambers without having to invest money in different film analysis equipment.

An ISR Users' Meeting was recently held at CERN (see page 128) where the preliminary thinking about the initial experiments on the intersecting storage rings was presented to a large gathering of European physicists. Following the meeting, participation of the European Universities in evolving the ISR experimental programme will grow. The lengthy preparation for specific experiments will need to begin soon.

During the Council session, Dr. K. Johnson, Director of the ISR Construction Department, reported the encouraging progress so far on the building of the intersecting storage rings. There is every indication that this vast project will be built on schedule and that the expenditure will be within the estimated budget.

300 GeV

The discussion on the proposed 300 GeV accelerator project opened with the following statement by the UK delegate, Professor B.H. Flowers: "At the Council meeting in December, I said that my Government were giving very careful consideration to the question of participating in the 300 GeV project. They had obtained advice from various scientific bodies, which has since bean published. My Government were particularly concerned at the effect which participation in this project might have on the balance of resources between high energy physics and other scientific activities and they also had to review the implications of the devaluation of sterling.

My Government have now decided in the light of their other commitments that expenditure involved on this very large project would not be justified. H.M.G. regret this decision because they fully appreciate that the project is well conceived and that strong scientific views have been expressed in its favour. But they are satisfied, after an exhaustive review of the arguments, that they should not enter into this commitment.

In reaching this conclusion my Government have had in mind that through CERN, which they will continue to support, the European high energy nuclear physics community already has an important project in hand in the Intersecting Storage Rings. This will give European physicists a unique instrument which will enable some further advances to be made in the physics of very high energies."

Professor Flowers continued with a personal statement which, however, carried the unanimous support of the UK Science Research Council of which he is Chairman. He recalled that UK nuclear physicists consider the 300 GeV project as first priority even at the cost of closing down a national Laboratory before the end of its useful life. The scientific and technical merit of the project has never been in question and Professor Flowers hoped that some way will be found to go ahead without the UK and that high energy physics in Europe will prove strong enough to withstand one adverse decision. It remains the policy of UK physicists to urge their government to support the project and, in the meantime, they will avoid taking any steps which could prejudice eventual participation.

The Chairman of the European Committee for Future Accelerators and delegate for Italy, Professor E. Amaldi, said that the UK contribution to CERN, financially and scientifically, has always been of the greatest importance but urged that other countries should now do everything they can to keep the project going, leaving the door open for the UK to join at a later date. CERN, of all the European Organizations, has always been the most successful both from the point of view of the governments and of the scientists. The project must not be allowed to decay.

Spokesmen for other delegations including France and Germany echoed the same feelings and Professor G. Puppi wound up the discussion by announcing that the Scientific Policy Committee, of which he is Chairman, has already considered what could be done to keep the project viable in the advent of the withdrawal of a major State or a group of smaller States. There has been no thought of changing the main features of the machine and the final aim would still be an energy of 300 GeV, high beam intensity and capacity for extensive exploitation. The revision has concentrated on such things as a longer time-scale to reach full exploitation, a reduction of the investment in experimental equipment, constructing only one experimental area, and the possibility of beginning operation at an intermediate energy. Accepting restrictions of this nature would reduce the annual budgets. A detailed analysis of the possibilities will be available very soon.

Finally, the Director General urged all the other countries to press forward for a decision as quickly as possible, taking it as a premis that a sound variant of the project will be produced.

Others topics

Three other topics from those covered at the Council meeting have been picked out for mention.

In June 1967, the German delegation requested that German should be recognized as a language of CERN (the two official languages being English and French). A Working Party consisting of Mr. A. Chavanne (Switzerland), Dr. W. Kummer (Austria) and Ambassador Chr. Sommerfelt (Norway) was set up to examine the problem and to present recommendations to the Council. These recommendations were accepted at the Council meeting.

They involve an amendment to the Council 'Rules of Procedure'. From now on, interpretation will be provided at meetings of the Council and its subordinate bodies in English, French and German and the associated documents will carry a summary in these three languages. In addition, a German text of the CERN Convention will be published. Otherwise the present practice, whereby the use of languages other than English and French is left to the discretion of the Director General, who decides whether it is in the interests of CERN, will continue.

The Council approved the Agreement between CERN and the European Southern Observatory (ESO) which allows the staff of the Observatory to join the CERN Staff Insurance Scheme. The number of ESO personnel is very small (around twenty) and it is obviously impracticable for them to establish an Insurance Scheme themselves. Since their conditions of service are very close to those at CERN they can readily be absorbed into the CERN scheme.

The Council renewed for three years the appointment of Dr. M.G.N. Hine as Director of the Applied Physics Department.

Support for pure science

V. F. Weisskopf

In the March issue of 'Scientific American', Professor V.F. Weisskopf (former Director General of CERN, now at the Massachusetts Institute of Technology) reviewed the book 'The Politics of Pure Science' by D.S. Greenberg. A large part of his review was devoted to encouraging support for pure science. It relates particularly to the science scene in the USA but is applicable also to Europe especially in the light of the proposal for a 300 GeV accelerator.

Why should the Government use the taxpayer's money to support basic science? In most other areas of public spending, Congress and the people can judge (or believe they can judge) the value and the implications of what public money is spent for ; they believe they can find out whether the money was spent well or not. When it comes to basic science, however, they are not able to judge the quality and relevance of what they get for their money, and they are well aware of it. Only scientists themselves can gauge a project's importance and its success or failure. They are recipients, administrators and judges all at the same time. The trouble comes from the fact that the layman cannot understand science well enough to make responsible judgments. He may have a rough idea of what is going on, but he is far from able to evaluate new scientific developments. It is a most unusual and most irritating situation.

The problem has become acute only during the past two decades. Before the war, the cost of basic research was so low that it could be borne by private sources and by public money earmarked for education. That is no longer so. The annual expenditure on basic science in the U.S., $3 billion, is too much for such sources. To be sure, it is not much compared with $13 billion per year on alcoholic beverages, $8.4 billion on tobacco and more than $3 billion on 'durable toys, sports equipment, pleasure boats and pleasure aircraft.'

I mention these figures in order to suggest why we should do away with one popular argument against basic science, which goes as follows : It is immoral to spend so much money on something that has no immediate use and is of interest only to a very small community, when money is needed for the antipoverty program, for social services and for the rehabilitation of cities. This argument derives its strength from the fact that we spend even less on the war against poverty than we do on basic science. This is a shameful state of affairs that should be changed. The problem must, however, be put in a different form. Clearly the support of basic science is less urgent than the war against poverty. That is not the question ; all we need to show is that basic science is more important, than, say, 15 percent of drinking, smoking and 'durable toys'.

Even this may be a difficult task. We should distinguish between two groups of basic sciences. One group I would call the 'obviously applicable' kind of sciences. The other is the not so obviously applicable kind for which I shall use the term 'frontier' sciences, without meaning to imply that the sciences of the first kind are not also scientific frontiers. The first group includes molecular biology, solid-state physics, plasma physics and so on. These disciplines function as pure sciences, that is, they are pursued with the aim of discovering basic phenomena and without any practical applications in mind. Still, it is obvious that any progress in molecular biology will be relevant to some medical problem, that any deeper understanding of the solid state will be helpful for the production of metals and synthetic materials, and that plasma physics will eventually enable us to exploit the energy of nuclear fusion.

The second group includes elementary-particle physics, galactic and extra-galactic astronomy, cosmology and so forth. These sciences deal with distant objects; elementary particles in the modern sense are also 'distant', since mesons and baryons appear only when matter is subjected to extremely high energies that are normally not available on the earth but are probably found somewhere else in the universe. The 'distant' feature of these sciences is what makes them expensive. It costs money to create conditions in the laboratory imitating conditions that may exist only in some exploding galaxy. It costs money to build instruments for studying the limits of the universe. In short, these sciences do not have obvious applications because they deal with phenomena that do not occur on the earth.

The problem of public support is quite different for the two groups of sciences. Support for the first group is no problem at all. It is true that even in these sciences only scientists are able to judge the results of their work; therefore the scientific community has been both the recipient of funds and the distributor, and will have to remain so. The system has worked fairly well and has produced remarkable results. It is well known that these results have had a heavy impact on medicine and technology. Everyone wants cures for cancer, everyone wants an economic method for de-salting seawater, everyone understands the necessity of basic research of the first kind for these results. There will always be money for basic science of the first kind. It will sometimes be too little and sometimes even too much, but there is no fundamental problem in convincing the non-scientist of the importance of these sciences for many practical aims.

The situation is different with the second group of sciences. There are two aspects to these sciences. Let us take high-energy physics as an example. One aspect is that the research is directed toward the innermost structure of matter and therefore is looking for the most fundamental laws of nature that govern the behaviour of matter. It seeks the reasons for the existence of electrons, protons and neutrons and for their having the properties they exhibit. The other aspect is that sciences such as high-energy physics uncover a new world of natural phenomena unknown to us before.

One must grant that the first aspect is exciting primarily to the scientists involved, since only they can sense and evaluate the fundamental nature of the discoveries. To the outsider the second aspect also has a rather esoteric character. It seems to have no connection with the rest of our activities and vital interests. To be sure, these discoveries are interesting, sometimes even fascinating, as when cosmology touches on questions such as 'Did the world begin with a 'big bang'?' Still, the ordinary citizen may feel that he can live without this excitement and that it does not seem worth several hundred million dollars a year.

The 'obviously applicable' sciences deal with objects that have been under study for a long time and belong to the human environment. That is why these sciences are relevant to each other and to technology. The argument against the 'frontier' sciences is that they deal with problems far removed from the human environment and are therefore of minor social relevance.

I believe this point of view is thoroughly inconsistent. What is the human environment? Ten thousand years ago there were no metals in the human environment. Metals are rarely found in pure form in nature. After man discovered how to create them from ores, however, they played an important role in his environment. The first piece of copper must have looked very esoteric and useless. In fact, man for a long time used it only for decoration. Later the introduction of this new material into man's ken gave rise to interesting possibilities that ultimately led to the dominant role of metals in his environment. In short, we have created a metallic environment.

To choose another example, bulk electricity in nature is rare; it appears only in lightning and in frictional electrostatics. It was not an important part of the human environment. After long years of esoteric research into minute effects it was possible to recognize the nature of electrical phenomena and to find out what a dominant role they play in the atom. The interaction of these new phenomena with the human world created the completely new electrical environment in which we live today.

The newest example is nuclear physics. In the early days prying into the nucleus was considered a purely academic activity, directed only toward the advancement of knowledge about the innermost structure of matter. In 1933, Lord Rutherford said 'Anyone who expects a source of power from the transformation of these atoms is talking moonshine'. I imagine his conclusion was based on the same kind of reasoning I have cited above: Nuclear phenomena are too far removed from the human environment. It is true that, apart from the comparatively small contribution of natural radioactivity, nuclear reactions must be artificially induced with costly fluxes of energetic particles. Large-scale nuclear phenomena on the earth are strictly man-made; they occur naturally only in the centre of stars. Here again the introduction of these man-made phenomena into the human environment has led to a large number of interactions: artificial radioactivity has revolutionized many branches of medicine, biology, chemistry and metallurgy, and nuclear fission is a steadily enlarging source of energy. Nuclear phenomena too are an important part of the human environment.

Physics is now in the process of discovering another new world of phenomena at even higher energies. The discovery of this new world is one of the most remarkable feats of science. Its importance is usually not recognized by the layman, who is more likely to be impressed by the discoveries concerning the surface of the moon. What is the surface of the moon compared with phenomena that in nature are probably happening only in the interior of quasars and exploding galaxies? The lack of public understanding is the fault of scientists; they try to explain SU3 symmetries to newspaper reporters instead of telling them what the whole thing is about. They themselves cannot see the forest for the trees!

When this new world of sub-nuclear particle phenomena is introduced into the human environment, it is bound to interact with the environment in new ways. Nobody knows what will happen when it becomes possible to produce beams of particles thousands of times more intense than those of today — beams in which all the new particles will be mass-produced to react with the environment. Even now some people are speculating about the special clinical effects of pion beams, effects that cannot be produced by ordinary radiation. It reflects a rather conservative attitude when our high-energy physicists say that their field will never be of any practical use. I would consider it highly unlikely that among the many new phenomena that will result from the interaction of intense high-energy beams with ordinary matter there would not be one with any practical application.

Here we see the relevance of 'frontier' sciences: they open up new realms of natural processes and deepen the pool of phenomena we can use for scientific and

Professor Weisskopf photographed at CERN during his years as Director General. He returned to his research work at MIT at the beginning of 1966. Professor Weisskopf has long been one of the leading exponents of the cause of pure science.

CERN/PI 4627

technological purposes. This, I believe, is part of the answer to Greenberg's question: 'When a handful of particle physicists, at the expense of several hundred millions of dollars per year in public funds, explore the 'particle zoo' are they fulfilling a purpose of society? Or are they merely pursuing their own curiosity in virtually total disengagement from the society which supports them?'

This, however, is not the only relevant aspect of the frontier sciences. Another aspect lies in their importance for scientific education and for the state of science as a whole. The frontier sciences are directed toward the investigation of phenomena that are distinctly different from what is known. At the same time they are directed toward problems concerning the foundations of our present natural laws and the limits of their validity; they get at the deeper significance of these laws and their still unknown connections. The expansion of the universe, the origin of the universe, the relations among electrodynamics, nuclear forces and gravity, the origin of the elementary electric charge, the conservation of baryons, the nature of weak nuclear interactions — all are problems of this character. Science cannot shun these questions; it is the essence of scientific inquiry to proceed toward the bottom of things. New phenomena cannot be ignored; they must be investigated. Laws and regularities cannot be accepted, they must be understood.

The value of fundamental research does not lie only in the ideas and results it produces. The spirit that prevails in the basic sciences affects the whole scientific and technological life of a community because it determines its way of thinking and the standards by which its creations are judged. An atmosphere of creativity is established that penetrates to every frontier. The applied sciences and technology adjust to the intellectual standards that are developed in the basic sciences. This influence works in many ways: Some fundamental-research students go into industry, where the techniques that have been applied to meet the stringent requirements of fundamental research, serve to create new technological methods. One example that comes to mind is the technique of measuring very short intervals of time, which was developed for the purposes of high-energy physics.

In a variety of ways, the style and the level of scientific and technical work are determined in pure research. This is one of the important social functions of pure science; it establishes the climate in which all scientific and technological activities flourish; it pumps the lifeblood of ideas and inventiveness into laboratories and factories.

But it is not only the scientific and technological world that is influenced by basic science. The deeper insights into the workings of nature that pure science provides are also relevant for the non-scientific part of the community, even if the non-scientist has little knowledge of the underlying ideas and concepts. It is an awareness of the far-reaching results of science that counts, an awareness that we know about the age of the earth, the evolutionary development of life, the origin of the elements, the indestructibility of matter — above all, an awareness that nature works according to exact laws that exclude magic and demonstrate that man is not at the mercy of a capricious universe. In many instances science is more relevant when it predicts what cannot happen than it is when it makes positive predictions.

There are similar reasons why science must play an important role in education. Here the 'frontier' sciences are of especial significance. When students are introduced to the workings of nature, the open questions and the unsolved fundamental problems are bound to be the centre of interest. There is more to it than just the teaching of science. There is no scientific education without the active pursuit of research. The scientists and engineers of the future will have had to be immersed in the spirit of inquiry, they will have had to have tasted the atmosphere of continuous search at the frontiers of knowledge if they are to be successful in any field — pure or applied. Basic research, therefore, is an essential part of higher education in science and engineering.

Such considerations may help in answering one of the most difficult questions of science policy: Given that pure science must be supported, how much money should be spent on it? What determines the right quantity of pure science and how fast pure science should develop? I believe the answer lies in the educational role of basic science. There should be enough support of pure science — particularly the frontier sciences — to ensure that scholars and students at our major universities can actively participate in such research. This criterion does not allow an exact determination of the amount of money needed, but it furnishes a sound order of magnitude. On this basis, the support of pure science in the U.S. has been adequate up to the present. Now, however, all signs point toward a steady decline; the future looks dark.

On the one hand we face a rapid expansion of our system of higher education; we also face a steady increase in the cost of pure research. On the other hand, the present political trend is against any expansion of Federal support of science. Today the main problem in the politics of science is: How can we protect this important sector of modern society from the onslaught of our current moral, social, financial and military crisis?

CERN News

CERN/Serpukhov experiment

An experimental team at CERN are packing their equipment to move very soon to the Institute of High Energy Physics at Serpukhov, USSR. There the team will join Soviet scientists for the first collaborative experiment to be carried out at the newly commissioned 70 GeV proton synchrotron — the highest energy machine in the world.

The collaboration is in the context of the CERN/Serpukhov Agreement (see vol. 7, page 123). To recall briefly its main features: CERN are providing a fast-ejection system for the 70 GeV accelerator and radio-frequency particle separators for a beam-line to feed a large bubble chamber. (Progress on the separators was described in vol. 6, page 252 and progress on the fast-ejection system will be covered next month.) CERN teams have access to the machine for experiments carried out in joint groups with their Soviet colleagues.

The first experiment in the collaboration is of a type which usually features among the first to be done on a new machine. It is often known as a 'yield experiment' since it gives information on the number of secondary-particles of the different types which are yielded by targets bombarded by the accelerated proton beam. A more formal title would be 'a measurement of production cross-sections at energies up to 70 GeV'. It is an experiment which does not make heavy demands on the machine performance (like all the other big accelerators, the Serpukhov machine can expect its share of operational problems before it is really tamed), and yet knowledge of the yields of different particles is very important for optimizing the lay-out of secondary-particle beams in the experimental hall.

The accelerated beam will be directed onto an internal target (i.e. a target inside the accelerator ring) and the experiment will measure the number of negative pions, of negative kaons and of anti-protons produced by the proton-nuclear collisions. To complete the information, the intensity of the proton beams which gave these numbers of secondary particles needs to be measured and this is done by monitoring the radio-activity produced in the target. (The target will be brought to the radio-chemistry group at CERN when it is withdrawn from the machine.) In general, an aluminium target will be used.

The CERN component of the joint team has just completed a detailed series of measurements of the same type at an energy of 19 GeV on the CERN synchrotron and the Serpukhov machine may be operated for a while at this energy to give some points for comparison.

In addition to being important for the planning of beams for the Serpukhov experimental programme, the experiment will be a useful pointer, combined with present knowledge of yields at lower energies, as to what can be expected at energies of several hundreds of GeV. It will thus help in the planning of experimental areas for the USA 200 GeV machine and the proposed European 300 GeV machine.

The more specifically 'physics content' of the experiment will be to assemble more data to check various theories about the particle production processes which go on at high energies.

Following the yield study, there will begin a programme of measurements of total cross-sections. For example, the negative pion-proton total cross-section will be measured by guiding the negative pions produced at the internal target to a liquid hydrogen target where they will interact and the absorbtion of the pions can be measured. This is another of the 'first things to do' when a new energy range becomes available. It is expected that, once a sufficiently high energy is reached, the total cross-sections should no longer vary as the energy increases further. Some scientists believe that this levelling out of phenomena will occur only at energies well beyond a thousand GeV (Professor S. Lindenbaum spoke at a recent CERN Seminar, subtitled 'A view of asymtopia', of energies of thousands of thousands of GeV). The measurements at the Serpukhov machine will give some more points at higher energies for the curves.

The CERN team are taking with them most of the assembly of counters and electronics which they used in their experiment at the PS. It includes scintillation counters (which record the passage of a charged particle by giving a flash of light) and a DISC counter (Differential Isochronous Self Collimating: a special type of Cherenkov counter developed at CERN which makes it possible to distinguish between particles which have velocities very close to one another — the use of the DISC counter will be very important for sifting the pions, from the kaons, from the protons at these high energies).

CERN scientists will probably go to Serpukhov in groups of about six at a time and they will be drawn from the team who did the equivalent experiment at CERN — J. Allaby, A. Diddens, A. Klovning, E. Sacharidis, K. Schlüpmann, A. Wetherell, F. Binon, P. Duteil, R. Meunier, J.P. Peigneux, J.P. Spighel and J.P. Stroot. They will probably work at Serpukhov for periods of three to six months at a time and, whenever possible, their families will go with them. Appartments are available in blocks of flats at Protvino, the Laboratory village. The village has grown to several thousand people. The town of Serpukhov itself is about 20 km away and Moscow is about 100 km to the North.

ISR Users' Meeting

On 10, 11 June a large gathering of potential users of the Intersecting Storage Rings took place at CERN. More than a hundred scientists from outside CERN came to the meeting, predominently from the European Universities but also with some observers from Laboratories in the USA. During the two days, the Main Auditorium was packed for a series of lectures and it was obvious that the excitement and the challenge of using this unique instrument for physics is attracting many scientists.

The aim of the meeting was to review the present thinking about how the initial programme at the ISR might take shape and to bring the potential users fully into participation in the evolution of the programme.

Since the beginning of this year a 'working party' of experimental physicists and

The formidable shielding block of closely packed steel ingots, which was used in the neutrino experiments, being re-built to allow another beam-line to be taken to the heavy liquid bubble chamber.

ISR builders have been meeting weekly at CERN to discuss the problems involved in using the ISR for experiments and to clarify ideas on the large-scale detection equipment which will be needed. The working party has been led by E. Picasso and K. Winter. The two-day meeting was a start towards bringing about the largest possible participation of teams from the Universities. This participation needs to begin now, about three years before the ISR is scheduled for completion.

Experiments on the proton synchrotron require a long time of preparation (probably of the order of a year on average) before a team actually begins to receive a beam from the machine but the preparation time for experiments on the ISR will be even longer. A large part of the planning of conventional experiments can go on virtually divorced from the machine supplying the particles and experiments involving major modifications to the PS itself are very rare — one beam-line, for example, can serve a sequence of experiments which come to sit at the end of it. Experiments with the ISR, on the other hand, may often involve major changes in the interaction regions. Special magnets may be needed to separate secondary particles, coming from the interactions of the proton beams, and these magnets will have to be integrated in the magnet lattice of the rings so as not to disturb the continued storage of the beams. Special vacuum chambers may be required in the interaction region where there is ultra-high vacuum (10^{-10} to 10^{-11} torr). Modifications of this type and scale take a long time to plan and then involve a long time for manufacture and installation. It is considerations like this that make it necessary to plan the experiments now.

Discussions at the meeting resulted in the decision that European groups who wish to participate actively in the preparatory work will send 'letters of intent' to CERN. These letters will give some estimates of the number of people who could become involved, the effort they could supply, and the type of physics they would be interested in. All the work which emerges from this stage is to be made immediately available to the European sub-nuclear physics community.

A second meeting is planned for October and it is hoped that, by then, groups from outside CERN will be playing a leading part in the presentation of information.

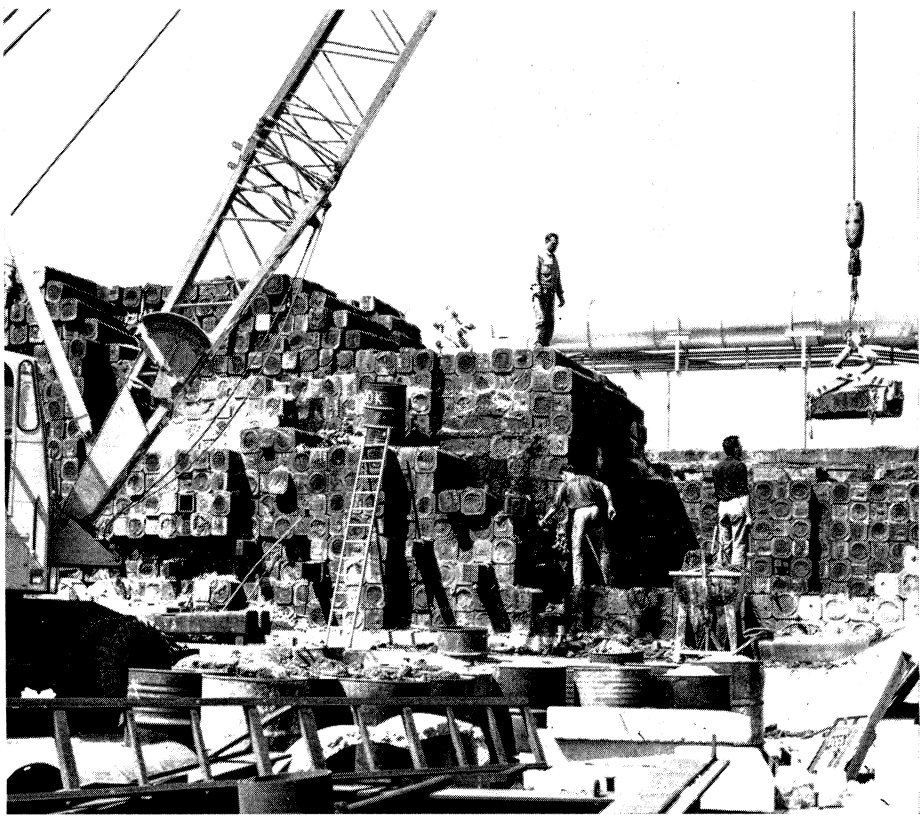
The 1 metre model

In July 1967, the decision was taken to build a large European hydrogen bubble chamber (BEBC). As a preliminary to the construction of this 3.7 m chamber, a model, 1 m in diameter, has been built and was 'cooled down' for the first time at the beginning of June. The model is to be used for some very refined studies of bubble chamber properties. For the benefit particularly of people involved in the bubble chamber field, we present here a detailed description of the model and its scheduled programme of tests.

The European chamber (which was described in CERN COURIER vol. 7, page 148) differs considerably from the chambers at present in operation. The design incorporates a number of new features — the use of a large superconducting magnet to give a field of 35 kG; an arrangement of the expansion system at the base of the chamber (an idea which emerged almost simultaneously at CERN and at Brookhaven in 1965); the use of plastics for the piston and for a floating disc at the bottom of the chamber, and the use of Scotchlite coating on the walls to give 'bright-field' illumination (where the particle tracks are photographed as lines of black bubbles against a bright background). Apart from the design of the superconducting magnet, the greatest problems rest in the need to take photographs through two to three metres of liquid hydrogen. For this the temperature of the liquid has to be kept highly uniform to reduce optical distortion — the temperature gradient in the chamber needs to be about 1/20 of that in conventional chambers.

The model

Construction of the 1 m model began in June 1967 and was finished in May 1968. It is not an exact replica of the large chamber, since it has no magnet and only one 'fish-eye' (as against five) for photography. The problems connected with the



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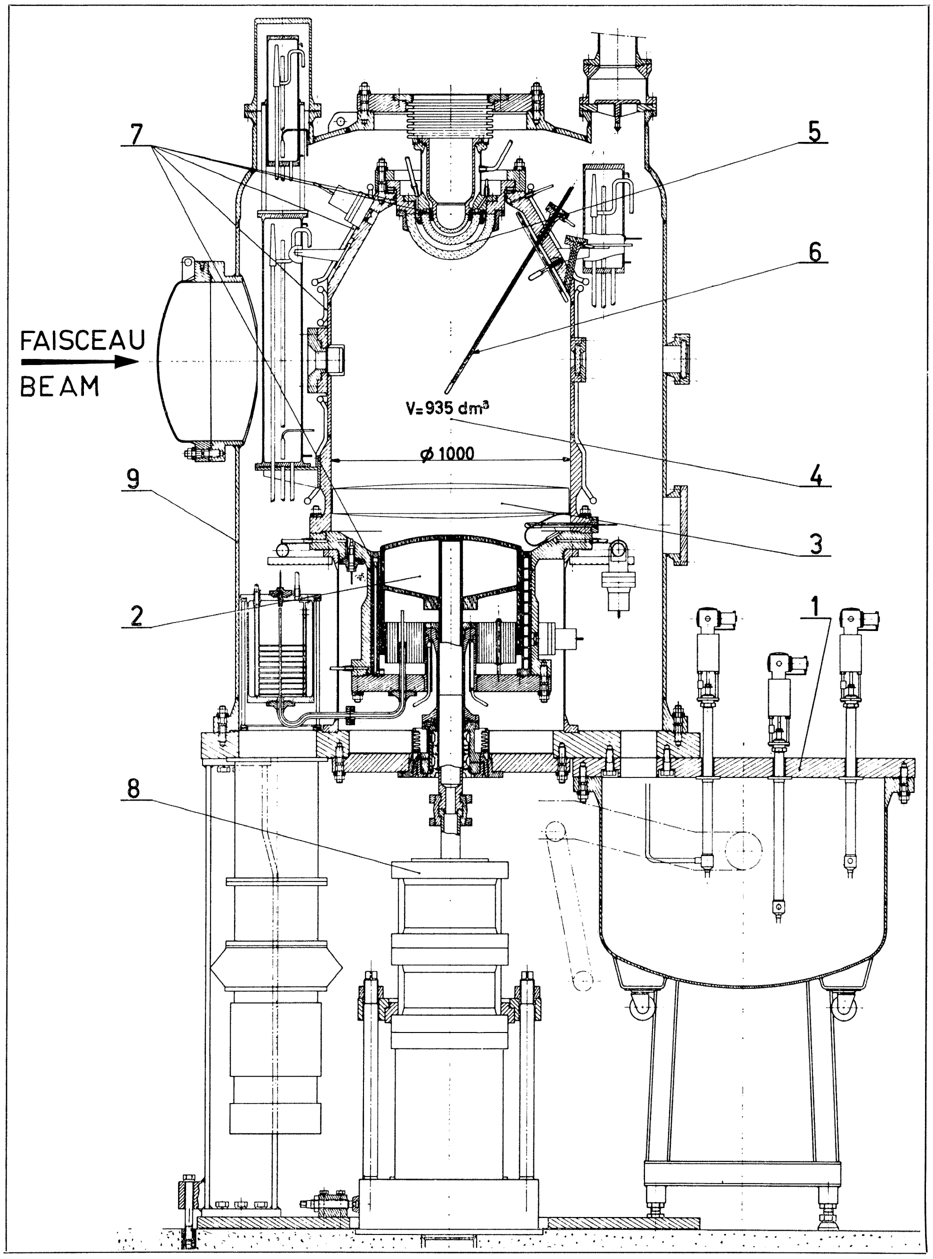


A detailed cross-section of the 1 metre hydrogen bubble chamber model. The components picked out are: (1) control valves, (2) piston, (3) disc, (4) volume of liquid hydrogen, (5) fish-eye, (6) mobile thermometer, (7) heat-exchangers, (8) expansion system, (9) vacuum chamber.

giant superconducting magnet will be solved separately, mainly using the BRARACOURCIX test assembly (see CERN COURIER vol. 8, page 23). Otherwise, the model comprises all the essential components of the BEBC.

The body of the chamber and the vacuum tank (supplied by MAN, Federal Republic of Germany) are of low-carbon stainless steel. There are several apertures — one for the beam window, two for a laser beam, one for the camera window, and two for the installation of mobile vapour thermometers which can measure temperatures in different parts of the chamber.

The piston weighs 37 kg and is of highly novel construction, largely made of a plastic honeycomb material coated with glass-fibre-reinforced epoxy resin. These materials provide a twofold advantage; they reduce the moment of inertia and eliminate eddy currents which are generated in any metal moving in a non-uniform magnetic field producing a troublesome source of heat. The structure of the piston in the model is still in the experimental stage and the information gained from its performance will assist in the development of the piston for the large chamber, which will weigh approximately 1000 kg. The piston skirt, also of reinforced epoxy resin, is shaped like a bell the bottom of which dips into the liquid hydrogen and the top of which holds a volume of gaseous hydrogen which exerts a pressure counterbalancing that of the liquid hydrogen. The temperature of this gaseous cushion, and hence the pressure, is controlled by a heat exchanger. The upper part of the piston is covered with Scotchlite so that experiments on the optical system can begin before the disc, which is still under construction, is installed.

The disc insulates the piston from the rest of the chamber and is of very nearly the same diameter as the piston. It is also of honeycomb construction coated in this case with Mylar, in turn covered with Scotchlite. In order to achieve a density as close as possible to that of the liquid in the chamber, it is intended to fill the disc with gaseous hydrogen via an independent circuit. It will then easily follow the movement of the liquid and convey the pressure changes to the chamber in a uniform manner.

The novel expansion system was constructed by CONTRAVES (Switzerland). It is a forced-servo system in which the required expansion curve is produced by a function generator (with cycles variable from 20 to 80 ms). This signal is amplified and controls an oil feed, via four fast-response servo valves, which actuates the ram. The movement is compared to the control signal and a control mechanism then corrects any differences.

The model has only one aperture for photographic purposes. A simple, flat inspection port is being used for the initial experiments, but will eventually be replaced by a hemispherical one, or 'fish-eye', exactly like those for the larger chamber (see figure). It consists of three concentric hemispherical windows. For safety reasons, the two inner windows will be of quartz (supplied by HERAEUS-SCHOTT, Federal Republic of Germany, cut and polished by SAGEM, France). The outer window will be of B.K. 7 optical glass. The wide-angle lenses (105°) to be used for the larger chamber are at present under examination at ZEISS, Federal Republic of Germany, and SOPELEM, France.

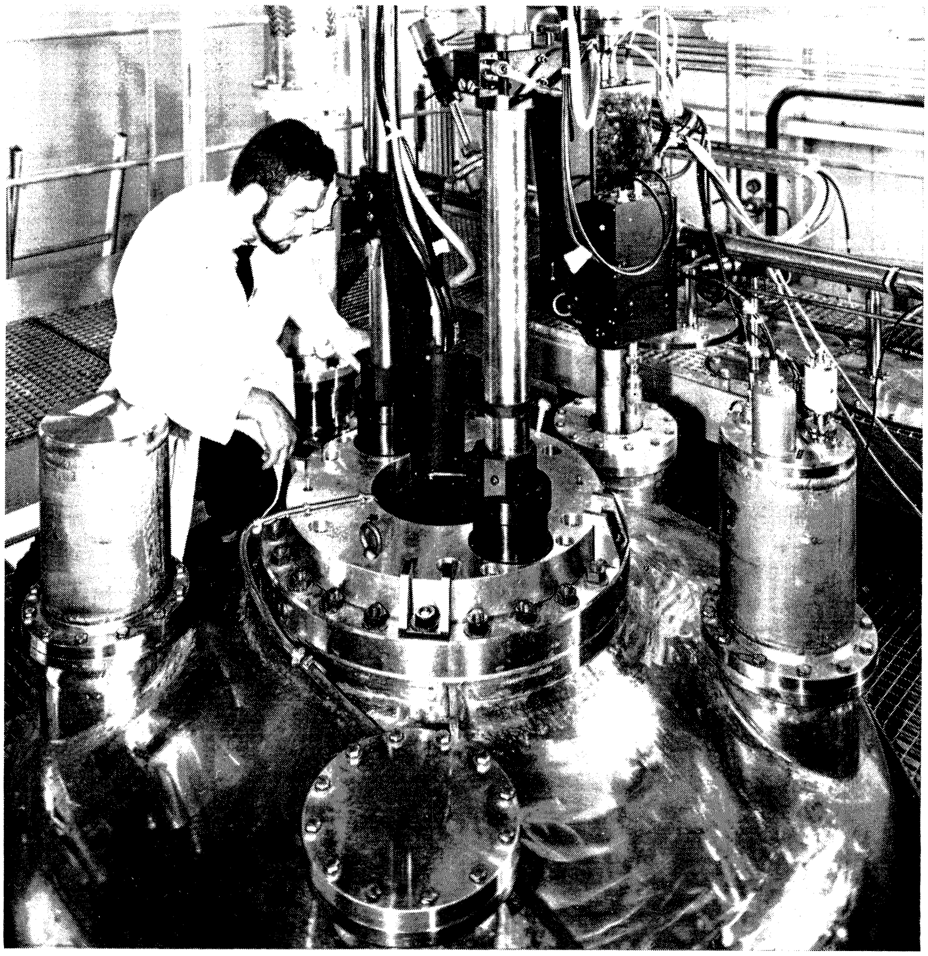
The exchangers in the model operate in open circuit for simplicity, though, to reduce consumption, the circuits will be closed in the BEBC. As well as the three exchangers arranged on the body of the model (one around the fish-eye, one on the dome and the third on the cylindrical section — see CERN COURIER vol. 8, page 99) there is another underneath the piston to regulate the pressure of the gas volume and a final one constituted by the expansion cylinder.

Controls for the model are taken to a separate control room, where all operations, including filling, emptying and rinsing, can be remote-controlled.

Test programme

On 4 June, the model was pressurized at room temperature with a mixture of helium and nitrogen (10 kg/cm² for the chamber and 5 kg/cm² for the vacuum tank). Cooling to 77°K then took place and, after further pressure tests, the chamber was filled with liquid nitrogen. This preliminary test was

A view looking down on the 1 metre hydrogen bubble chamber model. The observation window in the centre of the dome of the chamber body can be seen with a television camera in place. The black cylindres around the dome are used for connecting electrical control circuits and for the hydrogen evacuation lines.



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not essential, but was a safety precaution to do the first filling under pressure with a less dangerous liquid than hydrogen. Tests with hydrogen began on 18 June; they are planned to take place in the following stages, though the plans may be changed depending upon how the experiments go.

First stage: Photographs will be taken of cosmic rays and of Compton electrons generated by a gamma source. The temperature regulation will be checked and the dynamic losses measured as a function of the expansion cycle and the operating temperature. A laser beam passing through the hydrogen will be photographed and will appear brighter than the background. The laser (lent by the University of Heidelberg) will send a horizontal beam through a quartz window into the tank.

The assembly will then be dismantled to install the floating disc and the fish-eye. At the same time, if the results obtained with the laser beam are encouraging, small mirrors will be fitted inside the chamber to reflect the laser beam in the form of a starred concave polygon. The points where the beam crosses will provide reference marks for the measurements on the photographs. The bonding of the Scotchlite on the steel will also be examined and, if necessary, an intermediate layer of Mylar will be applied. It is probable that some of the Scotchlite will be replaced by 'Super-Scotch', which should provide better contrast.

Second stage: When the proton synchrotron begins operation again in October, a particle beam will be taken to the chamber. It will then be possible to obtain more precise measurements of the minimum acceptable size of bubbles, their time of formation, optical distortion, thermal turbulence and the optical contrast.

Third stage: In the spring of 1969, it is hoped to do some tests on the use of a Mylar target filled with hydrogen located in the chamber. Mixtures of neon and hydrogen could be used in the surrounding chamber volume to make it possible to detect gamma rays (see CERN COURIER vol. 7, page 112).

This series of experiments will also involve the development and testing of a large quantity of electronic and pneumatic control equipment, which will afterwards be used directly for the BEBC. It is hoped that a great deal of the equipment, especially the vacuum and control equipment, can be used in the construction of the large chamber.

The detailed features of the large chamber will be frozen by the end of 1968, before the contracts are placed during the first months of 1969. This will be done following the answers to the invitations to tender which were recently sent out.

Allowing eighteen months for construction, the various components of the large chamber should be delivered to CERN by the autumn of 1970. Assembly will take at least seven months, and the first cool-down could then take place towards the middle of 1971.

Ars Antiqua

The series of five concerts organized by CERN in 1968 was brought to a resoundingly successful conclusion on 18 June. The main auditorium was packed for a concert of period music given by the 'Ars Antiqua' ensemble.

The audience thoroughly enjoyed a delightful and unusual musical evening. The performance was given in beautiful costumes of the 17th Century; rare, genuine instruments from the same period were played, and candles were used for lighting. The six musicians were grouped around a processional organ, a very rare instrument 400 years old, with a clean, bright tone which was brought out to the full under the skillful hands of Richard Anthelme Jeandin, Professor at the Conservatoire of Geneva.

The variety of the pieces played, originating from all over Europe, reflected CERN's image. The bold notes of a flourish of brass by Henry VIII of England was followed by an aria by Frescobaldi (1583-1643), a Jewish dance of the 16th Century (which greatly resembled the music of Bartok), and a psalm by Dufay (1474). Then came a fantasia for three viols on the song 'Der Hund' (by Heinrich Isaac, 1450-1517). Everyone enjoyed the fine singing of Antoinette Matthey de l'Etang (soprano) who brought the concert to a close with a cantata for soprano, three viols and organ, composed by Giovanni Riccio in 1520. To complete the list of musicians — Marcel Retchitzky, Daniel Reichel, Elisa-Isolde Clerc and Elfriede John performed on a variety of instruments.

Linac Conference

A brief report of some of the topics covered at the sixth proton linear accelerator conference held at Brookhaven, USA, on 20-24 May. The Editor would like to thank C.S. Taylor for helping in the preparation of this report.

The accelerator builders who think straight met at Brookhaven National Laboratory for the latest of their series of bi-annual conferences. Major features of the conference were the reports on the work that has gone into linac structures over the past two years; increased understanding of space charge effects, which are beginning to trouble many people now that very intense beams can be accelerated; 'factory-type' accelerators; and finally a feeling, rather than any specific pointers, that superconductivity will soon be coming into its own in the design of linacs.

Factory-type accelerators

W.B. Lewis from Chalk River, Canada, opened the conference with a talk on future factory-type accelerators. He concentrated particularly on the Chalk River proposal for an Intense Neutron Generator (ING) — see CERN COURIER vol. 7 page 200. To recall the main parameters: it would be a 1 GeV proton linear accelerator producing 65 mA continuous. This could be used as the basis of a meson factory and also, by firing the beam into a liquid lead-bismuth target, could produce 10^{16} neutrons/cm^2/s. A long term aim is to find a way of producing neutrons other than by nuclear fission at a competitive cost.

Other accelerators which come under the heading of 'factory-type' are the cyclotrons of Zurich and British Columbia (see page 136) which were of course not covered at this conference, and the Los Alamos Meson Physics Facility (LAMPF).

LAMPF

Since LAMPF is the most formidable proton linear accelerator at present under construction, and was the subject of several papers at the conference, it is worth describing the machine in some detail.

It is designed for a peak proton energy of 800 MeV, with an average beam current of 1 mA. The duty-factor (the percentage of time that the machine is producing beam) is 6 to 12 %. These are the parameters which qualify the machine for the title of 'meson factory'. The energy is sufficiently high for copious production of muons and pions; the average current is high (ten thousand times the intensity of any existing accelerator at that energy) and the duty-factor is way above the usual 0.1 % for a linac.

To achieve these parameters, a lot of new thinking has had to go into the design which has evolved as follows:

The input will be from an expanded duoplasmatron ion source and a short accelerating gap giving 750 keV (as used on the CERN PS, see vol. 6, page 88). Then come four tanks which are of the Alvarez type (but probably with some modifications to the structure — see the section on Linac Structures below), operating at 201.25 MHz and taking the beam energy to 100 MeV.

For energies much above 100 MeV, the Alvarez structure becomes inefficient and LAMPF therefore changes to the waveguide type where the particles are swept along, as it were, on the crest of a radio-frequency wave. In the Alvarez structure, particles are accelerated by r.f. fields between drift tubes and are hidden inside the drift tubes when the fields are decelerating. The fields between the drift tubes are in phase — all pointing the same way at the same time — and this is known as the zero mode of operation. Power is propagated along a waveguide accelerator more efficiently if the $\pi/2$ mode is used. Here a series of cavities have fields which are, at one point in time, successively accelerating, zero, decelerating and zero (the decelerating fields swing to accelerating as the particles reach them). The zero field cavities, however, waste half the accelerating length of the linac and the Los Alamos people have moved them out to the side as shown in the figures. The waveguide section of LAMPF is therefore known as 'side coupled' operating in the $\pi/2$ mode. It operates at 805 MHz and has 90 tanks taking the protons from 100 to 800 MeV.

The total length of the accelerator is 850 m and the average r.f. power consumption at 6 % duty cycle is 3 MW. Construction of the accelerator began early this year and is scheduled for completion in 1972. The cost estimate is $55 million.

Los Alamos have been working on several electron models prior to finalizing the LAMPF design and their latest, which came into operation last December, is a 20 m linac capable of energies from 20 to 35 MeV using side-coupled cavities. It is working successfully with high intensity and a 6 % duty cycle and is also being used to study the extent to which computer control of the accelerator can be reliably achieved.

MTA

Before leaving the factory-type accelerators it is interesting to recall what was achieved some sixteen years ago with the 'Materials Testing Accelerator' at Livermore, USA. This monster of a machine has been largely dismissed as a failure since it did not achieve its aim, originally promoted by E.O. Lawrence, of using intense deuteron beams to produce weapons quality plutonium from 'depleted' uranium. It was made economically unsound by the dramatic fall in cost of natural uranium and the project was abandoned in the mid 50s. Nevertheless, the MTA design team, though their project did not succeed and though their aim was far removed from that of present-day accelerators, made contributions to accelerator technology which underlie many of the recent developments.

Construction of the MTA was completed in January 1952. It was a linear accelerator with a single huge vacuum vessel that you could drive a truck into. It measured about 28 m long by *19 m in diameter.* The drift tubes weighed up to 30 tons each and were so large you could crawl through the bore ... and face an unhealthy drop if you fell out. (That compares with present drift tubes bores of a few centimetres.)

The required deuteron beam intensity was never achieved and the machine suffered from fierce sparking problems. But the list of achievements is considerable. MTA had the first expanded duoplasmatron type ion source — this type has only recently come into vogue on the high energy accelerators leading to very high linac currents on the CERN PS, for example. The team developed vacuum techniques so far as to reach a pressure of 10^{-7} torr in their huge tank — in 1952 so high a vacuum had only been achieved on a laboratory scale. A similar feat was to put 9 MW of r.f. power into the tank. Even their breakdown troubles proved useful since they sparked off the work at Berkeley which resulted in the famous

In Figure 3, an artist has extracted the main features of LAMPF — Los Alamos Meson Physics Facility — an 800 MeV proton linear accelerator.

Figure 1 shows the structure of a waveguide accelerator which operates in the $\pi/2$ mode. By moving the zero cavities (cavities with no field in them) out to the side, the alternate cavities actually seen by the beam have their fields in opposing directions as shown.

Figure 2 is of a portion of a waveguide accelerator with 'side-coupled' cavities (the boxes sticking out above and below the accelerator pipe) such as will be used for the higher energy portion (above 100 MeV) of LAMPF. (Photos Los Alamos)

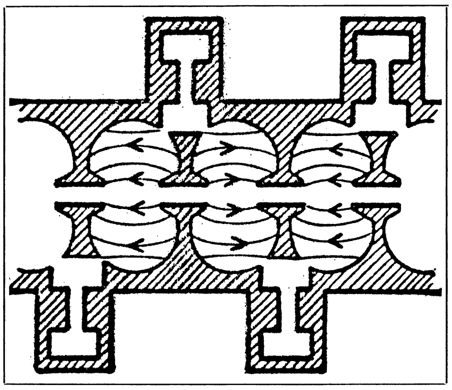


Figure 1

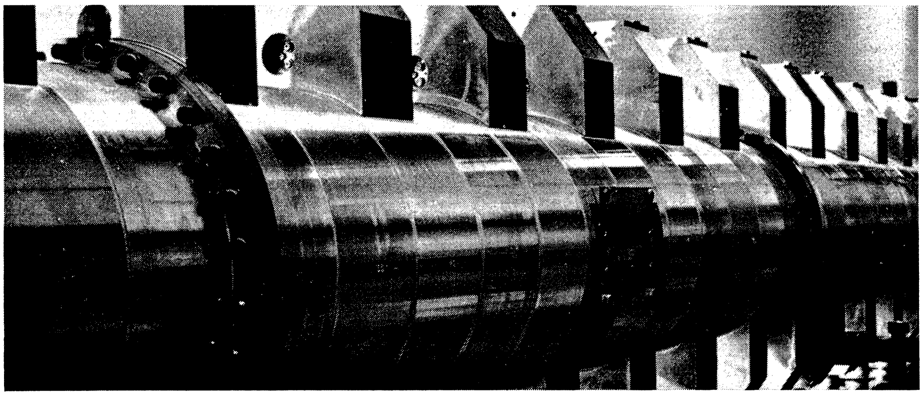


Figure 2

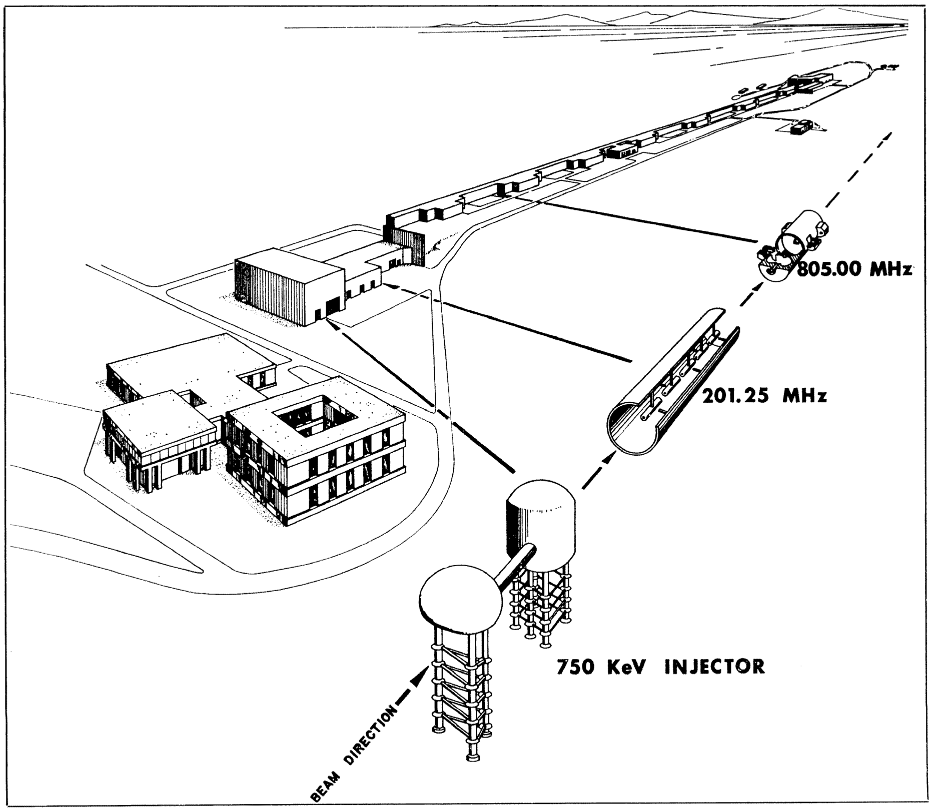


Figure 3

Kilpatrick criteria on breakdown. Problems of beam loading, beam control and focusing were mastered and a proton beam intensity of ¼ A was reached in part of the accelerator. This still stands as the world record in proton linac intensity.

Finally, a sequence of events has linked MTA to CERN in a most roundabout way. The MTA team initiated the use of copper-clad steel for their linac and produced tons of it. When MTA was dismantled, some went to build the new Bevatron injector, some to build the Yale HILAC (Heavy Ion Linear Accelerator), and some to build the Manchester HILAC. Some surplus from Manchester found its way to the Rutherford Laboratory, and from Rutherford some came to CERN to build the 3 MeV linac model which has just been completed.

Linac Structures

This topic is one which has been intensively investigated over the past two years, chiefly at Los Alamos, at Brookhaven and at CERN, and a very intriguing position has now been reached. The interest of Los Alamos is obvious from the description of their project above. Brookhaven's concern is in relation to the 200 MeV linac which is part of the improvement programme at the Alternating Gradient Synchrotron. (Weston also have an interest here since, for the 200 GeV project, they hope to take over the Brookhaven design in its essentials.) At CERN, a good deal of consolidating work has been done with model structures (see the photo on page 100 of the last issue) and G. Dome gave a comprehensive paper on the theory of compensated structures.

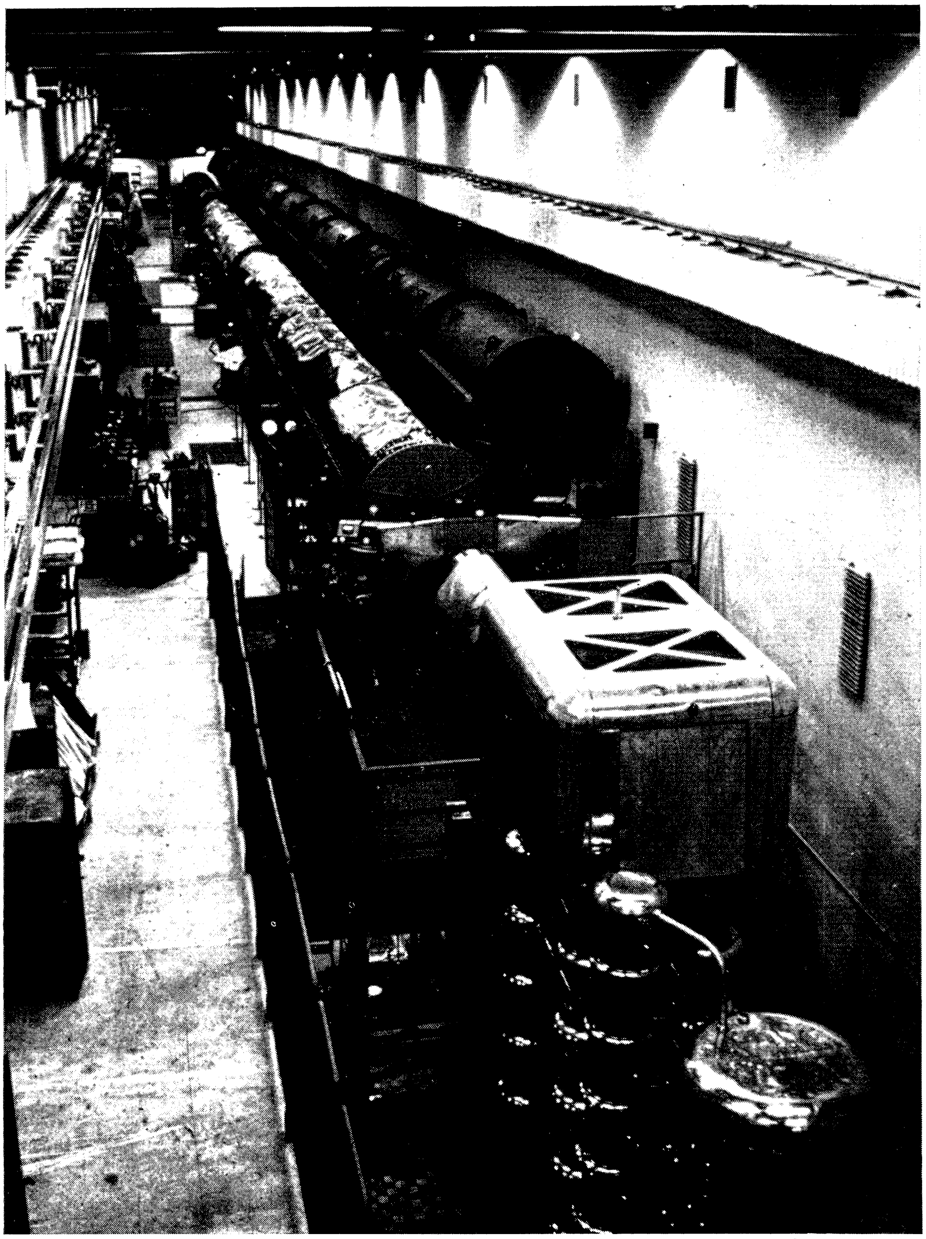
This work has been prompted by the need to cope with the heavier beam loading that will be experienced with the more intense beams that linacs are now called upon to produce, and to improve on the efficiency of the Alvarez structure for higher energies. The aim is to modify the simple Alvarez structure by making the drift tube supports (or by introducing other posts) in such a way as to change the r.f. characteristics of the linac tank. This can increase the coupling between the separate cells of the linac. The velocity at which power is propagated along the structure is improved and the various modes in which the tanks can resonate are pushed

The linear accelerator at Serpukhov. There are three tanks, seen in the photograph with their vacuum lids removed, taking the proton beam to an energy of 100 MeV. On 15 February, an intensity of 100 mA at full energy was reached, an outstanding achievement for a linac of such high energy.
(Photo Serpukhov)

further apart giving higher stability to the r.f. fields. It also reduces the mechanical tolerances involved in constructing the linac.

A considerable variety of structures have been put forward involving drift tube supports of different thicknesses and orientations. Los Alamos are proposing a 'post-coupled' structure which has a single drift tube support and a post projecting from the side of the tank in the plane of the drift tube, though not actually connected to it. Brookhaven are proposing four drift tube supports at right angles (they need spring-loaded connections so that they can be detached when it is necessary to get into the tank).

A great deal has been learned about the properties of such structures, but as a sobering thought it should be noted that, with long structures of the simplest uncompensated type, a beam of 100 mA has recently been taken to 100 MeV on the Serpukhov linac. A question linac designers have to ask themselves before going on to the final hardware is, 'Is your structure really necessary?'



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Space charge effects

Another problem which has raised its head with the advent of high intensity beams is that of space charge. It also has received a lot of attention since the last linac conference. The session on space charge opened with a review, by P. Lapostolle from CERN, of bunching problems in the presence of space charge.

Mrs. R. Chasman from Brookhaven has carried out a thorough investigation, developing a computer programme which adds the effect of space charge to the normal six dimensional approach to beam dynamics in a linac. She traces, for example, a 100 mA beam through a linac structure and computes the effect on a single proton of the proximity of all the other positive charges in the beam. Beam 'blow-up' (loosely speaking — increase in the cross-section of the beam and the angles that the protons travel with respect to the axis of the beam) due to transverse-transverse coupling and to transverse-longitudinal coupling could be identified, and it emerges that the 'blow-up' is not affected very much by the linac parameters, implying that the beam behaviour is dominated by the space charge effect.

Other topics

J.M. Lefebvre from Saclay reported on the progress of the new linac which is to replace the existing 3.6 MeV Van de Graaff as injector for the 3 GeV proton synchrotron 'Saturne'. He was able to announce that, in the middle of May, the linac had accelerated a proton beam (1mA) to the design energy of 19 MeV for the first time. It will be coupled to Saturne in about six months' time and will considerably improve the performance of the machine.

A new-comer to the agenda of a linac conference was the Electron Ring Accelerator (discussed in full in CERN COURIER, vol. 8, page 28). A.M. Sessler gave a paper concentrating on the difficulties which might confound the high hopes for this exciting new accelerating principle. Development of ERAs is under way at Berkeley, USA, and Dubna, USSR, and Sessler remarked that, by the time of the next conference, 'we should know whether to talk of a new era or of an old error'.

An aerial photograph taken some months ago of the Alternating Gradient Synchrotron at Brookhaven National Laboratory. Coming from the wheel-shape of the machine can be seen the path cut through the woods for the 200 MeV linac which is to be constructed as part of the AGS improvement programme. Construction of the building to house the linac has now started. (Photo Brookhaven)

The 750 kV accelerating colomn of the new 19 MeV linac at Saclay. In a very neat design the Saclay team have incorporated the duoplasmatron ion source, short accelerating gap and the Cockcroft-Walton set producing the high voltage, all in one unit which is enclosed in a tank filled with a carbon-dioxide/nitrogen mixture under pressure to reduce sparking problems. (Photo Saclay)

Some of the work on, or in connection with, the CERN PS linac was covered by C.S. Taylor and D.J. Warner. The progress report on the performance of the linac concentrated particularly on the success of the expanded duoplasmatron ion source and high gradient colomn which has led to currents up to a maximum of 130 mA being accelerated to 50 MeV.

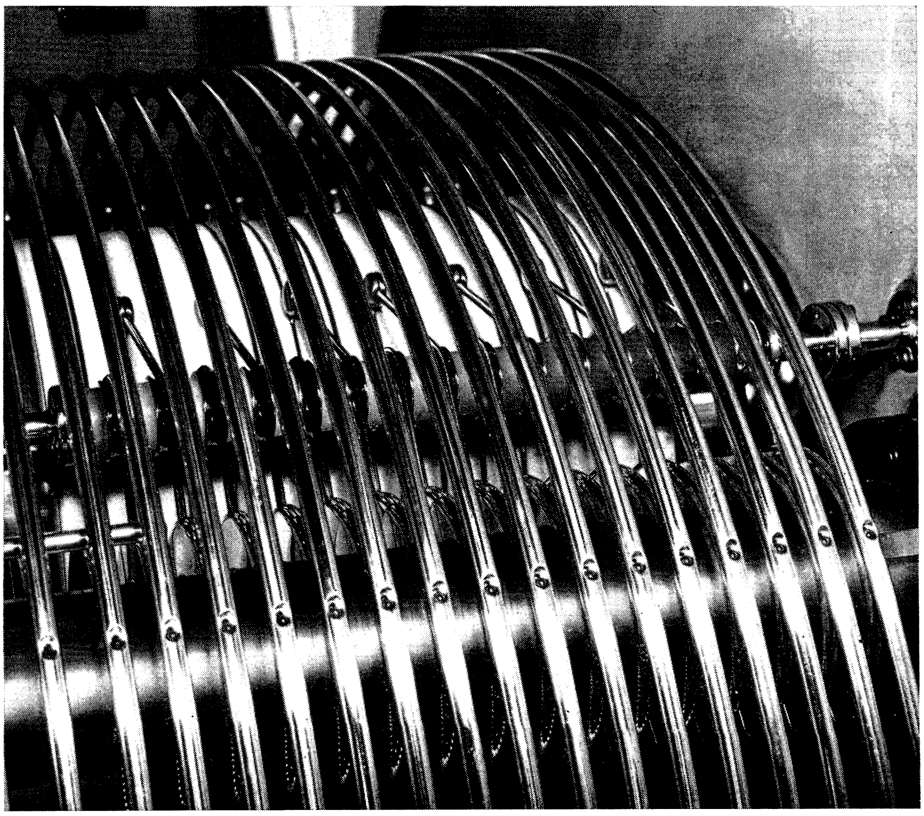
Mention was made of an unexplained observation on the PS linac beam when it was accelerated to 10 MeV and then allowed to drift over 24 metres. Unexpected beam blow-up occurred but the effect did not repeat itself when the same test was done with higher energy beams. Further investigation will be carried out during the present PS shutdown.

The heaviest beam loss in linacs usually occurs at low energies and some thinking is being given at CERN to increasing the energy of pre-injectors to above 1 MeV. Also, to understand better what is happening particularly at the low-energy end of a linac, a 3 MeV model linac (mentioned above) has been built for experiments.

Another development reported was the coupling of the emittance measurement equipment on the PS linac to the IBM 1800 computer in the Main Control Room. A typewriter can print out the phase-space area and the current distribution inside it.

Finally, we report a contentious conclusion reached by A. Pearson from Chalk River who discussed the philosophy of computer control. This subject is growing in importance in the accelerator world. In the USSR, work on a 'cybernetic' accelerator where the computer is an integral part of the machine operation has advanced to the stage where a 1 GeV model has been built. Los Alamos are planning extensive computer control of LAMPF and other Laboratories are sampling the possibilities (e.g. injection at Berkeley, ejected beam at Rutherford...)

Pearson brought the twelve years experience of computer control of reactors into the discussion and stated that, in his opinion, it is never easier to make changes to the software of a computer programme than to go down to the machine and make changes to the hardware. This opinion was questioned by other speakers but has certainly provided food for thought.



News from abroad

TRIUMF

The Canadian government announced, in April, initial grants amounting to $1.3 m for a cyclotron to be built at the University of British Columbia. The project is known as TRIUMF, an acronym for TRI-University Meson Facility since it was initially proposed by three Universities — Victoria, Simon Fraser and British Columbia. The University of Alberta joined the group in 1967. TRIUMF is intended to provide an advanced instrument for intermediate-energy physics to serve particularly the scientists on the West Coast of Canada.

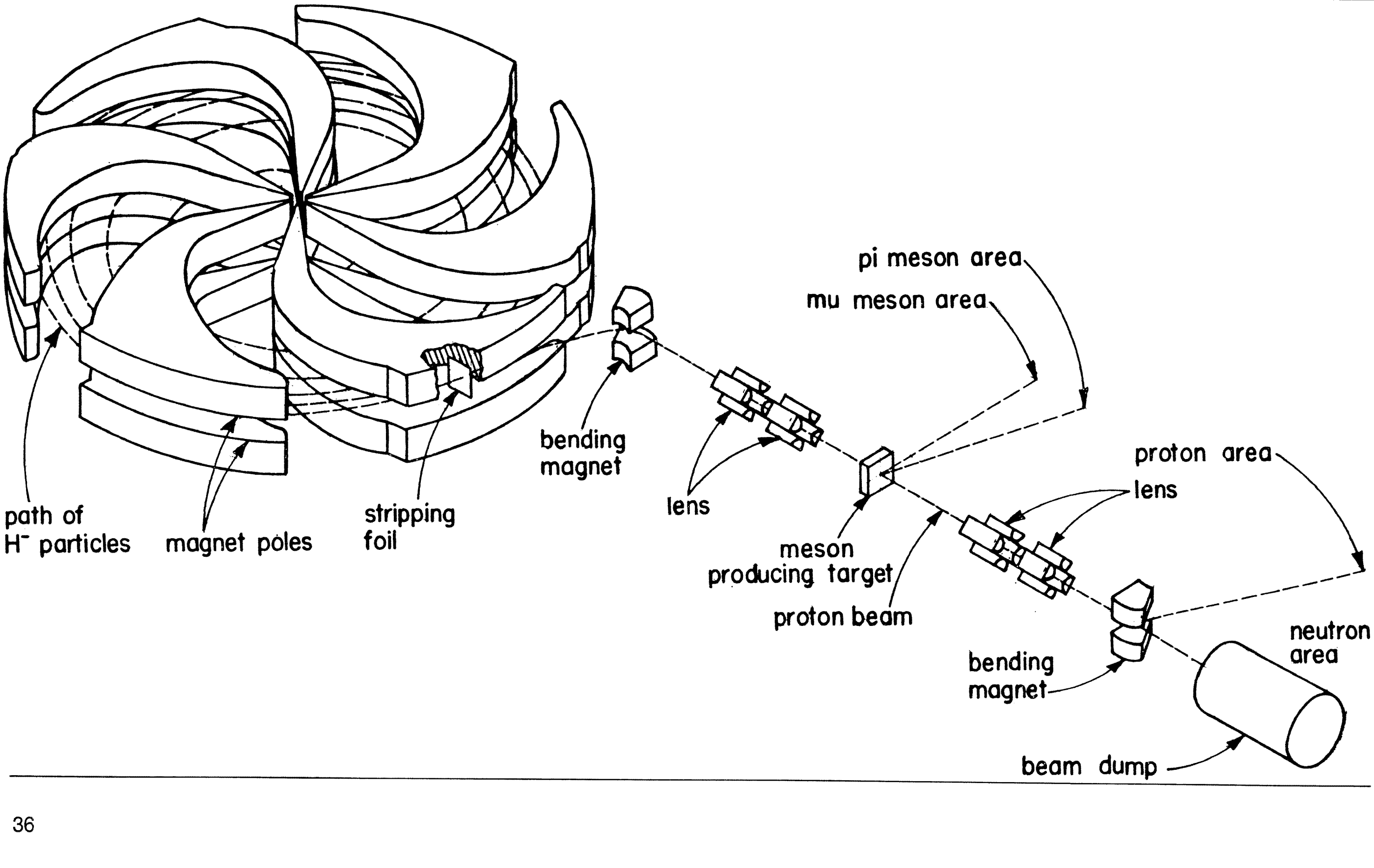
Together with the Zurich cyclotron (which will be covered in a future issue) and the Los Alamos linear accelerator (see page 132), TRIUMF will be a major centre for meson physics research as from about 1974.

By incorporating two comparatively recent advances in cyclotron technology, it will be able to produce protons in the energy range 200-500 MeV with a beam intensity a thousand times higher than at existing equivalent machines. Research will be possible using the proton beam itself, intense beams of pions and muons and a high flux of thermal neutrons. TRIUMF also has the great advantage that all these beams can be produced and used simultaneously (see Figure).

One of the two advantages which yield the higher performance figures for the machine is the use of sector-focusing. This involves replacing the conventional cyclotron magnet by specially shaped magnet sectors which introduce strong (or alternating-gradient) focusing and maintain a constant revolution frequency for the particles so that the r.f. accelerating frequency can also be held constant (rather than adjusting to the revolution frequency as in the synchro-cyclotron).

The second development involves producing and accelerating a beam of negative hydrogen ions (H^-) rather than protons. In the ion source an electron is added to the hydrogen atom and it is this negative ion which is injected into the cyclotron. When the desired energy has been reached, the ion is stripped of its two electrons by being passed through a very thin foil (for example, 0.00004 cm berylium), thus releasing the proton. The advantage in this procedure is that, since the protons are of opposite charge to the accelerated ions, the magnetic field of the cyclotron bends the protons out of the machine. This circumvents one of the major problems of cyclotrons which accelerate protons — the problem of extracting the protons. Extraction efficiencies on proton cyclotrons rarely exceed 50%, while TRIUMF will achieve 99%. Overall efficiencies of TRIUMF will be at least 80% at full energy, rising to 95% at lower energies, the losses arising from dissociation of the negative hydrogen ions and not from the extraction process.

Negative ion cyclotrons require, however, a bigger magnet and a lower vacuum (almost 17 m overall diameter and 10^{-7} torr in TRIUMF) than their proton equivalents. The idea of H^- cyclotrons has been developed principally at University of California, Los Angeles where it was first shown to work in 1961. (50 MeV machines accelerating H^- ions are now in operation at UCLA and at Manitoba.) The design of TRIUMF



A schematic diagram of TRIUMF. The way in which meson, proton and neutron research, can be carried out simultaneously can be realized from the lay-out of the extracted beam-line.

A 1/20 scale model of the TRIUMF magnet. Four Canadian Universities are now involved in this cyclotron project — University of British Columbia is responsible for the cyclotron itself, University of Victoria for the beam-transport system, Simon Fraser University for the neutron dump facility, and University of Alberta for one of the large experimental areas and the computing and data handling facilities.

owes a lot to a similar proposal from UCLA which was turned down in favour of the higher energy Los Alamos linear accelerator.

A few further features of the machine are as follows. Because of the need for high vacuum, the ion source, with a 10 mA output current, is external to the cyclotron and the beam is injected axially at 200 keV. The r.f. system operates at a frequency of 23.8 MHz (the rotation frequency is 4.76 MHz) and gives a maximum energy gain per turn of 400 keV. There are six magnet sectors, each weighing 580 tons, providing a field rising to 5.93 kG at the 500 MeV orbit. The macroscopic duty cycle of the machine is 100%.

The total cost of the 'meson-workshop' to be built around TRIUMF is estimated as $27 million and the machine is expected to be in operation by 1974.

Weston Easter Egg *

The fertility of the group working on the American 200 GeV project continues to be made manifest — they have laid an egg and are looking at it. A proposal to include a storage ring in the main ring tunnel was resurrected by R.R. Wilson over Easter week-end and became known as the Easter Egg.

The purpose of the Easter Egg is to ease the problems of injection into the main magnet ring and to take the pressure off the booster, the most difficult component of the new generation of accelerators. The machine design described in CERN COURIER vol. 8, page 31, involved a fast-cycling 10 GeV booster operating at 15 Hz. Thirteen pulses from this booster fill the circumference of the main ring in 0.8 s, during which time the magnetic field is held constant at about 500 g. This stage in the magnet cycle is known as the 'injection platform'.

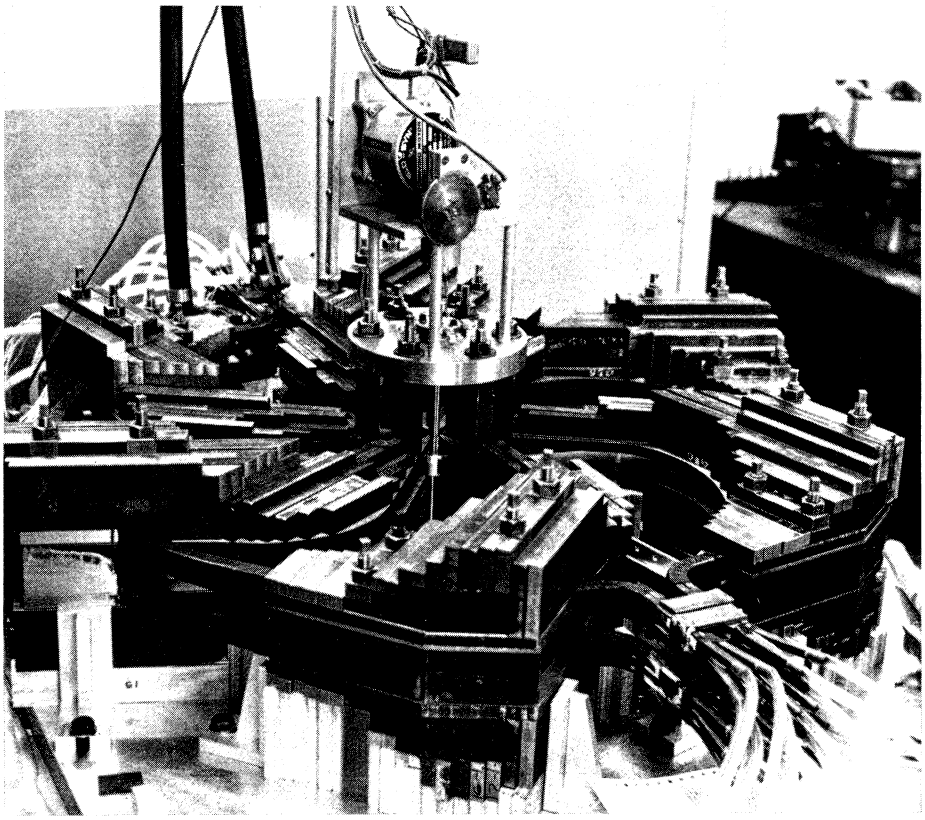
If a storage ring, operating with a fixed magnetic field of 500 g, were included in the main ring tunnel, it could be fed continuously with protons from the booster (over the whole magnet cycle) and injection into the main ring would be a straightforward transfer from the storage ring. There would be no need for an injection platform and the booster could operate at a lower repetition rate (5 Hz). While retaining the design intensity of 1.5×10^{13} protons per second (running without flat-top), the storage ring would make it possible to reduce the number of protons per pulse or to increase the time for acceleration (since the 0.8 s filling time would be eliminated). The lower repetition rate of the booster would more than halve the cost of its radio-frequency system and go a long way towards financing the storage ring itself.

The addition of the Easter Egg adds a further stage to the machine but it is a very easy stage to design and construct though injection and ejection into and out of the egg may be complicated.

It could consist of an iron box of rectangular cross-section strung up from the roof of the main ring tunnel with simple magnets (coils wrapped around to provide the bending and focusing fields) with no precise alignment.

A first look at the Easter Egg in relation to the 300 GeV design indicates that, because of the different acceptances built into the two machines, it would not be as interesting for the European machine. The Egg may not prove fertile for the American machine either, but it is an interesting idea and is yet another reminder that the excitement really begins when the project team finally gets down to the detailed design of the accelerator.

** We have just learned from NAL that the Egg has been dropped.*



Logic from Rutherford

On 27-29 May, an exhibition of equipment from eight UK firms was held at CERN under the auspices of the Scientific Instrument Manufacturers Association (SIMA). It included exhibits of instruments for low temperature work, high vacuum conditions, radiation measurements and fast electronics, and examples of superconducting materials.

Among the fast electronics exhibits was the Miniature Logic System manufactured by Eliott Process Automation Limited which has evolved from the work of an electronics section at the Rutherford Laboratory led by P. Wilde. (This is the work referred to in the last issue of CERN COURIER, page 107.) The section was confronted with the task of developing fast electronics, to cope with the very high rates at which counter and spark chamber experiments accumulate data, at a time when no appropriate system was commercially available from Europe.

In many experiments now being carried out at particle accelerators, hundreds of electronic units can be involved in distinguishing the required event from a host of others, in controlling the firing of spark chambers, in feeding information on the good events to a computer and so on. The electronics take the decisions involved in performing these various operations and are often referred to as the logic. In order to take advantage of the high speeds and multiple detection capabilities of modern detectors, and of the insatiable appetite of modern computers, the logic has to be fast — making decisions on a nanosecond timescale.

The Rutherford system overcomes two limitations in speed. It uses tunnel diodes and tunnel rectifiers, capable of operating at rates up to 180 MHz, for the stages where the fastest logic is needed, reverting to transistors (capable of up to about 80 MHz) only for stages where slower speeds are acceptable. It also reduced the physical distances over which pulses had to be passed. The importance of this can be realized from the fact that transferring pulses from place to place eats up time at the rate of about 5 ns per metre.

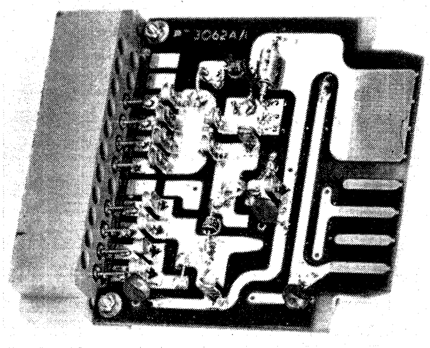
The electronic circuits in the system are standard but what is new is the way in which they can be packed together to form an extremely compact and versatile assembly. Individual circuits are mounted on miniature cards 8×6 cm^2 and up to 62 of the cards can be stacked vertically in a rack unit which supplies stabilized power to each card via connections on the back edge. Connections between the circuits are made with miniature co-axial cables.

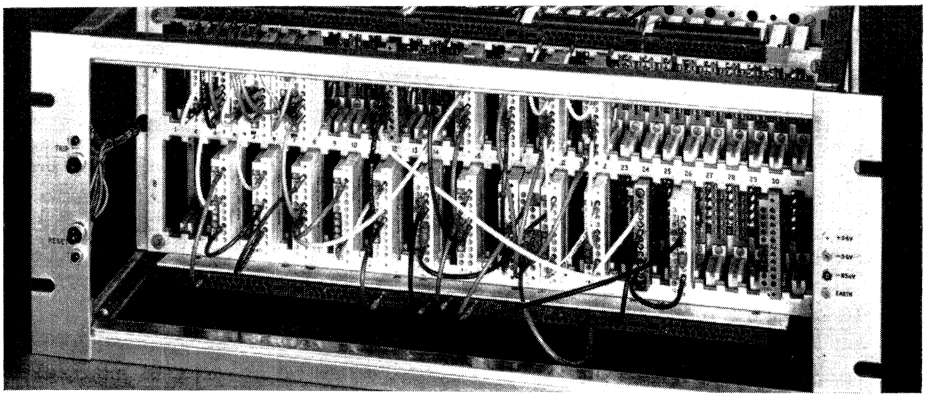
The system was first used (with success) in an experiment at the Rutherford Laboratory to measure asymmetries in negative kaon scattering on polarized protons. The team was led by J. Thresher who will also lead a team coming to CERN in the Autumn bringing eight racks of the Miniature Logic System with them.

One of the cards, 8×6 cm^2, carrying a circuit used in the 'logic' developed at the Rutherford Laboratory. The commercial version has small changes particularly in its connection supports.

A front view of one of the rack units showing how the cards are slotted in, a maximum of 62 per rack, with very short leads connecting the individual circuits.

(Photos Rutherford Laboratory)





LOOKING INTO THE FUTURE

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The system energy resolution is improved by fitting a cooled preamplifier first stage. Field effect transistors, specially selected for low temperature operation, are thermally 'floated' at 30-70°C above liquid nitrogen temperature to optimise their contribution to the spectral peak width. (Ref. Smith and Cline, IEEE Transactions on Nuclear Science, June 1966, Vol. NS-13, pp 468-476).

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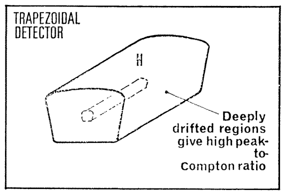

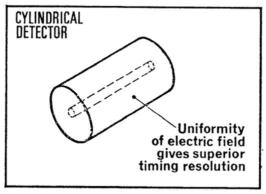

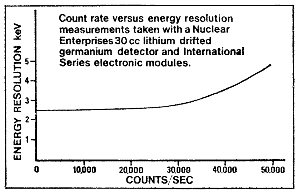

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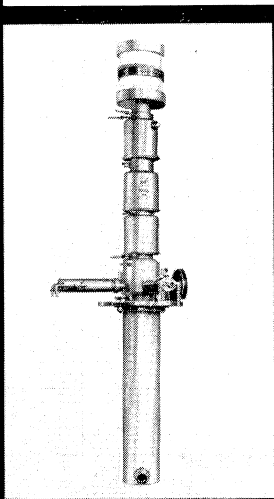

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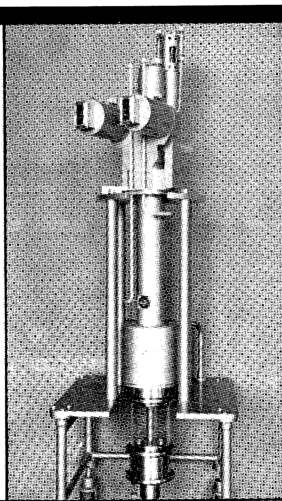
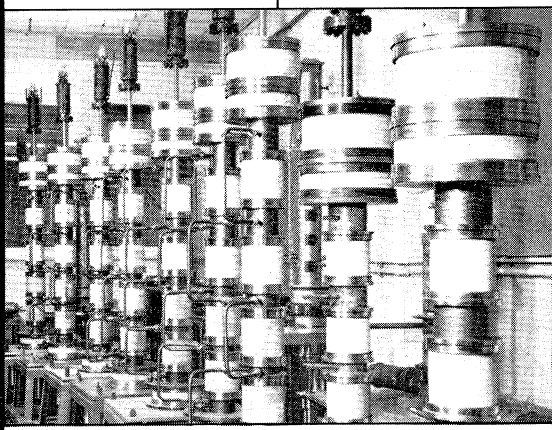


F 2042 (KA 437)
30 MW cr/25 kW moy.
Bande S



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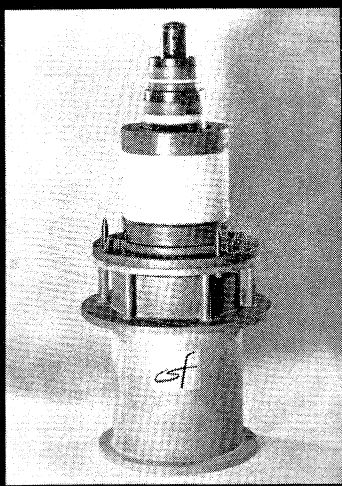

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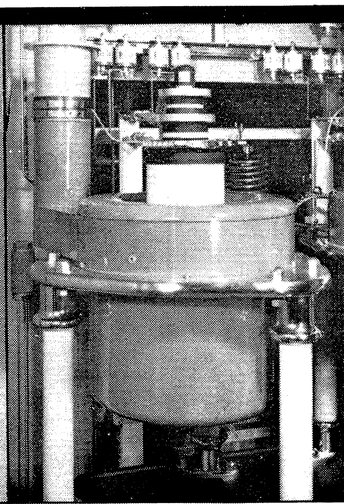
18 MW



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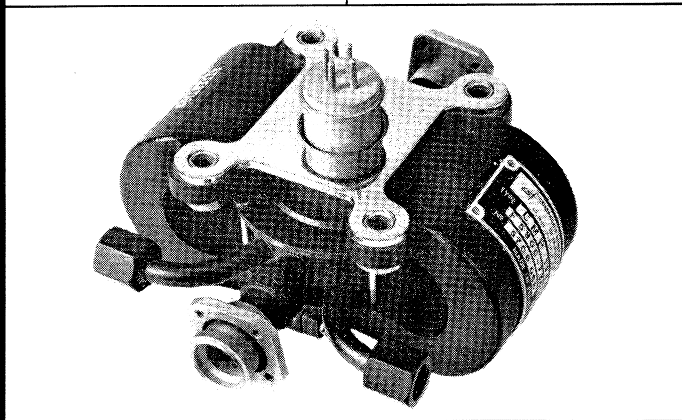

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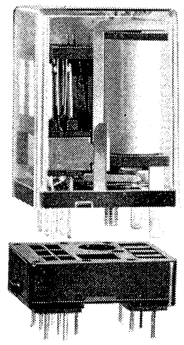

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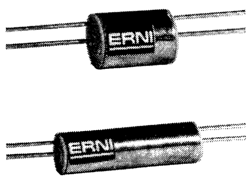

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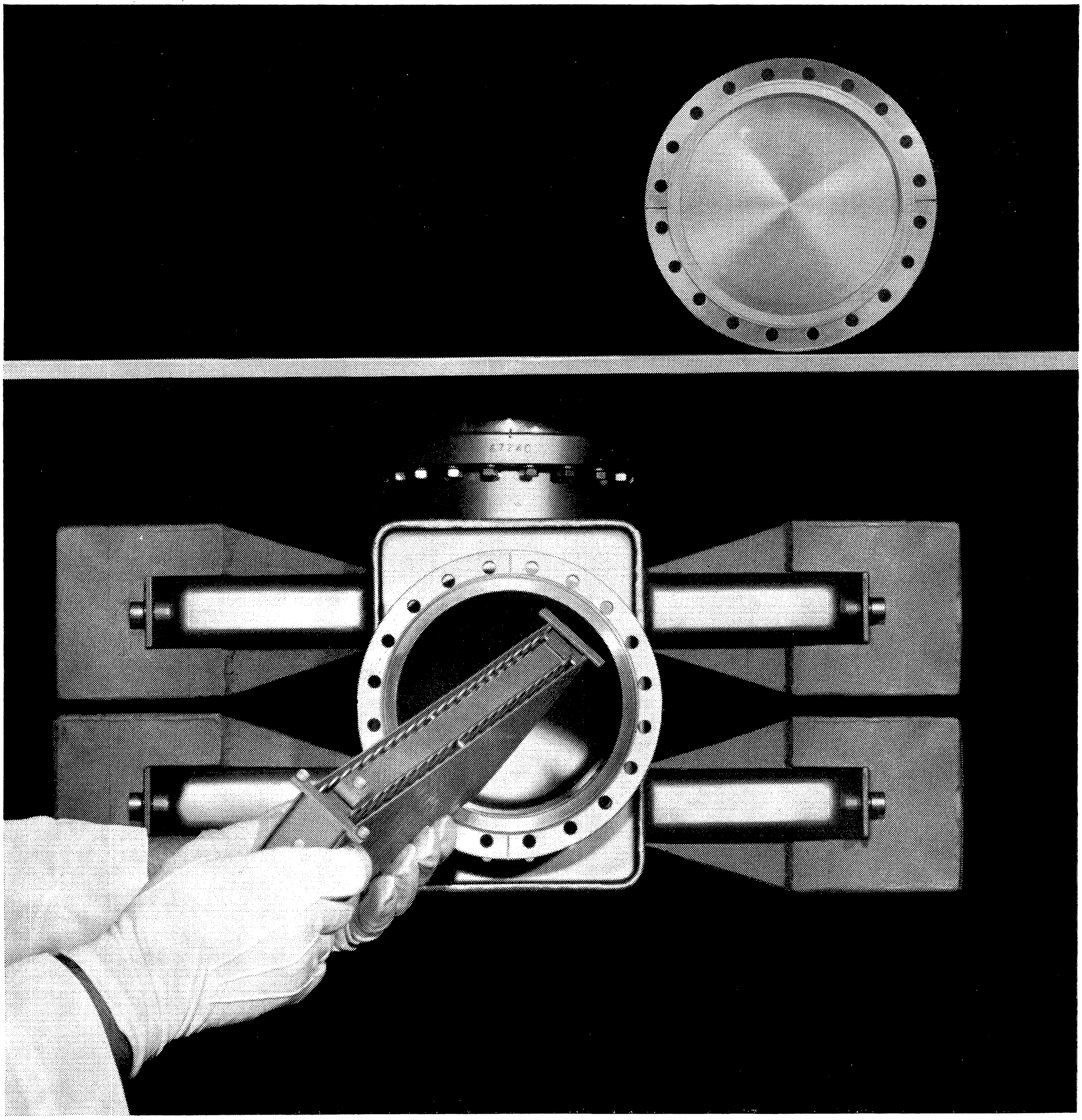

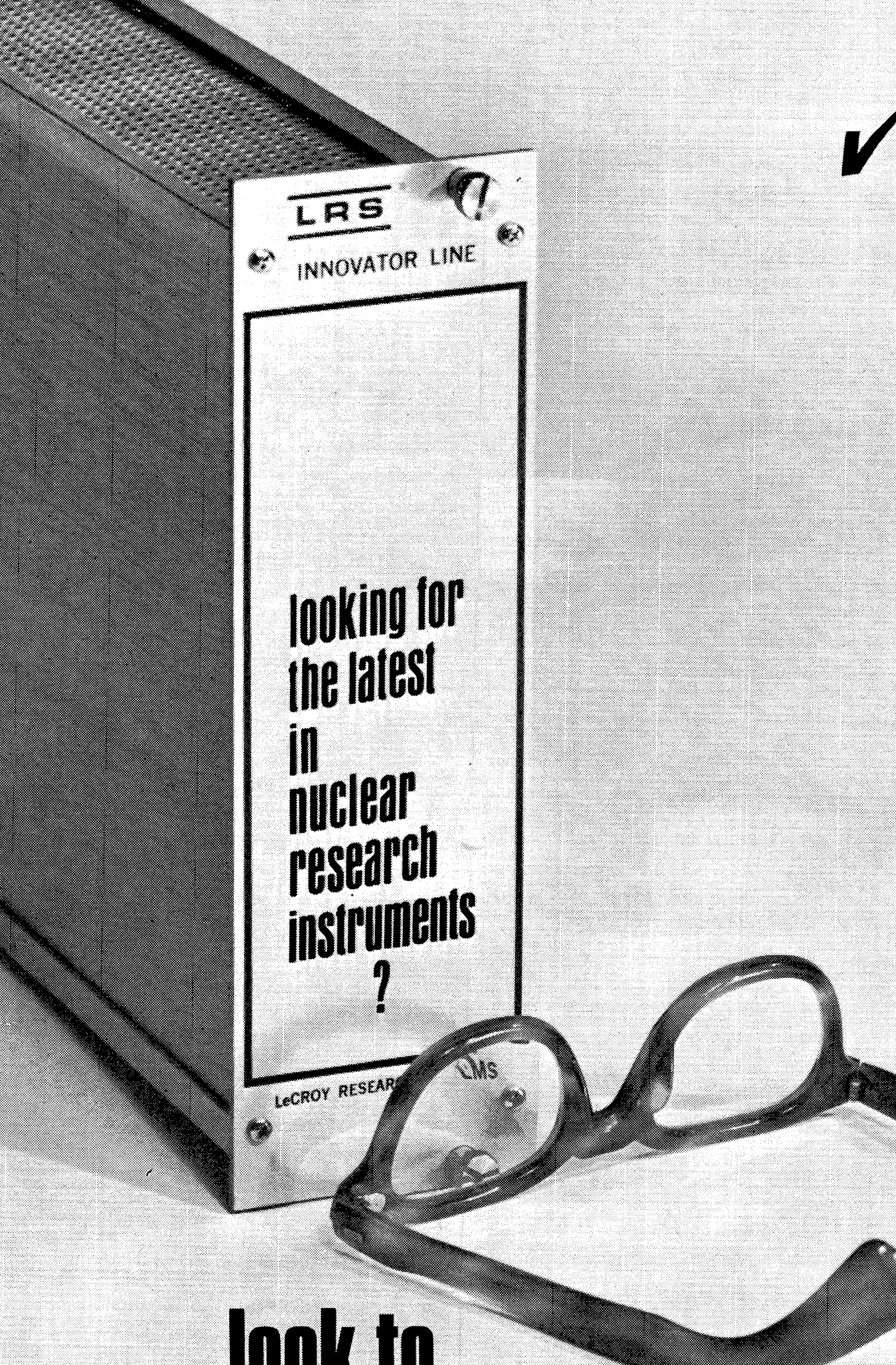

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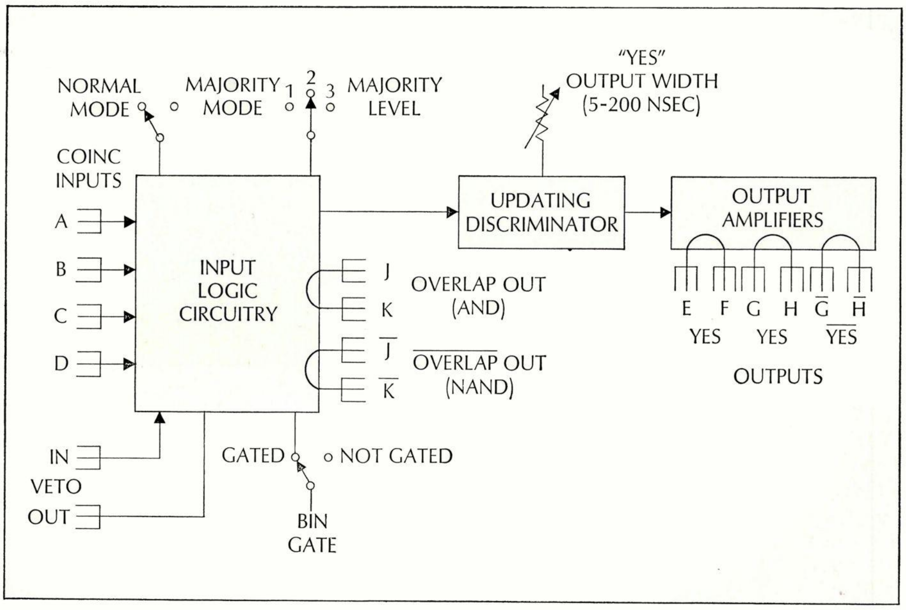

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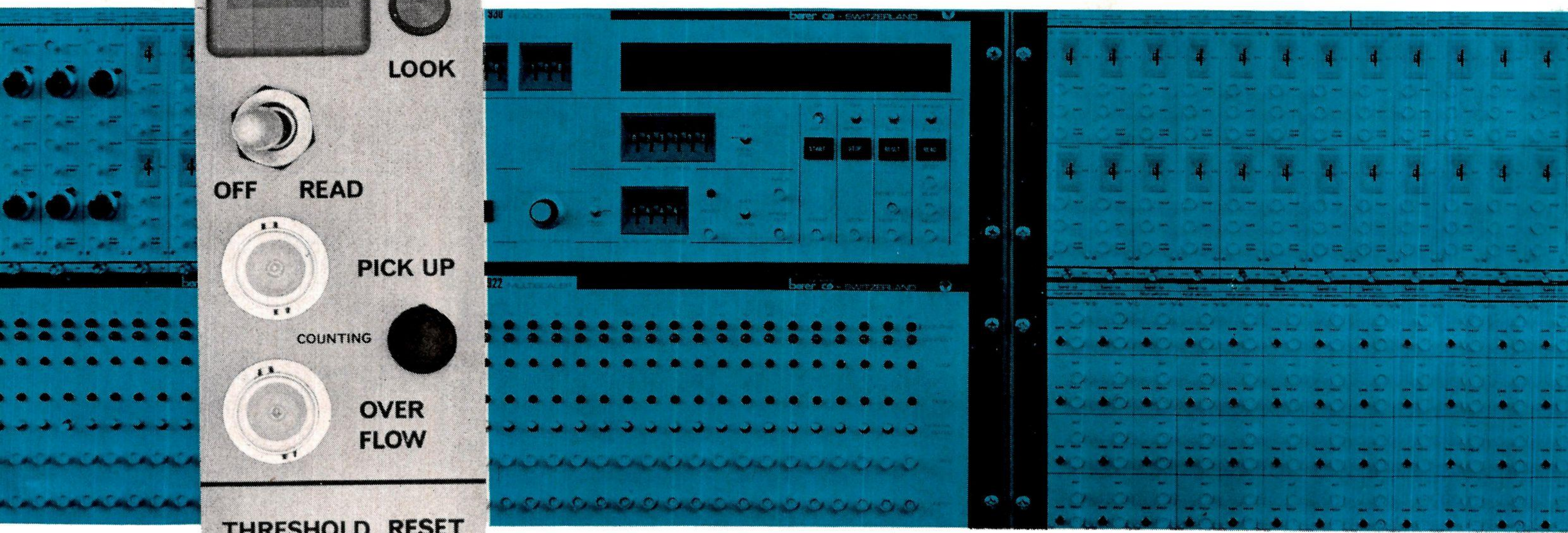

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