CERN COURIER

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European Organization for Nuclear Research

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific 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 1200 physicists draw their research material from CERN.

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 2850 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, 236.2 million Swiss francs in 1969, 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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41st Session of CERN Council

The Council met on 19-20 June under th> Chairmanship of Dr. G.W. Funke.

Progress Report

The Director-General, Professor B. Gregory, selected a few topics from the activities at CERN over the past six months.

The performance of the accelerators has been very reliable and some major improvements have been made to the basic operation of both machines.

At the 600 MeV synchro-cyclotron, breakdowns have absorbed less than 3% of the available operating time. Further developments in beam sharing techniques (new ability to run both the extracted proton beam and an internal target simultaneously) have almost doubled the effective beam time available for physics. The extracted beam has reached a record intensity of 5.6 X 10^{11} protons per second. At the 28 GeV proton synchrotron, reliability has been improved to reduce breakdown time to about 5 % and here also record intensities have been achieved with weeks of operation at an average intensity of 1.7 X 10^{12} protons per pulse. A new method of taking the beam through 'transition energy' (the energy at which the beam behaviour in the machine changes) has been successfully tested. This is an important development in view of the imminent much higher intensities where high particle loss could have occurred at the transition energy. Physics results from both machines are to be reported at the Lund Conference (25 June - 1 July).

Collaboration with Soviet scientists on the 76 GeV machine at Serpukhov has yielded its first published results (see CERN COURIER vol. 9, page 99). These were on negative particle production at high energies and the first stage of total cross-section measurements has recently been completed. A search for high mass (4 to 8 GeV) negative bosons using the missing mass technique has been accepted for the coming experimental programme at Serpukhov, and members of the team who have carried out the very successful experiments at CERN using this technique will be participating.

Construction of the ISR is continuing well to schedule. Practically all components are now on order. About half the magnet cores and coils are now at CERN and many are installed. All major components of the r.f. system have also arrived. In preparation for the experimental programme, the general purpose magnet system for one of the interaction regions has been selected and detailed design work has started. An Intersecting

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Cover photograph : Russell Schweickart, astronaut of Apollo 9, splashed down at CERN on 4 June. Story page 167.
(CERN/PI 125.6.69)

Storage Rings Committee has been set up under the Chairmanship of Professor W. Jentschke and is tackling the difficult job of selecting from the flood of requests to do colliding-beam experiments to fix the initial experimental programme.

300 GeV

The main topics of the Council session concerned the final preparatory steps for the decisions on the 300 GeV accelerator to be taken in October. J.B. Adams, Director of the 300 GeV programme, presented a paper which summarized much of the wealth of information concerning the project which has been produced since 1963.

In particular he confronted questions centring on whether the design is making full use of developments in accelerator technology and whether it might not even be better to wait a few years to see whether recent ideas result in a cheaper machine.

The design prepared in 1964 absorbed many of the technological advances which had emerged up to that time — such things as a new method of r.f. acceleration in the main ring, and the use of a vacuum vessel fitting snugly round the beam requiring highly refined beam control. Later developments do not indicate that the design has erred on the side of conservatism. However, many of the assumptions may well be challenged in order to achieve economies in the final design.

The 1968 design of the 200-400 GeV accelerator, now under construction at the National Accelerator Laboratory at Batavia, USA, has received a lot of attention. The NAL magnet lattice makes later extension to higher energy easier but involves a problem of selecting the best energy at which to optimize costs (where 'optimize' means taking into consideration construction costs and subsequent operating costs). The very compact magnet design at NAL has coils installed on the medium plane which has an element of risk due to the radiation flux in this plane. The smaller circumference at NAL is achieved at the sacrifice of 'free' space between magnet sections. The CERN design may prove too generous in this respect but with existing accelerators 'free' space has always become usefully occupied. All these points will be examined again and the final design of the 300 GeV machine and Laboratory will take into account the cost saving ideas of NAL

The costs of the two accelerators are virtually the same but the construction time-scale is very much faster in the USA — 5 years compared with a scheduled 8 years in Europe. It involves an annual rate of spend during the peak construction years about twice as high as in Europe, a fact which is unlikely to commend itself to European Finance Ministers.

Radically new principles or new technologies for particle acceleration such as the collective ion method (Electron Ring Accelerators, see CERN COURIER vol. 8, page 28) or the use of high field superconducting magnets (see CERN COURIER vol. 8, page 186) may hold out, in the long term, the possibility of very high energy accelerators at comparatively low cost. However, it will take many years before questions as to feasibility, let alone cost, can be answered. Europe, which is now several years behind the USA and the USSR, would be unwise to wait when the hopes held out by the new ideas may not be realized and may, in any case, prove just as expensive to implement.

The possibility of European groups working at the USA 200 GeV accelerator, perhaps in an exchange arrangement for access of USA groups to the CERN ISR, could only go a very small way towards meeting Europe's needs. The demand for machine time at Batavia from American groups is likely to be overwhelming, and though NAL would probably go out of their way to help European participation, the available machine time would almost certainly be very small. Operating with groups across the Atlantic would be more expensive per unit of achievement than building a new European Laboratory. There is also the fear that CERN would thus be organizing emfgration to the USA, which is contrary to one of the reasons for which CERN came into being.

If the decision to go ahead is taken in October with, initially, a limited number of participating countries, the new Laboratory will begin to implement a 'Stage 1' programme based on a 200 GeV accelerator which, with simple additions, will become the full 300 GeV programme when more countries are able to join. Even if no further resources become available, the Stage 1 programme will provide powerful facilities in Europe for particle physics research into the 1980s.

Programme Definition

The Council accepted the text of The Programme for Construction and Bringing into Operation of the CERN 300 GeV Laboratory'. This is the document which defines the scope of the Laboratory and the commitments of Member States who join it. Since it is the crucial document within the terms of which the Laboratory must operate and which lays down what governments are signing their name to in joining the project, we reproduce it here in full :

I. Preamble

1. Article II, 3 (c) of the Convention provides for the construction and operation of a Laboratory to include a proton accelerator for energies of about 300 gigaelectronvolts (3×10^{11} eV). A study for such a Laboratory and its facilities was reported in documents CERN/563, CERN/700 and CERN/702, which together have formed the background to the present decision of Council. The cost of the Programme described in these documents was estimated to be 1776 million Swiss francs at 1967 costs and constant prices.

II. Approval of the Programme

In accordance with Article II, 4 of the Convention, the Council hereby approves the Programme defined in this document for the construction and bringing into operation of the new Laboratory and its facilities. The Programme can at any time be amended in accordance with the provisions of the Convention.

III. Description of the Programme

1. The aim of the Programme is to provide in Europe a Laboratory and facilities which will enable nuclear particle physics research to be carried out at incident proton energies of about 300 GeV. The principal facility of the Laboratory will be a 300 GeV high-intensity, high-utilization proton accelerator. The cost of this Programme, estimated to be 1776 million Swiss francs at 1967 costs and constant prices, would be 1902 million Swiss francs at 1969 costs and constant prices.

2. The Programme shall be executed in consecutive stages according to the financial provisions made available by the Member States participating in the Programme.

3. The first stage of the Programme shall comprise a Laboratory containing a machine capable of accelerating an intense beam of protons up to an energy of at least 200 GeV, together with all necessary buildings, supplies and experimental equipment sufficient to enable nuclear particle physics research to be carried out up to that energy level.

4. The design of the Laboratory and the accelerator shall be so arranged that, by economical extensions to the first stage of the Programme, a proton energy of about 300 GeV and an internal beam intensity of at least 10^{12} protons/second can be reached.

5. A Laboratory which would meet the requirements of paragraphs 1, 3 and 4 of this Section is described in document CERN/869.

6. The site of the Laboratory shall be at...

IV. Financial Provisions for the Programme

1. In accordance with Article III, 4 of the Convention, the Council determines that there shall be for the Programme a minimum initial period of participation which shall end on the date of the bringing into operation of the Laboratory referred to in paragraph 3 of Section III, or eight years after the commencement of the

execution of the Programme defined in paragraph 1 of Section V, whichever is the sooner. During this period, expenditure shall not exceed 1431 million Swiss francs at 1969 costs and constant prices.

2. The estimated annual costs of the Programme, within the financial ceiling of 1431 million Swiss francs at 1969 costs and constant prices mentioned in paragraph 1 of this Section, are as follows :

Financial year after the date of commencement of the execution of the Programme
(million Swiss francs at 1969 costs and constant prices)

1	2	3	4	5	6	7	8	Total
16	50	140	220	235	250	260	260	1431

3. The annual budgets for the Programme shall not exceed by more than 15% the estimated annual costs set out in paragraph 2 of this Section adjusted for any cost variation which may be determined by the Council.

4. The Council shall determine in accordance with the Financial Rules and the Internal Financial Regulations of the Organization the circumstances in which money uncommitted in any one year may be carried over into the following year. Any such money shall not be taken into account in applying the terms of paragraph 3 of this Section.

5. The scale of contributions of the Member States participating in the Programme, calculated in accordance with Article VII, 1 (b) of the Convention and taking into account paragraph 6 of this Section, shall be decided by the Council for the period up to 31 December 1971 and for subsequent periods of three years.

6. In accordance with Article VII, 1 (b) (i) of the Convention, the Council determines that, as long as the Member States participating in the Programme are confined to those listed in the table of contributions first decided underthe terms of paragraph 5 of this Section, no Member State shall be called upon to contribute a percentage of the annual costs of the Programme greater than 38.5%. If additional Member States join the Programme, the maximum annual percentage contribution shall be 38.5% multiplied by the ratio of the sum of the average net national incomes at factor cost used in calculating the scale of contributions then current to that to be used in calculating the scale of contributions after adherence of the Member States concerned, or 25 %, whichever is the greater.

7. For the purpose of Article VII, 4 of the Convention, all expenditure incurred in respect of the Programme during the minimum initial period of participation as defined in paragraph 1 of this Section shall be deemed to be capital expenditure.

V. Execution of the Programme

1. The execution of the Programme shall commence on the date when the Council has appointed a Director-General for the new Laboratory or a person to act in his stead and voted a budget for the Programme.

2. Within one year from the commencement of the execution of the Programme, the Director-General shall present to the Council for approval :

(a) a master plan showing the proposed layout of the Laboratory and its equipment on the site ;
(b) detailed specifications and estimated costs of the proton accelerator, its buildings and supplies ;
(c) approximate specifications of the experimental equipment, its buildings and supplies which will initially be constructed at the Laboratory, together with the financial provisions to be allocated for these facilities ;
(d) an estimate of the running costs of the Laboratory which will enable research to be carried out with the facilities provided by the first stage of the programme.

3. The specifications for the first stage of the Programme as required by paragraph 2 of this Section shall be consistent with the aim of the Programme as described in Section III, and the cost estimates and financial provisions referred to in sub-paragraphs (b) and (c) of paragraph 2 of this Section shall enable the first stage of the Programme to be carried out within the duration and financial ceiling as set out in paragraph 1 of Section IV. The cost of the research phase mentioned in sub-paragraph (d) of paragraph 2 of this Section is not included in the financial ceiling set out in paragraph 1 of Section IV.

4. The Director-General shall, together with the Director-General of the CERN-Meyrin Laboratory, ensure close collaboration between the two Laboratories in the implementation of their respective programmes of activities.

5. The Director-General of the new Laboratory and the Director-General of the CERN-Meyrin Laboratory shall jointly present as soon as possible to the Council for approval co-ordinated Financial, Staff and other Rules and Regulations for the two Laboratories, including social security arrangements for the staff. Meanwhile, those in force at the CERN-Meyrin Laboratory shall apply also to the new Laboratory.

6. The Director-General of the new Laboratory, in consultation with the Director-General of the CERN-Meyrin Laboratory and with the Scientific Policy Committee, shall propose to the Council in due course the establishment of consultative machinery to ensure that scientists in the participating Member States take part in the planning of the Programme, including bringing the new Laboratory into operation.

7. The Director-General of the new Laboratory shall report periodically to the Council the value and distribution of the contracts arising from the Programme. In view of the fact that those contracts concerning advanced technological goods and services have an important effect on the industries of the Member States, such contracts shall be awarded in conformity with the Financial Rules of the Organization in force at the time whilst being reasonably well distributed amongst the Member States participating in the Programme.

Staffing and Tendering Policy

Section V5 of the Programme Definition requires the Directors General of the two Laboratories to present co-ordinated staff rules and regulations to Council. In the meantime, the present arrangements in force at CERN-Meyrin will apply to both Laboratories. The appointment policy that is currently applied at CERN-Meyrin is to be adopted throughout the construction period of the 300 GeV.

The policy for the placing of tenders is referred to in V7 of the Programme Definition. This clause gave rise to serious misgivings on the part of several Member States. It implies that tenders for the purchase of plant, equipment, supplies and services for the 300 GeV will normally be limited to manufacturers and contractors located in participating Member States, unless it is not reasonable technically and, or economically to do so. This ensures that the countries financing the new Laboratory gain from the advanced technologies which will be required.

Several delegations pointed out that this clause abandoned the 'free-tendering' principle which had been of great benefit to CERN in the past. They felt that, long-term, this could lead to the difficulties which have beset other European organizations where contracts have to be distributed in approximate proportion to contributions, and could be a hindrance to other States joining the project at a later stage. This last point was, however, contested by other States who have declared their intention to participate.

Procedures for the final decisions

It is hoped that at the October Council session the final decisions on the 300 GeV project can be taken and the procedures for these decisions were agreed as follows :

1) States affirm their intent to participate.
2) The short list of sites for the Laboratory is established. (Since the host country must participate in the project, the short list at present stands at Doberdo (Italy), Drensteinfurt (Federal Republic of Germany), Focant

(Belgium), Gôpfritz (Austria), Le Luc (France).
3) The site is selected. (Each Member State will name one site and a double two-thirds majority is needed — two-thirds of all Member States and two-thirds of participating States.)
4) The selected site is inserted in 1116 of the Programme Definition.
5) The Definition is then approved.
6) Formal letters of participation are presented.
7) The scale of contributions is established.
8) A Director-General is appointed.
9) A budget is voted.

Another requirement in order that the 300 GeV may go ahead is that the amendments to the CERN Convention (see CERN COURIER vol. 8, page 56) are approved by all Member States. Delegates were able to announce that the administrative measures to bring this about are under way or complete in all Member States. If all ratifications are not through in time, an interim arrangement bridging several months may be necessary.

Future of CERN Meyrin

CERN was asked to make forecasts on the development of the existing Laboratory so that Member States will have a clear idea of budgets during the construction period of the 300 GeV. Dr. M.G.N. Hine led a detailed analysis of the future through to 1975, taking into account the available facilities and chosing levels of exploitation to define a 'nominal' programme from which to estimate costs. The programme recognizes that sacrifices will be necessary and that all that would be ideal cannot be realized. The analysis also took into account the role of CERN Meyrin in the overall context of European resources in coming years.

The nominal programme leads to a budget in the region of 350 million Swiss francs (at 1969 prices) for the year 1975. After that date; there could be some gradual reduction but it is considered too soon to attempt to predict for the years beyond 1975 since many important factors (such as the degree of success of the ÎSR project, the financial development «n Europe, etc..) are not known.

The Council praised the analysis, accepted the lines of development used in drawing up the nominal programme, and considered that budgets for 1975 in the range 330 to 350 million Swiss francs will be acceptable. The precise annual budgets will be worked out as usual following the Bannier procedure.

Withdrawal of Spain

The Council received with great regret the confirmation of the decision of Spain to withdraw from CERN with effect from 31 December 1968. Spain first announced in August of last year that it was considering withdrawing, but great efforts have been made, right through to the beginning of June this year, on both sides, to explore all the possibilities which might allow Spain to remain a Member State. No solution could however be found.

Spain's withdrawal is due solely to economic and financial reasons. Despite the decision of the Council to reduce the contribution of Spain by 50% for the years 1969-71, the Spanish government felt unable to meet its contributions for the coming years. The government stated that it views, without the least reserve, the usefulness and efficiency of CERN and is fully convinced that CERN is an organization of the greatest value, to which it wishes every success in the noble task to which it is devoted.

Ambassador E. Pérez-Hernandéz, Permanent Delegate of Spain in Geneva, in confirming the decision of his government, thanked CERN for the kind consideration Spain has been accorded and conveyed the great appreciation of the scientific community in Spain for all that it has gained by participating in CERN. Ambassador Hernandez concluded with the hope that one day in the future his country will again be able to take part in the work of CERN.

In his reply the Director-General recalled that when Spain joined the Organization in 1961 it was largely an act of faith, for the country had hardly any scientists active in high energy physics. One of CERN's essential tasks is to help university professors and students to develop expertise by providing facilities for first-class research. This task has certainly been fulfilled in the case of Spain where, by now, many excellent groups of experimental and theoretical physicists have come into being. It is because of this excellent potential that CERN has tried in every way to solve the present problems. The Director-General concluded with a particular tribute to Professor J. Otero Navascués without whose drive and enthusiasm all that has been achieved in collaboration with Spain would not have been possible.

Computers in control

A review of some of the tasks assigned to computers in accelerator operation at Laboratories throughout the world. It brings out just how far the use of computers in accelerator control has come in a very few years.
The review does not aim to be complete. In particular, developments covered in recent issues of CERN COURIER will be mentioned rather than repeated.

At the Washington Accelerator Conference in March, M.Q. Barton of Brookhaven presented a paper on 'Computers in accelerator control rooms — a personal appraisal'. The following extracts make an appropriate introduction to this review.

'Some view the computer as something that is to take over complete operation of the machine. We can then discharge all of the operators, etc., except for one person who punches the cards to tell the computer the desired parameters for a given accelerator run. Others view the computer as an intermediary between human operators and the accelerator. Here the computer in no sense controls the accelerator but merely centralizes, miniaturizes, and conveniently formats the instruments and controls for the human operator who still exercises the conventional operator's role. Still others view the computer as a diagnostic tool. Finally, a sizable number of people still view the computer as an infernal nuisance; an infinite sink of money and effort which accomplishes nothing that couldn't be done more economically without using a computer.

About ten years ago it seemed to me that if one knew enough about the accelerator to program such a computer, one would not need the computer. (I still hold this view towards many proposals for computer 'control' of accelerators.) My subsequent experience was in line with a more general trend of events. In the first place, there has been a major revolution in the availability of computer hardware. The modern computer has expanded enormously in size, speed, and capability and the price has been spiralling downward. On the other end of the connection, the accelerator has developed in directions which make the on-line computer more and more attractive. In the Cosmotron, we had one set of pickup electrodes; in the AGS we have 36 sets and it is probably cheaper now to build a system to analyze 36 such devices around a small computer than without the computer, even if one charges the entire cost of the computer to the project. With future machines involving larger numbers of sets, the computer method is the only really reasonable solution.

Similar arguments apply to other parameters such as vacuum gauges and controls, correction winding controls, r.f. parameters, etc., which seem to proliferate in ever larger numbers with each generation of accelerators. The large distances over which large accelerators are spread make it attractive to telemeter information in some coded form. The computer is then desirable to unscramble and process the information.

More and more of the usual instrumentation and control functions around future accelerators will be channeled through computers. Most if not all of the meters, indicator lights, etc., will be replaced by messages on computer-controlled display tubes or other computer-controlled audio and visual presentations. The engineer trying to get a job doing instrumentation or control at future accelerator Laboratories will have to demonstrate a proficiency in computer techniques. Certain well-understood control functions will indeed be taken over by the computer. Some of the more complicated control loops such as, for example, closed orbit control may only be possible with computers.

To balance this glowing advertisement of computer power, I should perhaps point out a couple of the pitfalls. One of the first things one notices when trying to use an on-line computer is that the instruments taking the data used by the computer must measure what they are supposed to and nothing else. Computers are very stupid and can usually not discriminate between a valid signal and complete nonsense. More than one person has found that when the instruments were built well enough to connect to the computer, the computer was no longer necessary.

A second major pitfall is programming. It is a sobering experience to add up the costs of hardware, engineering time, technician time, etc. for some project and then to multiply by about 2V2 to include the programming costs. Fortunately, many instrumentation and control problems are most cheaply solved using computers even if these programming costs are included. There is a tendency to alleviate this problem by using a larger computer than really necessary for the job. Now everyone agrees that larger computers are easier to program than small computers. But there is a computer version of Parkinson's law which states that a problem which requires five hours to program for a small computer and uses one third of its memory can (and will) be replaced by a more sophisticated problem which requires five hours to program for a large computer and will use one third of its memory. Anyone who denies this law is either not very observant or not being candid.

In conclusion, I do not believe it is possible to form an objective evaluation of the usefulness of the on-line computer to the operation of an accelerator. Other practitioners of this black art probably have personal appraisals quite different from this one. But I am sure that each of you who makes a serious effort to solve some accelerator problem using an on-line computer will soon share with me this one simple conclusion : *the computer is here to stay.'*

Argonne

Taking the Laboratories in alphabetical order, Argonne, appropriately in this context, comes first. From the early days of the design and of the Zero Gradient Synchrotron (ZGS), they thought about the use of a control computer and established a position of leadership in the use of online computers in accelerator operation.

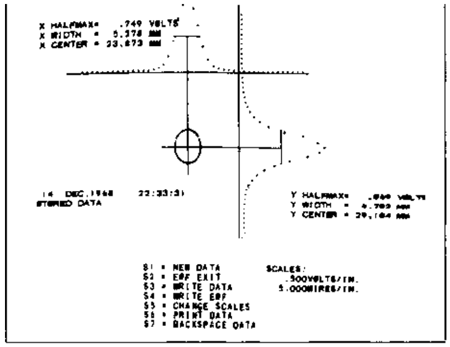
The monitor and control computer system now performs variety of functions. Data on ZGS operation is gathered and analyzed for presentation to the human operator either as graphs on the computer operated oscilloscope or as line-printer outputs. Pertinent data are also transmitted to the ZGS users. The computer has revise instructions in the programmer memory to alter the operation of the accelerator thus providing on-line feedback control.

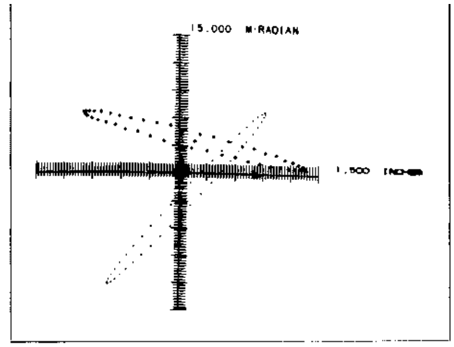
A special multi-programming executive program has been developed to meet the requirements for real-time control synchronized to the ZGS cycle. This permits nine control programs to operate simultaneously and one non-control program to operate in the unused time. This last feature has proved very valuable making it possible to develop new control programs in the environment in which they will be used. It also permits many other non-control, but nonetheless accelerator-related

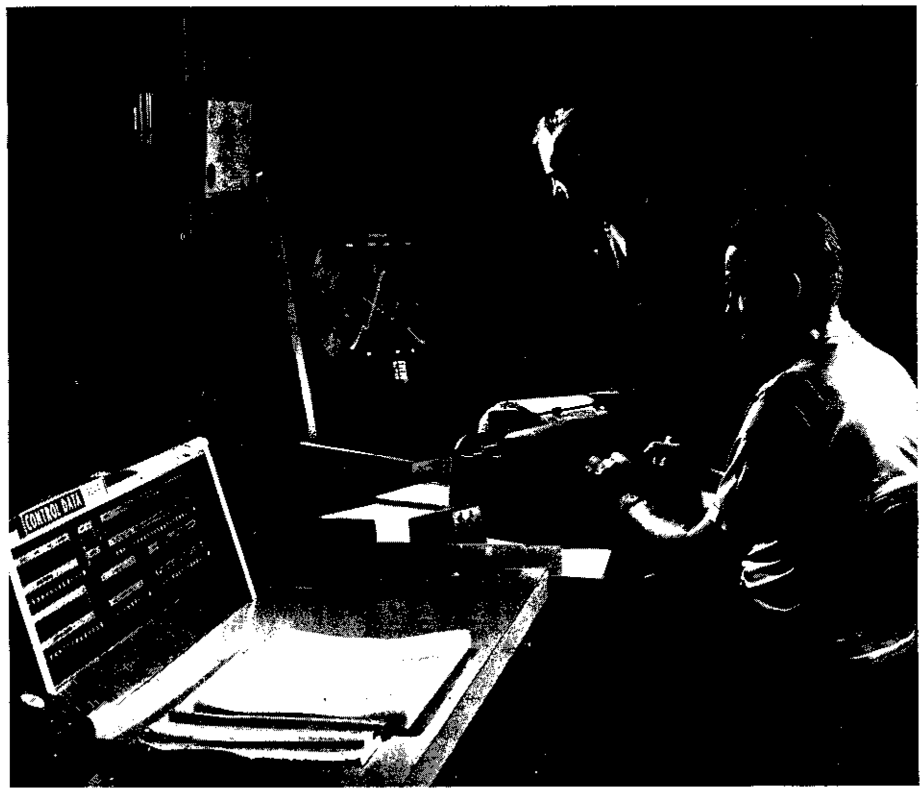
1. A beam profile display produced by the ZGS control computer from data obtained from segmented wire ion-chambers installed in an ejected proton beam-line.

2. A display of the emittance of the ejected proton beam calculated by the computer for a particular point along the beam-line.

3. The console of the ZGS control computer (CDC 924A) showing the operators' typewriter and the computer operated oscilloscope. The scope is displaying the beam envelope of the ejected proton beam.







activities, such as data reduction and display, during the time the control computer is on-line. A second feature that has proved valuable is the ability of the executive program to change a control program without interrupting its control function and without shutting off the accelerator. An example of this is the ability to change beam spill conditions.

Experience has shown that many of the difficult problems are not in the digital system but in the instrumentation for converting accelerator variables into voltage signals appropriate for the analog to digital converters. This has required the development of special instruments. The tuning of external proton beam-l has depended heavily on these special instruments. EPB-I is a multiple target line with as many as three foci plus a septum line ; experiments are run from all of these positions simultaneously and the beam-line must satisfy the needs of all of the experimenters. Special new instruments were developed to measure beam positions (BIPS) at selected locations along the beam and to measure, using segmented wire ion-chambers (SWIC), the distribution of particles within the beam cross-section. The results of this direct monitoring are transmitted to the experimenter when needed and are used by the computer for beam-line tuning calculations.

Data from three SWICs are used by the computer to calculate the emittance of the external proton beam at a position near the ejection point from the ZGS. The computation of emittance has proved very useful since it can check the effects of changed extraction conditions.

The computer also calculates the currents required in the beam-line magnets to produce the required conditions at each target. These currents and the resultant beam envelopes are displayed for the benefit of the operator, who can accept them or call for alternative settings. Present efforts are directed towards making the tuning of the beam-line completely automatic and in extending the system to cover EPB-II.

The ZGS delivers as many as ten separate beam spills during a single cycle of the accelerator. The amount of beam used for each spill is measured by the computer system, logged and transmitted to the individual experimenters. A separate control program for spills to the several experimenters is capable of meeting complex priority rules. These rules may give absolute amounts of beam or may give fractions of the amount in the accelerator to a given experimenter. They can permit or prevent certain spills depending on the amount of accelerated beam.

Experience indicates that many of the more important computer control tasks do not have to be performed every accelerating cycle. For example, calculations of emittance of the EPB-I need to be done no more than a few times a day, but need to be available for use if a SWIC monitor indicates a change in beam conditions. In a similar way, diagnosis of the injected beam and a matching routine need to be implemented on demand rather than continuously.

Data collection and presentation to the operator on demand provides a valuable method of studying the accelerator and of learning how to make improvements. The computer has proved to be a very valuable machine research tool.

In the future, the ZGS will be fitted with a titanium inner vacuum chamber which, together with associated pole face windings, present an opportunity to obtain better tuning of the synchrotron. The computer is expected to play an important function in this task by displaying equilibrium orbits, median plane distortions and 'tune maps'.

Batavia

The general plan of the control system for the 200 GeV proton synchrotron is still evolving, but it is clear that it will have at least one control computer for each of the three major accelerators (linac, booster and main-ring) plus computers for beam-extraction systems, radiation monitoring, experimental areas, and so forth. These computers will carry out the control and monitoring functions for their own part of the job and will communicate to a central computer. The central computer will be able to call up any data it desires and carry out control functions through the other computers. The ultimate goal is to achieve operation of the whole accelerator complex with just one man in control.

There is no controls group specifically so called and responsibility for the co-ordination of work on control and for central control has been given to the Main-Ring Section. The other Sections work separately on their own control problems and participate in an intersectional co-ordination group led by the Main-Ring people.

Prototype work is going on. There are three SDS Sigma-II computers in operation in the Linac, Booster, and RF Sections and work is under way to hook them together. The individual sections are putting in considerable effort on software development for these computers. In particular, the Linac Section is using its computer in operation and emittance measurements of the 750 keV beam achieved in April (see vol. 9, page 135).

Berkeley

Recent work on computer control at the 6 GeV Bevatron was reported in vol. 9, page 113. They have achieved control of a dual channel ejected proton beam where the computer both monitors and sets the beam transport system for optimum performance. They are now extending control of ejected beams and are introducing control of the synchrotron main magnet power supply cycle to take care of some elaborate gymnastics giving a wide variety of beam-spill conditions.

Brookhaven

There are two small computers (PDP-8s) in the control room of the 33 GeV Alternating Gradient Synchrotron in use for experiments in monitoring and control. The most significant result is in the orbit measuring system where the computer receives the signals from pick-up electrodes and presents the information in easily assimilated form either as print-out, oscilloscope displays or X-Y recorder displays.

Even with this comparatively simple system some very valuable information is obtained. For example comparison of closed orbits made it possible to pin-point within one magnet (out of the 240 in the AGS) a failure in a backleg winding which was causing serious orbit distortion.

The computer has also been used for rather sophisticated statistical analysis of AGS performance and has been used in experiments for a simple control function. This concerned the voltage control on the main magnet power supply during 'flat-top' so as to achieve a uniform beam spill down a slow ejected proton beam-line. The computer received signals from a monitor in the beam-line at several intervals during the spill and calculated and generated the appropriate function on the power supply to give the desired uniform beam-spill.

CERN/ISR

A computer is being incorporated in the control system for the Intersecting Storage Rings. It will be employed in a supervisory role, as an aid to the machine operators, taking care of the large number of devices requiring straight-forward monitoring and control, rather than performing any very complex control functions.

The ISR has 300 magnet power supplies, 2 km of vacuum pipe with hundreds of pumps and gauges, and over 100 beam observation stations in the rings alone. In such a system, it is virtually impossible to display all the incoming data to the operator, or to control the large number of elements in the conventional way. Information must be pre-processed and presented to the operator in a condensed form, if only to keep the operating area small enough to be overseen by one or two men.

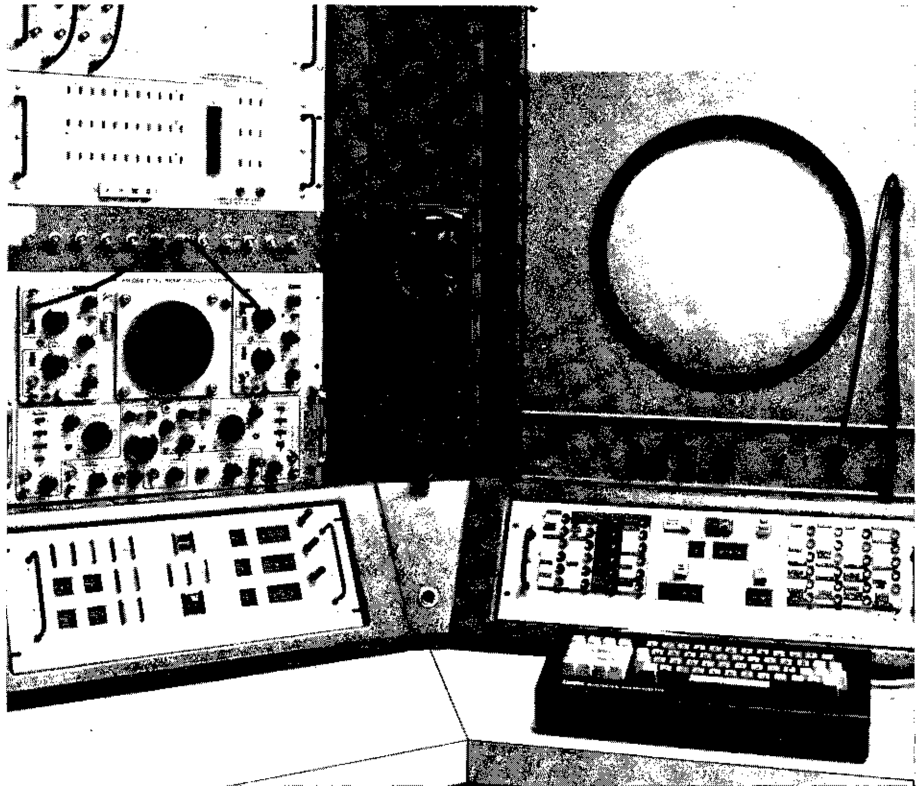
The main tasks for the computer are in beam observation and magnet power supply control. Data from secondary-emission profile monitors in the beam transfer system from the PS and in the storage rings themselves will be used to compute the beam emittance and matching corrections (to be applied by the operators). Data from 104 radio-frequency pick-up stations will be processed in order to provide displays of orbits in the storage rings, to be used in adjustment of the magnet power supplies. In this case, the computer will have to correct for zero offsets in the measuring system, apply calibration factors and calculate beam positions using the signals coming from each of 208 pairs of plates. In addition to printed numbers, a variety of displays can be generated to show the closed orbit, the betatron oscillations caused by injection errors, the variation of orbit with momentum, etc...

The computer will be used to compute and set the magnet power supplies via about 300 digital to analogue converters. The settings may be given directly by an operator, or be obtained from a disc store where a number of standard settings will be held, or computed for new conditions by interpolation between stored values. All magnet currents will be monitored so that the operator is warned of any drifts or faults.

Computer programs for beam observation and for magnet power supply setting will be developed so that optimization procedures of varying complexity may be applied later. This is a subject which is currently receiving a lot of attention, as it promises to give more consistent performance for present accelerators, or reduced construction cost for new machines (since more reliable beam control can reduce the safety factor built into vacuum vessel aperture which has repercussions particularly on magnet costs).

A large amount of general supervision and display will be undertaken by the computer system, primarily in monitoring the very extensive ultra-high vacuum system by means of 280 Bayard-Alpert gauges. In this area, it is intended to minimize the amount of special-purpose display equipment needed for the control room, by using general-purpose computer displays.

The computer selected is the Ferranti Argus 500. Two central processors will be installed, each with 16 384 words of core store. The two computers will be connected by a data link, so that optimization work and other special calculations can be performed on-line by the second machine. This duplex configuration is expected to shorten the program development time considerably, since an off-line machine will be available to programmers for virtually all the first year after the start of on-line work by the first computer. The availability of one computer for the basic work is expected to exceed 99.8% of operating time using the second computer as a source of spares. The computers have a 24 bit arithmetic word, with 1 |is core



The control desk of the model 20 MeV electron linear accelerator at Los Alamos where the ambitious plans for computer control of LAMPF are being tested.

(Photo Los Alamos)

store units, and have multiple accumulators and index registers.

Peripherals include fixed-head disc stores, a c.r.t. system with text and graphic facilities driving several screens, a fast serial printer and a digital plotter. Data is collected from the equipment buildings around the ISR by a digital scanner with over 8000 bits capacity, and a 3200-point analogue scanner. Remote control and data collection systems are designed to be very simple and straightforward in operation, so that they need not be duplicated for computer and manual operation.

Delivery of the computer system is scheduled for October 1969, with development of the main functions over the following twelve months, in time for ISR operation at the beginning of 1971.

CERN/PS

An IBM 1800 was installed in the control room of the 28 GeV proton synchrotron in May 1967 to help simplify and improve operation of the accelerator, and to investigate the advantages and problems of computer control (see CERN COURIER vol. 7, page 183). It has served for data acquisition from the linear injector and the main ring including, for example, some refined on-line monitoring of the quality of the injected beam (vol. 9, page 7).

The computer has also been applied in the monitoring and control of a fast ejected beam where it logs the ejection parameters (74 analog and 50 digital values), monitors the currents in the magnets of the beam transfer line (once every 100 cycles) and optimizes the position of the beam on the target. In this control of beam position the computer reads the charge induced on the target and the intensity of the emerging secondary beam and sets currents in the ejected proton beam transport system to achieve the best values.

DESY

Up to now, DESY have not incorporated a control computer in the operation of their electron synchrotron but are beginning to confront the problem ready for the construction of the 3 GeV electron-positron storage rings. Monitoring and control of large storage rings is in the first place more complex — more careful watch has to be kept on the intense stored beams — and the number of units which need to retain precision settings is much higher than in a synchrotron. If something goes temporarily adrift in a synchrotron, the cost is a few lost pulses in the machine and a few lost tempers in the experimental control rooms. If something goes temporarily adrift in a storage ring, the cost is the loss of the stored beams involving the lengthy process of re-stocking with particles.

In preparation for storage ring control the long beam-transport line from the new 300 MeV injector at DESY will be computer controlled. The computer will monitor the beams and set the magnets in the transport system. This will provide valuable experience for the programming and operating staff (see vol. 9, page 143).

Los Alamos

In the design of the 800 MeV proton linear accelerator, LAMPF, the control system is to be built around a computer. This followed a study, by an outside firm, of the comparative costs and merits of such a system and a conventional one. The cost estimates were about the same but computer control gave much greater flexibility and capability for expansion.

There will remain some functions with separate control systems not running through the computer (systems requiring very fast response times — of the order of microsonds — such as the fast phase control loop and the fast shut down) but the LAMPF control team are pushing the philosophy of computer control further than anyone (with the possible exception of the model work at RTI).

Advantage is being taken of the modular nature of the accelerator where power amplifiers, accelerating cavities and other systems repeat themselves along the machine. For the purpose of control, 54 modules have been designated including special ones at the injection end. For each module there will be a centralized control point. Each point will serve for the local control of a module, particularly during commissioning and maintenance, and will also be the intermediary giving the control room computer all information from the module and control of all components in the module.

In its monitoring role, the computer will receive and check all the data on the settings and performance of all the components in the accelerator, typically once every second. This data will be processed and stored on disc so that it can be recalled as a display, an operations log or a maintenance schedule.

In its controlling role, the computer will automatically sequence the various components to bring the accelerator into full operation and will then set up the accelerator parameters to achieve and retain the required beam. One of its most challenging tasks will be to optimize the performance of the accelerator according to certain well-defined criteria (for example, adjusting the settings of magnets spaced along the accelerator to achieve maximum output beam current).

It is intended to use the computer in such a way that it serves as an almost ideal operator. It will learn as operation proceeds, retaining in its memory the solution to each problem as it is overcorne. It will remember exactly the optimum operating conditions for a required beam and should make possible reproducible machine performance over months of operation. It will switch from one required beam state (energy, intensity and quality) to another, if necessary from one pulse to the next (within 8 ms). ... And it will not leave in search of a better paid job.

In preparation for this ambitious programme for computer control of LAMPF, a computer (SEL 810 A) has been incorporated in the control of the 20 MeV, 20 mA electron linear accelerator model where many of the design features of LAMPF are being tested. This prototype system is handling four modules. In the first year of operation, a bank of over 50 000 instructions for the programming system was built up (involving about six man-years of programming effort). Operation so far has been very encouraging.

RTI Moscow

It is at the Radiotechnical Institute that the philosophy of computer control is being taken to its limit. They have constructed a 1 GeV 'cybernetic' model synchrotron where the computer is fully integrated into the machine — monitoring the beam and setting all the relevant synchrotron components. Their eventual aim is complete computer control of machine operation in a closed loop.

So far they have used the computer to set up optimum conditions for injection of the beam and for steering the beam around the ring for several turns. They are now moving on to computer control during acceleration. A description of the model, and of the work so far, appeared in vol. 9, page 77 of CERN COURIER.

Rutherford

Effort is at present concentrated on the automation of the X3 ejected beam from the 7 GeV proton synchrotron, Nimrod. This beam-line feeds the new Experimental Hall 3 ; the associated ejection system is of the achromatic Piccioni type, though a resonant system may be tried later.

The beam current delivered by X3 depends on the. settings of the beam-line magnets, of the ejection system components, and on several parameters of Nimrod itself. Achieving optimum intensity involves finding the maximum of a function of some 40 independent variables, and while this can, in principle, be done manually it is an impracticably lengthy process. The control computer system will initially produce graphs of beam current versus any chosen parameter at a rate limited almost solely by magnet time-constants. Subsequent development will aim to achieve completely automated optimization of the beam-line.

The hardware is based on a PDP-8 computer with a store of 4K 12 bit words and a 32 K disc ; peripherals include a graph plotter and a tape reader punch. In the future it is intended to double the store and disc capacity, and to attach a CRT display. This will eliminate teletype printout and will have an interactive element similar in action to a light pen.

The data transmission system uses remote multiplexing and is an adaptation of the STAR system used at the CERN PS. This provides fanout to four zones, each with four extensions ; each extension has eight groups and each group has eight channels. There is therefore the possibility of having 1024 channels, though the modular construction of STAR makes it unnecessary to install all of them.

The STAR system is also used for command purposes, e.g. to change the setting of some magnet.

The sofware can be classified into three categories — computer, X3 system and user. It was necessary to write interrupt servicing subroutines for the PDP-8 to define interrupt priority levels. This hierarchy ensures, for instance, that if Nimrod data becomes available while hardware items needed to read it (e.g. a digital voltmeter) are in use, then the data is made to wait until the hardware is disengaged. This computer software has taken much time to develop. The X3 system software includes DVM routines and some STAR control routines. User software consists of programs enabling any non-expert user to edit a selection of the available subroutines into a program that will, for instance, plot graphs of beam intensity versus any chosen magnet current.

It is hoped to have the system working by the time that the X3 beam-line comes into use in mid-July. If the trials are successful, this form of control may also be applied to K9, which is a variable energy separated beam feeding a bubble chamber.

Stanford

Most control operations and data logging at the Stanford 20 GeV electron linear accelerator have, up to now, been done without use of a computer. It has been decided that some improvement in operating efficiency can be achieved most economically by the installation of a control computer system. The first part of this system, a PDP-9 built around, is now in use.

The computer's main task initially is to keep an eye on the 240 klystrons, which provide the accelerating power, and to switch in replacements in the event of klystron failure. Later, the computer will be used to prepare and analyse records, assist in setting up new experiments, and control other aspects of operation where rapid response is desirable.

When a klystron fails, the output beam energy drops by about 90 MeV. A 'status monitoring system' reports such a failure to the control room computer which selects an appropriate standby klystron and switches it into the accelerator (though the delay before any action can be taken as long as 0.7 s). To achieve faster response (down to the interval between two pulses — 2.78 ms) a pulse to pulse beam energy monitor is being developed which will alert the computer, and special klystron fast trigger circuits will then be switched by the computer. The two methods will complement each other in that the fast will hold the energy steady while the slow brings in a normal standby klystron releasing the special klystrons to leap into service again when needed.

In association with the status monitoring system which reports on some 3000 settings at 0.7 s intervals, the computer is being used for routine data logging.

Future plans for the computer include the setting of 45 focusing quadrupoles, of 40 sets of vertical and horizontal steering dipoles and of special klystron phase-shifters — though how far human intervention will be retained (particularlyduring initial 'tune-up' of the accelerator) remains to be decided by experience.

Around the Laboratories

Towards the end of May, the last magnet sections of the famous Cosmotron accelerator at Brookhaven were removed. The 3 GeV Cosmotron was the first proton synchrotron to contribute to particle physics coming into operation in 1952. At the end of 1966, it was closed down and despite efforts to revive its use, particularly for nuclear physics, it has been finally dismantled.

(Photo Brookhaven)

FRASCATI

Adone operation with colliding beams

It was announced in Lettere ai Nuovo Cimento on 21 May that the 1.5 GeV electron-positron storage ring 'Adone' at the Frascati Laboratory has operated with colliding beams, reaching a luminosity close to the design figure.

Adone was described in CERN COURIER vol. 8, page 12 and page 288. Construction of the ring was completed in 1968 and since then the design team has had a hard fight to overcome unexpected beam instabilities. Adone is the highest energy and highest intensity colliding beam machine in operation and, in working towards the design figures, several instabilities were encountered at beam intensities much lower than theory predicted. This was particularly true for positron beams where transverse betatron instabilities appeared at intensities as low as 200 |iA per bunch at an injection energy of 300 MeV. The instability was finally pinned down to an interaction between the beam and rapidly decaying electromagnetic fields induced by the beam with frequencies extending into the GHz range. All elements in the vacuum chamber have had to be terminated for frequencies in this range to increase the growth time of this instability.

Electrodes installed to sweep positive ions from the electron beam and to control the crossing angle were removed and the injected beams could then be increased in intensity by an order of magnitude. New electrodes, designed to damp out the GHz fields, are now being made. Until these electrodes are installed the beams meet head-on rather than at a controlled crossing angle.

The maximum beam energies are temporarily limited to about 1.3 GeV prior to the installation of a second r.f. cavity. Measurements of the interaction rate (observing events with known cross-sections — electron-positron single bremsstrahlung and electron-positron scattering at small angles) have been made up to 1.1 GeV. At this energy the luminosity is 3.4×10^{32} cm^{2} hr^{1} with stored beams of 40 mA of positrons and 23 mA of electrons.. The corresponding design value is 7.3×10^{32} with two beams of 100 mA crossing at an angle. When the new electrodes are installed within the next few months, the measurements indicate that a luminosity somewhat higher than the design value will be achieved.

The experimental programme at Adone is about to begin. It involves many Italian Universities, the Italian National Institute for Nuclear Physics (INFN) acting as the coordinating agency for Italy's high energy physics programme. Seven groups have prepared the following experiments :

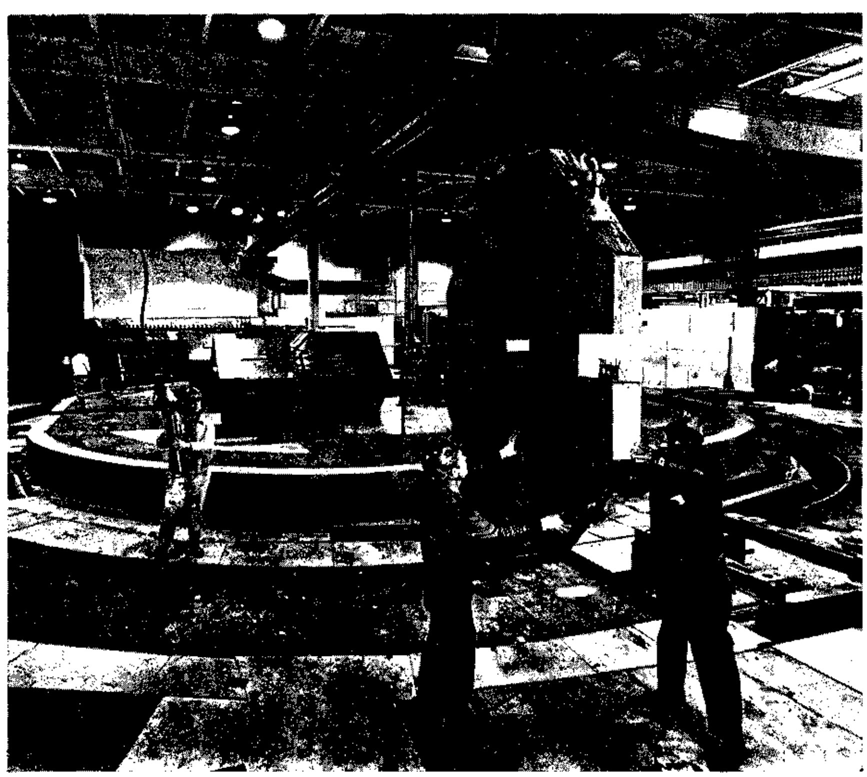
— Single boson production (Naples University/Frascati)
— Electron-positron annihilation into two bosons (Padua University/Frascati)
— Electron-positron annihilation into two gammas, neutral pion plus gamma, or eta plus gamma (Rome University/ Frascati)
— Muon pair production (Rome University/ Frascati)
— A study of the phi resonance through its charged kaon, muon and neutral decays (Istituto Superiore di Sanità)
— Nucléon pair production (Naples University/Frascati)
— Search for leptonic quarks and heavy leptons (Bologna University/Frascati).

TRIUMF

Annual nr>eeting

The annual meeting of people involved in the TRIUMF project was held at the University of British Columbia, Canada, on 5 - 6 May. Reports were received on various aspects of the cyclotron design and from experimentalists planning to use the machine.

The machine is a 500 MeV sector-focused cyclotron to accelerate negative hydrogen ions. At full energy, these will be stripped to protons and the magnetic field of the cyclotron will bend the protons out into the experimental area. Intense beams of mesons and neutrons will be drawn from the proton beam, with 100% macroscopic duty cycle, making possible



An artist's impression of the first building, now under construction, on the TRIUMF site. It will contain offices and laboratories and is scheduled to be occupied by the project staff in September.

Right : At the symbolic tree planting ceremony left to right — Chancellor J.M. Buchanan (University of British Columbia), the Honourable Jean Luc Pepin, Professor J.B. Warren (Director of the TRIUMF project).

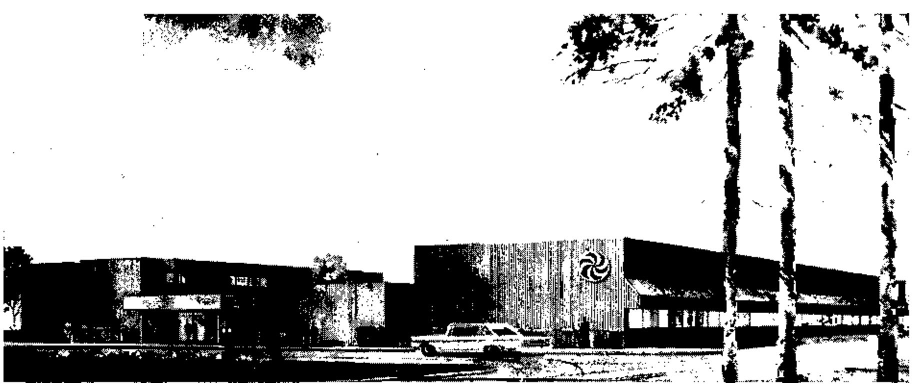
(Photos TRIUMF)

a wide range of experiments at intermediate energy. (See CERN COURIER, vol. 8, page 136, for a fuller description.)

Design work, including model studies, is under way on most machine components and many engineering firms, mainly from Canada but with some also from USA, are participating in this work. As a result of the measurements on negative hydrogen ion life-time in conditions which will prevail at the extraction orbit of the cyclotron (measurements carried out at the 50 MeV proton linear accelerator of the Rutherford Laboratory — see vol. 8, page 313) the machine diameter has been increased by 4 %.

TRIUMF will serve particularly scientists from Western Canada. Five users groups have been set up covering the main areas of research which will be possible at the cyclotron — Proton Users, Meson Users, Slow Neutron Users, Radiochemical Users, Radiobiological and Radiotherapy Users. The groups have each already met several times to begin thinking about the experimental programme and to contribute to the design and building layout.

On 5 May a symbolic tree planting ceremony was held. The Honourable Jean Luc Pepin, Canadian Minister of Energy, Mines and Resources, planted an apple tree on which had been grafted some scions of a direct descendant of the famous apple tree at Woolsthorpe Manor in Lincolnshire, England, under which Newton received inspiration for his laws of gravity. From March 1973, when the first beam is scheduled to be extracted from TRIUMF, scientists may well be seen grouped under this tree hoping for similar messages from above.



RUTHERFORD
Concrete Magnets

It is obvious from the information on page 178 that wrapping up the coils in a synchrotron magnet satisfactorily poses no small problem. The coils have to be electrically insulated, both from the yoke of the magnet and one turn of the coil from another, and the insulation usually has to serve mechanically to hold the coil together in the required configuration. The electrical insulation is straight forward but the mechanical stresses under the pulsed regime of a synchrotron are considerable.

Organic insulation of magnet coils has been highly refined but the problem of the eventual destruction of the insulation by radiation remains. When considering particularly the next generation of accelerators, this problem could be more troublesome, due to the acceleration of beams of higher intensity to higher energy subjecting the coils to intense radiation. Failure of coil insulation involving changes of magnets, which would interrupt operation of the machine, is something to be avoided if at all possible.

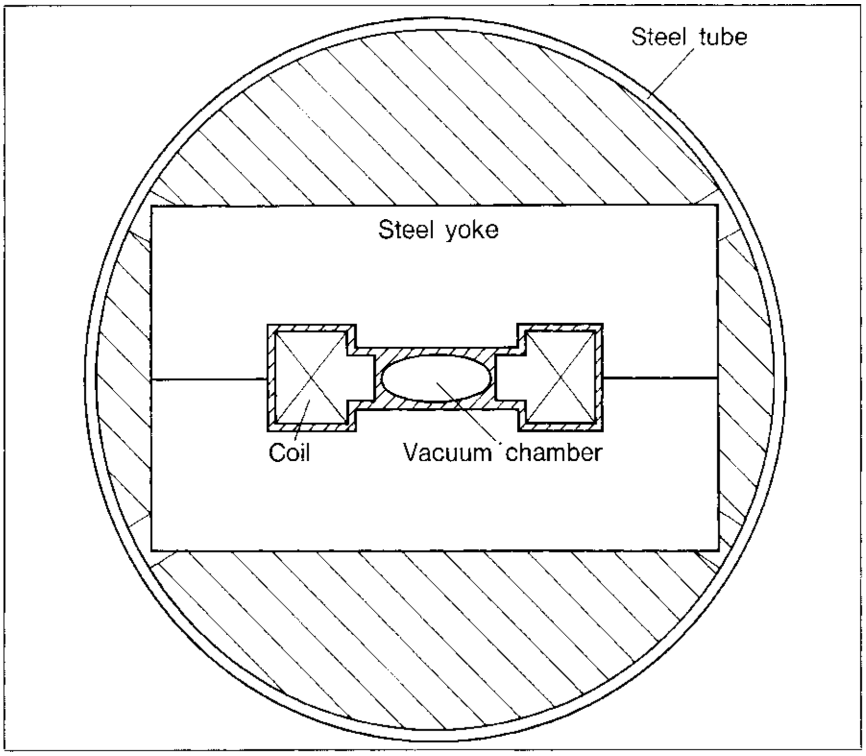
In thinking about this problem, R. Sheldon and G.B. Stapleton of the Rutherford Laboratory have proposed a novel method of magnet construction. It involves the use of concrete, more precisely castable ceramics, which are highly resistant to irradiation, to 'pot' the whole magnet, dispensing with all organic insulation.

The magnet unit is considered as an 'integral structure' — its components are assembled and fixed once and for all. The coil is wound without any insulation, the desired turn to turn configuration being set

up by introducing strips of an inorganic insulator such as alumina. It is then assembled onto the magnet yoke, again using spacers to avoid electrical contact. This assembly is done inside, for example, a mild steel pipe. The vacuum vessel is also fed in and temporarily filled with water to avoid distortion during the next stage of the process.

The ends of the pipe are sealed with steel plates which have apertures for the vacuum vessel and tie bars. The tie bars are then pre-stressed and concrete is pumped into the assembly under pressure. This operation is carried out in several stages using different concrete mixes — a fine aggregate being used for the insulation between turns and between the coil and the magnet, and a coarser aggregate for the main body of the magnet.

The concrete is given time to cure under pressure to keep the magnet like a concrete beam under compression. This overcomes the stresses subsequently introduced by expansion of the coil and the magnet yoke during operation of the magnet. The magnet is then heated for a



A cross-section of a 'concrete magnet', it shows the preliminary design of a magnet suitable for a high-energy accelerator. The castable ceramic fills the hatched areas — a coarse mix being used around the outside and a finer mix around the coil. Note that, using concrete as the insulation, the coil can confidently be placed on the median plane where the maximum radiation flux will exist.

Below : The new layout of the elected beam channels and experimental areas at Batavia.

while to complete the curing of the concrete and to optimize its properties.

Small magnets (up to 50 cm long) have been built and tested at Rutherford and Lintott Engineering. They have indicated that the method gives the required insulation and retains the necessary engineering tolerances following thermal cycling and pulsing.

A preliminary design study has been made for a magnet having characteristics suitable for the 300 GeV machine. (The method is more suitable for separated function magnets though it is not excluded for combined function.) This new concept in magnet design and construction holds out the prospect of magnets which could be cheaper and are free from the problems of radiation damage.

BATAVIA ~
Preparation for experiments

The 1969 Summer Study to study the experimental programme ready for the start up of the USA 200 GeV accelerator began in Aspen on 9 June. It will continue until 2 August.

Within the National Accelerator Laboratory itself a Physics Research Section has been set up which will be the Section through which resident physicists will participate in the particle physics research programme using the machine. The first proposals for experiments are now being evaluated.

Concerning the hardware for experiments, a new design of the experimental area layout has been developed and is shown in the diagram. The ejected proton beam coming from the Transfer Hall' comes first to Splitting Station SI where it can be allocated, wholely or partially, to the bubble chamber area E1 by sending it straight ahead to Target Area T1. The remainder of the beam can be bent through 7.5 degrees to Splitting Station S2 where it can be similarly divided between Target Area T2 (serving experimental area E2) and Splitting Station S3 (serving experimental area E3 and any further extension later).

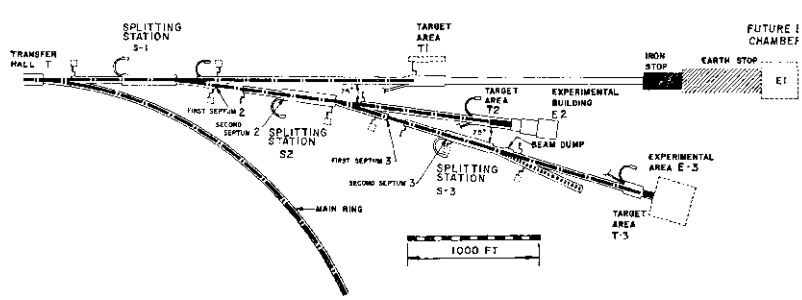
The bubble chamber area is the site for the planned 25 foot hydrogen chamber now being designed in collaboration with Brookhaven. It will receive a high intensity neutrino beam with a broad energy spectrum, and r.f. separated pion and kaon beams up to an energy of about 80 GeV. Counter experiments will also be possible in E1. Construction of the Area is scheduled to begin in 1971 for completion in July 1972.

E2 is intended for counter experiments exclusively and about six experiments will probably be mounted simultaneously, drawing charged and neutral secondary particle beams from Target Are^i 2. Construction of this experimental area is planned to start late in 1970 for completion in April 1972 shortly before first operation of the machine.

E3 is also designed for counter experiments allowing more flexibility and variety in the particle beams. (The beam-lines in E2 are intended to be virtually permanent features which w'.iî not be re-built very often.) Construction will not start before July 1972.

The major recent item of news on the design of the accelerator itself is the decision to reduce the output energy of the booster from 10 to 8 GeV. Since the booster diameter and magnet system will remain the same, the reduction in peak energy corresponds to a reduction in peak magnetic field and there will also be a reduction in the number of r.f. cavities from 16 to 14. The savings exceed some extra cost in the r.f. system of the main ring which now has to cope with a bigger frequency swing as particles are injected at lower energy.

Construction of the accelerator is going ahead at full speed. The linac building is almost complete and construction of the booster ring building has started. The drift-tubes of the first 10 MeV tank of the linac have been installed (the scheduled date for achieving a 10 MeV beam was 26 June).



Development of multiwire proportional chambers

G. Charpak

It has happened quite often in the history of science that theoreticians, confronted with some major difficulty, have successfully gone back thirty years to look at ideas that had then been thrown overboard. But it is rare that experimentalists go back thirty years to look again at equipment which had become out-dated. This is what Charpak and his colleagues did to emerge with the 'multiwire proportional chamber' which has several new features making it a very useful addition to the armoury of particle detectors.

In the 1930s, ion-chambers, Geiger-Muller counters and proportional counters, were vital pieces of equipment in nuclear physics research. Other types of detectors have since largely replaced them but now the proportional counter, in new array, is making a comeback.

Although CERN was the first to show the possibilities offered by these chambers physicists had for long toyed with the idea of using the wire chamber as a proportional counter. Now, the introduction of micro-electronics makes it possible to purchase miniature components for amplification of the signal on a wire for a thousandth of the cost only ten years ago. It should also be mentioned that certain attempts had been made to build multiwire counters, but these had not proved practical. Before discussing them it will be interesting to say a little about the properties of the proportional counter amplification in gases.

The conventional proportional counter was, for a long time, one of the detectors most widely used by nuclear physicists. In most cases, however, it was replaced by the scintillation counter as soon as the latter was introduced. There were numerous reasons for this, the most significant being its poor time resolution and the restrictions on its shape, which was normally cylindrical.

A proportional counter generally consisted of a very fine wire (less than 0.1 mm in diameter) located on the axis of a cylinder containing a suitable gas. When a particle traverses the cylinder and liberates ions in the gas the electrons are attracted to the wire, which is at a positive potential, in such a way that, in the vicinity of the wire, where the electric field gradient is high, electron multiplication occurs : a single electron creates an avalanche of M electrons (M being the multiplication coefficient). M can reach a value of 10^6 in stable conditions which makes it easy to detect very small energy losses since the electron avalanche can amplify the initial signal by this factor of 10^5. The avalanche starts at a distance from the wire of the order of the radius of the wire and develops rapidly, generally in less than 1 ns. The poor time resolution is due to the time taken by a primary electron to come near to the wire. This time depends upon the distance between the particle causing the electron and the wire ; in typical cases, for a distance of 1 cm it is several hundred nanoseconds. (We will see that with the multiwire chambers at least one order of magnitude has been gained on this figure.)

The cylindrical shape does not lend itself to providing large surface areas for detection of particles, but flat multiwire counters were built a long time ago for special purposes. These were usually composed of wires situated between two flat electrodes, alternate wires having the potential of the planes and a positive potential in relation to the planes. There were two reasons for this.

At first sight, it would seem that the equipotential lines are more regular in such a design and that there are no 'dead' areas between the wires. In fact, however, as the Figure on page 176 shows, even with a plane of wires all at the same potential, the equipotentials are cylinders in the region close to the wire which is of importance for amplification.

The main reason, however, for alternating the potentials in the old systems was the fear of coupling between wires. It is clear that capacitative coupling occurs between wires and, if a pulse is communicated to one of the wires, the adjacent wires are affected. If the electronic system is built to be sensitive to a wide range of pulse intensities there would be signals coming from a large number of wires and this would hamper localization of the particle. But by using alternating potentials on adjacent wires, the wires on each side of the wire receiving the true signal act as screens.

This view of the importance of coupling has proved to be incorrect. The situation is not at all what one might expect, and actually proves to be an advantage. It might be expected that capacitative coupling would result in a pulse of the same sign on all wires in a plane. As the coupling acts in a different manner, it is worthwhile describing it, since it bestows interesting and unexpected properties on the chambers.

When the wire collects the electrons from an avalanche which has occurred against it, the induced pulse is virtually zero : if collection of the charge (—Q) produces a pulse (—Q/C) in which C is the capacitance of the wire, the positive ions, since they are suddenly deprived of their electrons and are still very close to the wire (within 10^{-3} cm) because they move more slowly, will produce a pulse of (+Q/C) which cancels the first one. On the other hand, as the positive ions begin to move in the very intense field surrounding the wire, they induce charge (—Q') on the wire, with a rapid rise-time whilst they cover the distance of high field gradient, which is of the order of the diameter of the wire. The rise time varies between 10 and 100 ns in the chambers we have studied. If, during this time, the induced charge on the wire is (—Q'), it is (+Q') on the adjacent conductors, and

$$+ Q' = Q'_1 + Q'_2 + Q'_3 \ldots$$

where the indices 1, 2, ... designate the other conductors : adjacent wires, high voltage wires, etc.

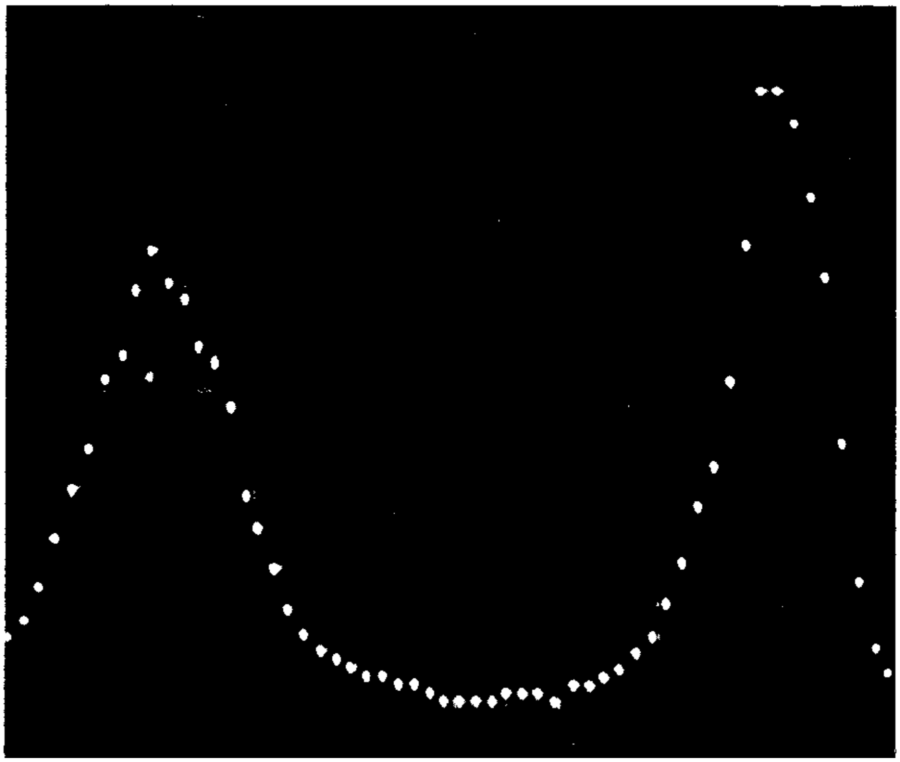
This opposed coupling has two important consequences :

a) it enables the position of the pulse to be traced to the wire which picks up the electrons. The positive pulse cancels the negative pulse on other wires which would result from capacitative coupling only

b) it induces positive signals on the high voltage electrodes which can be used for various purposes, such as measuring the total energy loss in the chamber (as it can integrate the pulses of several wires) or position-determination giving another coordinate. The same chamber can, if the three wire planes are differently arranged, provide three coordinates ; this prevents any ambiguity

A multiwire proportional chamber produced these signals of the profile of a secondary beam from the proton synchrotron. The two peaks correspond to the beam cross-section and particle distribution in two directions at right angles. The chamber was here monitoring a burst containing 50 000 particles lasting 100 ms.

Right : A chamber in use for an experiment at the synchro-cyclotron.



resulting from the combination of co-ordinates when there are several tracks.

There are certain chamber applications (such as the detection of X-rays or neutrons) in which the secondary charged particle cannot normally pass through two chambers ; the possibility of measuring two coordinates with a single chamber opens up a wide range of applications in these particular fields.

Some properties of multiwire proportional chambers

Let us consider a very simple structure, similar to that of a wire spark chamber : a series of wires, each 20 or 30 {i in diameter, stretched in a plane between two other planes 7 mm apart. The separation between the wires in the planes themselves is 2 to 3 mm. The two outside planes are composed of taut wires, 0.1 mm in diameter, one having its wires running in a direction parallel to the wires in the central plane and the other in a direction at right angles. Circulating between these electrodes is a gas, such as an argon-isobutane mixture (80% and 20%). A constant negative voltage of 5 kV is applied to the two external planes. Each wire is connected to a very compact integrated circuit which amplifies and shapes the current pulses received by the wire.

This structure operates as a multiwire proportional chamber and I would like to describe, briefly, its properties as they appear from the studies made by several groups at CERN. I will refer only to the most promising aspects and add that further work is certainly necessary if we are to avoid any unpleasant surprises when full-scale versions of the detectors are finally made.

Pulse height

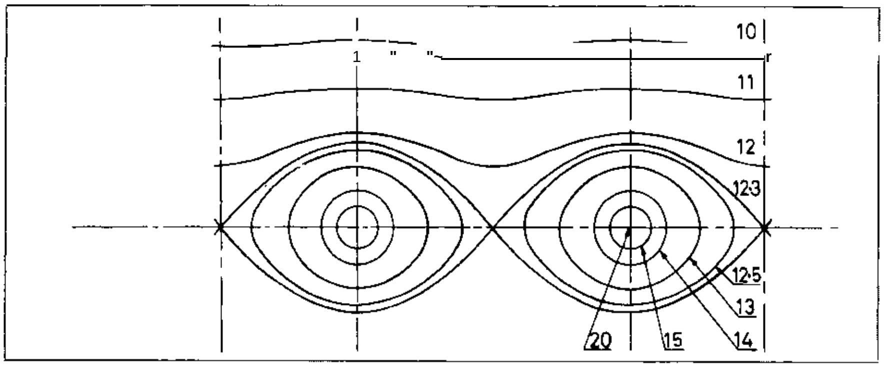
Pulses of 200 mV can sometimes be obtained from a wire, following the passage of a particle which loses energy of 6 keV in the gas. The chamber is then operating at the upper limit of the proportional amplification region ; depending on the diameter of the wire and the type of gas, it enters the Geiger-Muller region finally giving spark breakdown if the voltage is taken higher. It is convenient to use an electronic system capable of detecting all pulses of 0.5 mV and above. Using wires with a 3 mm separation, it has been shown that the efficiency exceeds 99.9% for particles producing minimum ionization.

Detecting simultaneous tracks

A pulse will cause a disturbance of the order of 10^{-6} on the potential of the wire which receives it. No drop in the efficiency of the chamber to detect particles is expected, irrespective of the number of particles arriving simultaneously. This has been verified for up to four simultaneous particles.

Resolution time

With a 2 mm separation between the wires, the maximum time fluctuation which has been observed for particular gases is 24 ns ; with a 3 mm separation, the time is 36 ns. The accuracy of the chamber in measuring times precisely is therefore the same, to within a factor of two or three, as that of the simplest scintillation hodoscopes.



A diagram showing the way the electric field is distributed around the wires in a multiwire proportional chamber. Note the way that the equipotentials are cylindrical in the immediate vicinity of the wire where the proportional amplification occurs. The figures denote voltages.

The Table compares some typical properties of different detectors.

	Scintillation hodoscope '	Wire spark chamber	Multiwire proportional chamber
Self-triggering	Yes	No	Yes
Minimum space resolution	2 mm to 1 cm (depending on length)	0.5 mm	1 mm
Time resolution	5 ns	500 ns	25 ns
Dead-time	less than 100 ns	100 ns	less than 100 ns
Unit price (relative)	50	1	5
Minimum thickness (relative)	100	2	1
Magnetic fields	sensitive	sensitive	insensitive

Localization

On collecting the electrons, which the passage of a charged particle liberates in the gas, a wire in the central plane produces a negative pulse. The adjacent wires, provided that they have not collected any electrons, will receive a positive pulse (for reasons brought out above). Consequently, if amplifiers are used which are sensitive to a single polarity (they only click when they receive a negative pulse), this type of coupling between adjacent wires presents no difficulty. Using wires with a 3 mm separation, a precision of ± 0.76 mm has been obtained when measuring the position of a particle trajectory by means of four chambers. With a 2 mm separation, we can expect an accuracy of ± 0.6 mm, which is comparable to that of spark chambers.

Energy Measurement

If one of the external planes is in the form of a metal sheet, mesh or a number of wires connected electrically together, it will receive a positive pulse proportional to the total energy lost by the charged particle in the chamber. The accuracy to which these chambers can measure the energy is equal to that of the best cylindrical proportional counters (15% at 6 keV). To be able to distinguish roughly between particles which give very different ionization (for example, a proton compared with a pion at 300 MeV/c) the resolution is sufficient.

Multiple coordinates

If the orthogonal wires of the external planes are also connected to amplifiers, they will detect positive pulses whose position will be located, though with less accuracy than in the case of pulses on central wires. Nevertheless, they enable a second coordinate of the track of the particle through the chamber to be obtained. In the case of neutral radiation (for example, X-rays or neutrons) which produce charged particles in the chamber that have not enough energy to leave the chamber, the multiwire proportional chamber is the only detector which provides both coordinates.

Use as a hodoscope

If the wires of the high voltage planes are grouped together (for example, in 5 cm bands), a pulse is collected on one band after the passage of a particle. This will provide a rough indication of particle position, similar to that given by a conventional hodoscope, and can be used to trigger other detectors or operate read-out systems. If the angle of the bands on the high-voltage planes is varied, not only will the chambers be able to provide both coordinates, but it will also be possible to measure the coordinates of several particles with the one chamber.

Counting rate

The counting rate is limited in practice by the electronic system which collects the pulses. A detection rate of 10^6 particles per wire per second seems possible with a suitable electronic system.

Comparison with other detectors

A comparison with conventional wire spark chambers shows that the time resolution is ten times better, spatial resolution is equivalent or perhaps a little poorer. In certain cases, however, by using the correlation between the arrival time of the pulse and its position, more accurate measurements can be made. Chambers have been built to exploit this effect, and an accuracy of ± 100 [JL in positioning the particle track was obtained.

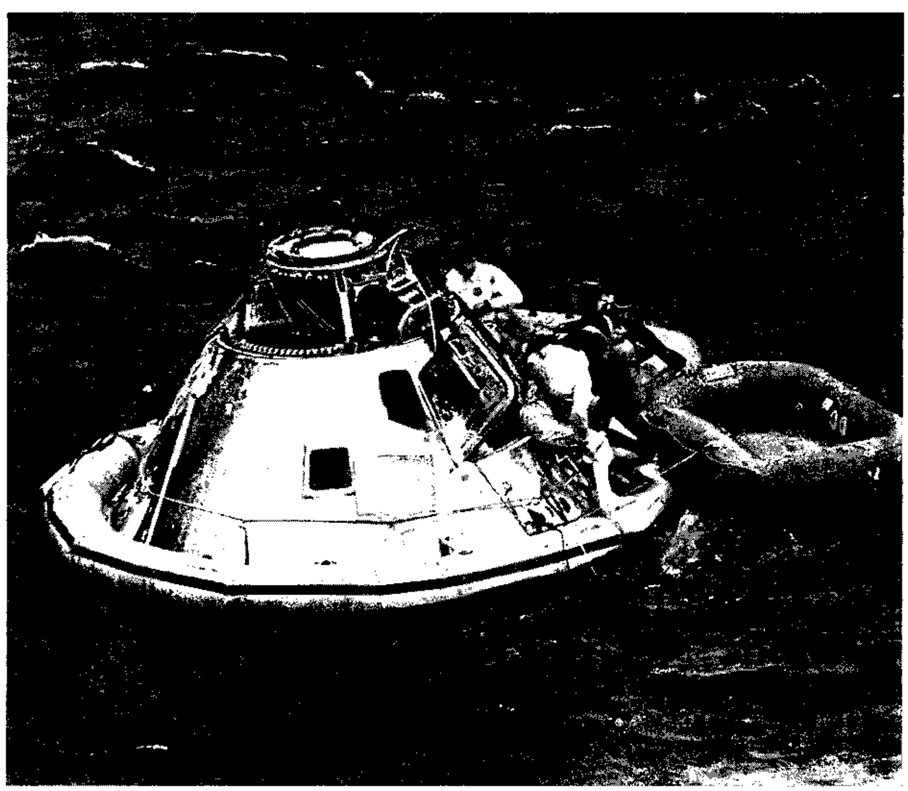
Where the comparison is not so favourable is in the price. It is likely that 50 Swiss Francs worth of components per wire will be needed to take the pulse from the wire through a ^ate to a memory. This is higher than the price per wire of a conventional chamber and for the giant systems which are planned to be built (10^5 wires and above) the price difference might be prohibitive. Most physicists feel, therefore, that, in such large systems, the multiwire proportional chamber will be used more often to trigger magnetostriction wire chambers. Scintillation hodoscopes, for their part, still maintain the lead where time resolution of better than 10 ns is required, but they introduce more matter in front of the particle, do not provide the same spatial resolution and are more expensive.

Conclusions

My description of the properties of multiwire proportional chambers has, perhaps, been rather optimistic because, at present, we lack sufficient experience to know what their limitations are. Nevertheless, two experiments at CERN are already using these chambers, and they are standard equipment for beam profile measurements. A detector of this type with at least 5000 wires is being designed by a CERN-Heidelberg group.

Finally, there are several groups investigating the various aspects of the mechanism of amplification in the chambers. It may therefore be expected that practical information will very soon be available for work on large units. There are already certain applications where proportional chambers can probably play a very useful part : in low-energy nuclear physics, as detection equipment in the focal planes of spectrometers, and, maybe, in medical physics for constructing large-surface detectors which measure the spatial distribution of X-rays emitted by radioactive elements in human organs. These various possibilities are at present being actively studied.

CERN News



Russell Schweickart climbs out of the Apollo 9 spacecraft at the end of the very successful mission, which took place from 3-13 March, to test the lunar module and the docking procedures with the parent spacecraft. This mission and the whole USA programme were covered in a barrage of questions that Schweickart faced during his visit to CERN.

(Photo NASA)

Watch this space

On 4 June, Russell L. Schweickart came to CERN on the invitation of the Staff Association, following an initiative by the Public Information Office, to talk on The Flight of Apollo 9 and the Future of Space Exploration'.

As could be expected in an environment like CERN, his visit aroused great enthusiasm. On the same day as the announcement of the talk, all seats had been reserved in the Main Auditorium and around 22 closed circuit TV extensions to the Council Chamber, Theory Conference Room, the Restaurant and the Cafeteria (the smooth working of those extensions represented a considerable achievement by the Auditorium technicians). All available rooms drew full audiences ; it is estimated that about 1250 people came to CERN that night to hear the astronaut and a further 1250 saw projections of the film Apollo 9 on the following two days.

In a very crowded day 'Rusty' Schweickart also managed to squeeze an hour in the afternoon to answer questions from the scientific staff. Then on Friday 6 June he returned to CERN incognito (not exactly wearing beard and glasses but without the red-carpet of the previous Wednesday) to take a good look around.

Russell Schweickart was Lunar Module pilot of the Apollo 9 mission. Together with David Scott and James McDivitt he was launched into space on 3 March to carry out, in earth orbit, a series of tests on the LEM (Lunar Excursion Module), the small space-craft which has to separate from the parent capsule when in lunar orbit to carry two astronauts down to the surface of the moon and back. During the Apollo 9 flight, the techniques of transferring men from the command module to the lunar module, the separation of the two craft and their 'docking' were successfully tested. These tests were repeated in lunar orbit during the Apollo 10 flight and all is now ready for the historic Apollo 11 mission due to be launched on 16 July for the first landing of man on the moon on 20 July.

A wide variety of questions on all aspects of the NASA space programme were confronted by Schweickart with humour, openess and thoroughness which kept his audiences fascinated for several hours. Here is his answer to the 50 000 million dollar question — why worry about the moon when there is so much to worry about on earth ?

'I don't think that one can avoid any of the problems that we have for the sake of research here at CERN, or moving into space, or any of the many other things that we do in extending the knowledge of man and man's capability. Also, we cannot foresake moving ahead, progressing into the unknown, and pushing back these boundaries for the sake of an internal problem, whether it is a government problem, a national problem or an international problem.

I use a particular analogy that has some meaning for me because I like music. If we gave up things like the space programme or research, it would be very much like a very talented violinist with a pain in his side, or even a cancer which may end up killing him in a year or two, giving up playing his concert before a great audience. He still contributes to man in exercising his talent to play the violin. I think this is an essential quality of man that I don't think we can give up for the sake of internal problems. At the same time, it would be foolish for him to neglect his internal problems.'

International education

In preparatien particularly for the establishment of the 300 GeV Laboratory, a lot of thinking is going into the evolution of a scheme for a multi-national school to meet the needs of the children of CERN staff and visitors. This thinking has taken as a starting point the results of the survey on education problems carried out in 1967 (reported in CERN COURIER vol. 8, page 187).

On 6 June, a meeting of specialists in international education was held at CERN to learn from their practical experiences, their successes and failures. In addition, a preliminary report was received from the Comparative Education Research Unit, Oxford, who have been called in as consultants to propose a model for the school at the 300 GeV site. The aim is to have a tailor-made proposition for international education ready for discussion with national authorities when the site is chosen.

The complexity of some of the problems was brought out by the divergences of emphasis among the experts and by the subsequent discussions, which could have absorbed many hours on each topic. Nevertheless, everyone saw the challenge of planning and constructing a school, adapted to the particular needs of CERN children, as a wonderful opportunity not only to meet the immediate needs but also to take a significant step forward in international education.

New neutrino shielding

When the neutrino experiment was set up in 1963, a 'filter' consisting of nearly 6000 tons of iron ingots was built in the path of the particles from the proton synchrotron to separate the neutrinos from all the other secondary particles produced with them. The unique ability of neutrinos to pass through considerable thicknesses of material without being stopped was thus used to provide a very pure beam which is essential for a neutrino experiment. Because of the very low probability of any interaction between these particles and the nuclei of the liquid filling the bubble chamber detector, neutrino events can be distinguished reliably only if the background due to other particles is very weak.

The iron ingots were provided by Messrs von Roll, and formed an integral part of the Swiss government reserves, on generous loan to CERN. Now, however, because of the shortage of this metal on the world market, von Roll have had to call for its return.

The next neutrino experiment is scheduled to take place in 1970 with the Gargamelle heavy liquid chamber, and will also need a neutrino filter. For technical and economic reasons (the requirement for as thin a filter as possible which will still stop a very high percentage of other particles, and the cost price) iron remains the best material available.

There were two possible courses of action — either to pay the full value of the ingots to allow the firm to obtain the same quantity of iron elsewhere (which would have removed the need to completely dismantle the shielding already in place), or to return the ingots and purchase another quantity elsewhere. This second alternative was chosen so that the shielding could be rebuilt with machined cast iron blocks rather than ingots which were conical in shape.

Convenience of handling is an important consideration and the handling time for ingots is twice that needed for machined blocks which, like the conventional concrete shielding blocks, can be fitted with a lifting cup. If, for example, with the Gargamelle chamber, a change-over were to be made from a neutrino experiment to an experiment on long-lived neutral kaons, part of the filter would have to be removed. This would take two to three months with the ingots and only half that time with machined blocks.

Experience has shown that the full 6000 tons is not necessary for the new neutrino experiment, but that 3500 to 5000 tons, depending on the design of the shielding, would be sufficient. (The main body of the filter will be 20 m thick with a cross-section of $3 \times 3.4\ m^2$ with further shielding added laterally.)

Since some of the ingots (about 5%) cannot be returned, because the induced radioactivity exceeds the tolerance level permitted by Swiss law, and since CERN already has some machined blocks available, an additional quantity of 2500 tons are to be acquired.

When the next neutrino experiments are finished, the blocks will be re-used at various points in CERN, particularly for shielding surrounding the targets in the new West experimental hall. Then, from 1972, it is intended to carry out anti-neutrino experiments with the Large European Bubble Chamber, filled with hydrogen, at the end of the West Hall and a filter will again be required.

Resisting radiation

When the CERN proton synchrotron was built in the 1950s, no systematic attention was paid to a problem whose importance is now very clear. The problem is that of aging effects in certain components used in the construction of the magnets of the synchrotron ring when they are subjected to radiation. Prior to that time, the intensities and energies of accelerators were not high enough to show up these phenomena.

Knowledge of the damage that could be caused came with experience. For example, PS magnet No. 1 is located downstream close to target No. 1 which receives a considerable proportion of the accelerated protons. It has therefore been bombarded by a considerable flux of secondary particles. In 1965 it had to be replaced by the only available spare magnet because of the damage caused to all its non-metallic components subjected to this flux.

Organic materials such as the insulation used on magnet excitation coils and pole face windings, electric cable sheathing, water supply pipes, adhesives used to bond the magnet steel sheets together, and gaskets, as well as components outside the magnets, such as toroidal bellows of the vacuum chambers, the camera windows, etc... all suffer adversely.

Systematic studies began in 1965 in search of organic materials with mechanical and electrical properties which would change only very slowly under irradiation. The aims were :

1) to lengthen the useful life of the PS magnets by replacing certain vulnerable components, especially in view of the planned increase in intensity of the PS
2) to make a judicious choice of materials for the construction of the magnets for the ISR where very intense beams will be stored.

Tests were made on plastics such as polyethylene, PVC (polyvinyl chloride), epoxy resins, polyesters, etc., and on elastomers, such as natural rubber, butyl rubber, etc. Most of the samples were subjected to radiation from external sources providing well-defined irradiation conditions (in the ASTRA reactor in Austria and the SILOE reactor in France).

In all these materials, it is the ionization produced inside them by the bombarding particles which causes changes in their structure. The excitation of molecules, leads to the breaking of molecular bonds and the formation of highly active free

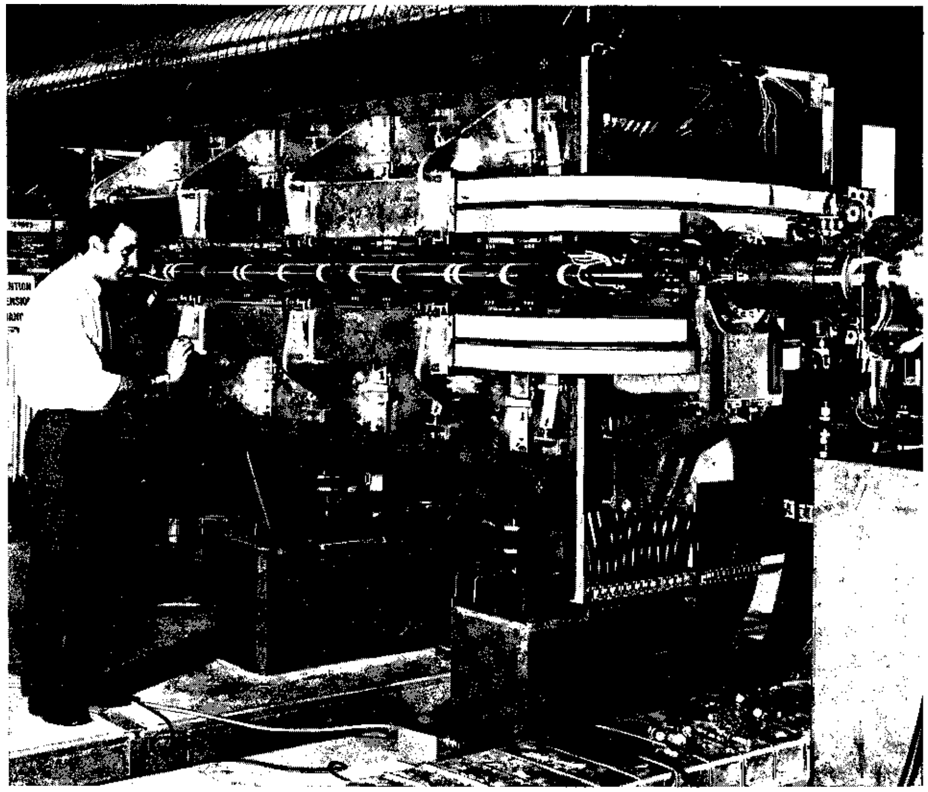
1. An ISR magnet in position in the tunnel. This photograph was taken after one of the first vacuum vessels was installed. It gives an impression of the variety and complexity of components used in accelerator construction, all of which have to have high resistance to radiation.

2. A water-cooling pipe made of PVC (polyvinyl chloride) showing the damage caused by a high dose of radiation.

3. Two samples of epoxy resin before and after receiving a dose of 5 x 10' rad.

The table shows the results of studies of the effects of radiation on a variety of plastics. (Elastomers have a much lower resistance — the best of them being polyurethane rubber which suffers serious damage after a dose of about 3 X 10& „d).
The plastics listed in the table are

1. Cellulose acetate
2. Polyamide
3. Polycarbonate
4. Polyethylene
5. Polyimide
6. Plexiglass
7. Polystyrene
8. Teflon
9. KEL-F
10. Polyvinyl carbazol
11. PVC (Polyvinyl chloride)
12. Polyvinylidene chloride
13. Epoxy resin (aromatic type)
14. Phenolic resin (unfilled)
15. Mylar
16. Polyester (unfilled)
17. Silicone (unfilled)
18. Urea-formaldehyde

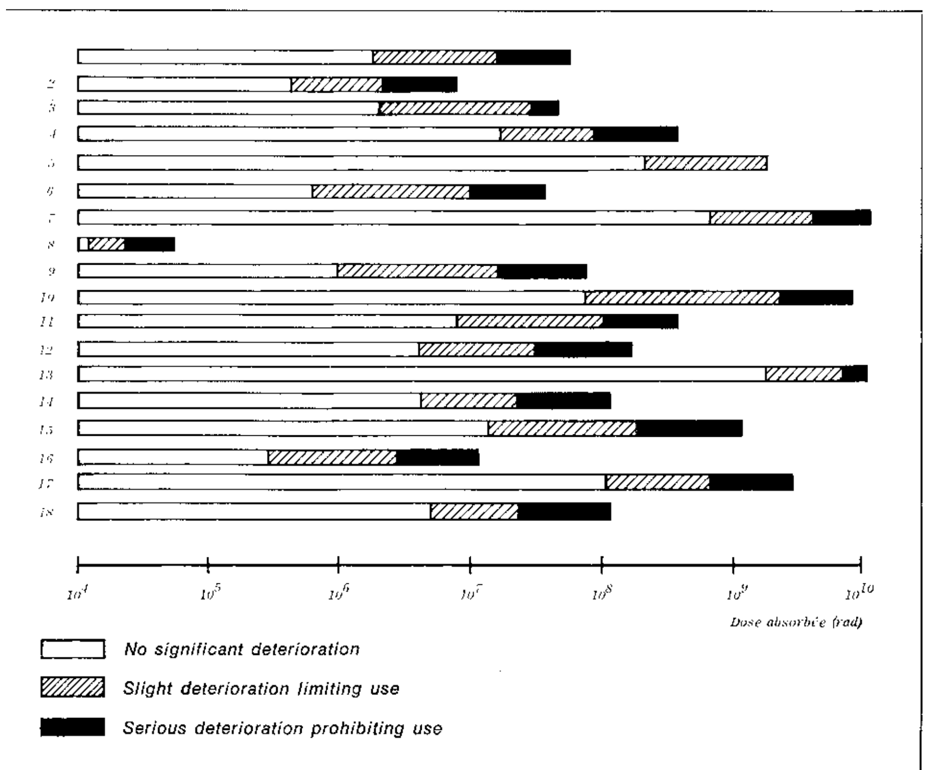


1.

radicals which, depending on the substance under consideration, react with one another or with the surrounding molecules. Most of the changes thus produced in the molecular structure are of the 'cross-linking' type (the formation of new transverse links between the polymer molecules) or are in the form of 'degradation' (the breakage of the primary links in the polymer chain). These two phenomena, which may occur simultaneously within the same substance, may also be accompanied by the formation of gaseous products, which give rise to internal stresses.

Changes in mechanical and electrical properties

These changes in the molecular structure cause a deterioration of mechanical properties beyond a threshold dose. The main cause of the failure of insulators subjected to radiation- is tbe reduction of their mechanical strength or the generation of gases rather than any change in their electrical properties as such. However, the resistivity is lowered due to the formation



of ions and free electrons, before becoming stabilized at a minimum level. It increases again when irradiation stops, but does not reach its original level — the stronger the irradiation, the greater the difference from the original level.

The investigations have shown that most modern epoxy resins with amine or aromatic anhydride curing agents and certain polyesters are highly resistant to irradiation. For handling and manufacturing reasons, however, epoxy resins are particularly suitable for the insulation of magnet windings, and also their cost has been reduced to a level comparable to that of polyesters. Compared with polyesters they have lower shrinkage (0 to 4% as against 7 to 10%), greater adhesive power, better dielectric properties, better temperature-resistance, longer shelf-life, etc.

The ISR magnets

Extrapolation of measurements made at the PS in 1966 and 1967 has made it possible to estimate that the 'hottest' points in the ISR will receive a dose of 2×10^9 rad in a period of ten years. It should be possible, by careful selection of the materials used in the construction of the magnets, to reduce to negligible proportions any breakdowns and maintenance problems connected with the aging of organic materials fora period of ten years.

Two firms are sharing the contract for coil insulation, Alsthom (France) for the excitation windings and BBC (Federal Republic of Germany) for the pole face windings. The excitation windings are first of all insulated by glass-fibre/mica tape wound around the conductor so as to cover it completely. The whole is then impregnated with an epoxy resin at about 85°C (this resin is a mixture of a conventional resin, a novolac resin, a curing agent of the aromatic anhydride type and a zirconium oxide surface filler) and subsequently baked to form a single block for each coil pancake. The pole face windings are insulated with a conventional epoxy resin with an aromatic amine curing agent.

Almost all of the cables, supports, toroidal joints, tubes, etc., are made of materials which behave well under radiation. All have been radiation-tested to check that they have adequate useful life.

Spares for the PS

To return to the PS, the most vulnerable magnets are now those downstream of the internal targets and the ejection zones (Nos. 1, 6, 58 and 62). To prepare for any breakdown, four spares are being constructed, using some reserve steel sheets left over from the construction of the initial magnets. They will be available towards the end of 1969.

ACEC are responsible for the excitation coils. The method used for their insulation consists of winding a pre-impregnated glass-fibre/mica tape around the conductors but, whereas in the case of the first PS magnets the imprégnant was of the polyester type, this time an epoxy resin is being used. The pole face windings, like those of the ISR are being made by BBC and the manufacturing process is the same.

These four magnets do not entirely solve the problem at the PS. Degradation will occur faster when the booster begins operation, increasing the present beam intensity. Although there is no direct relation between the increase in intensity (which could be more than 1000%) and the particle losses in the ring (which depend on the type of operation), the replacement of all the PS magnets could be necessary at some time to ensure that the ISR can operate for many years.

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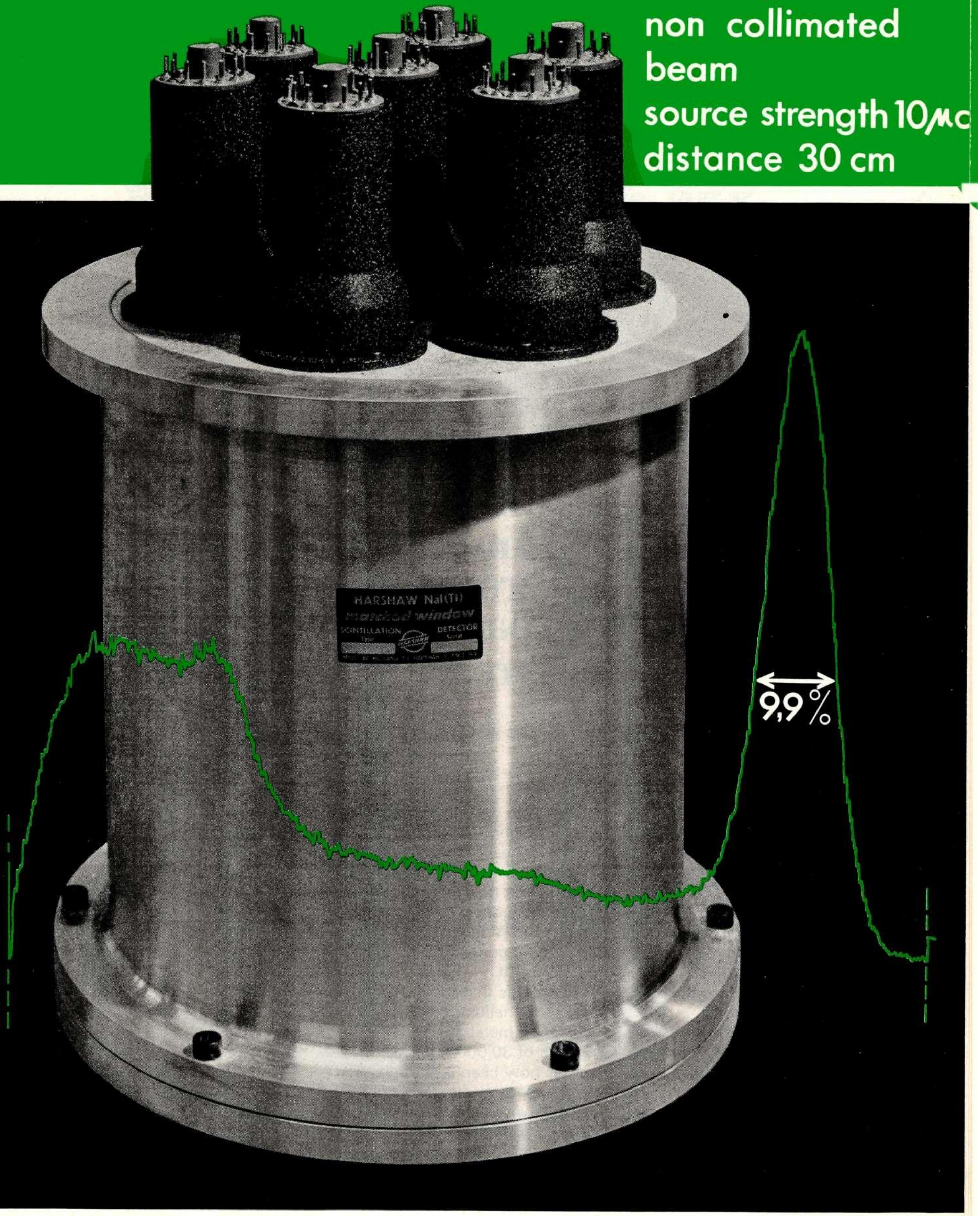
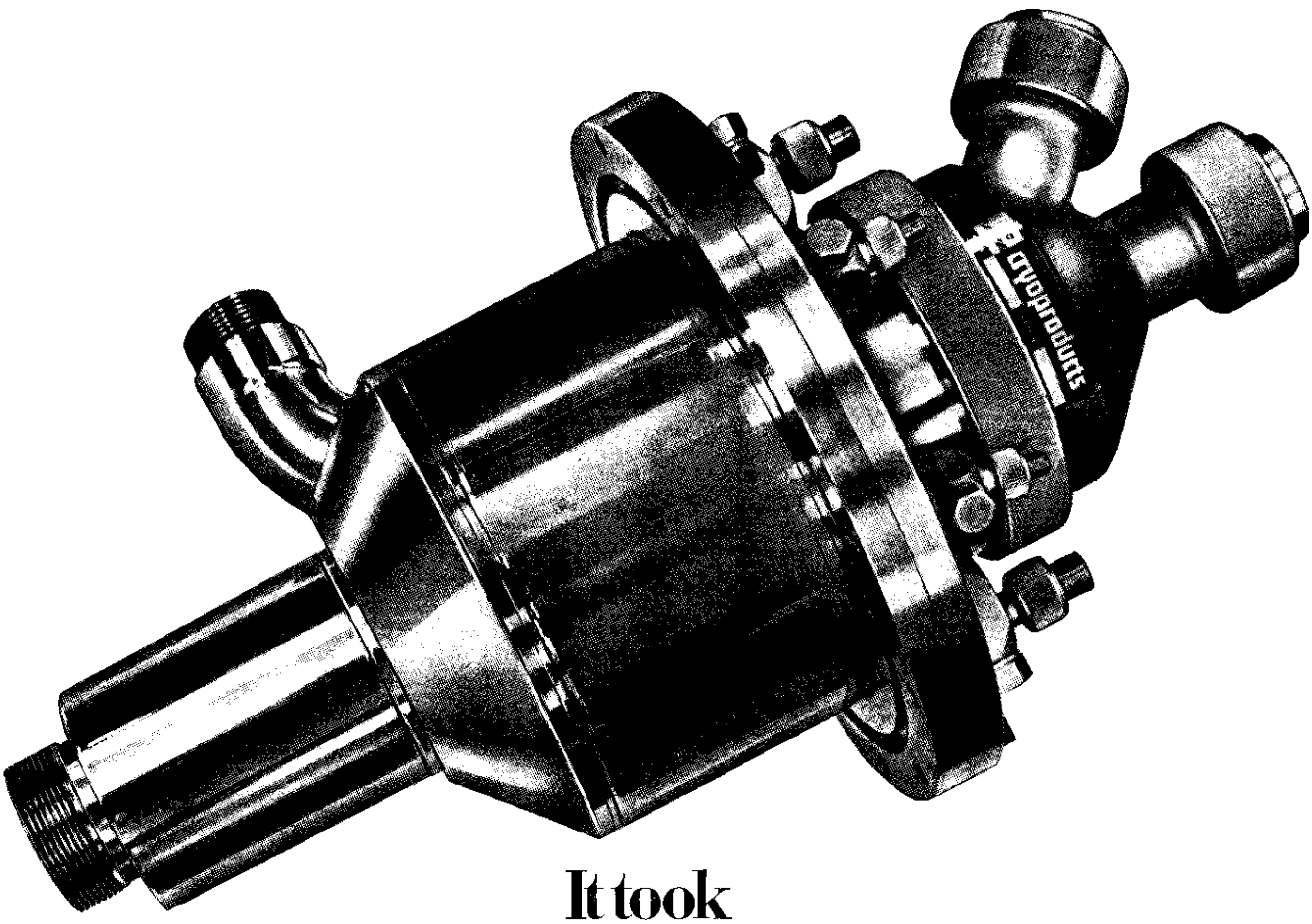
Cs^{137} spectrum
non collimated
beam
source strength 10 μc
distance 30 cm





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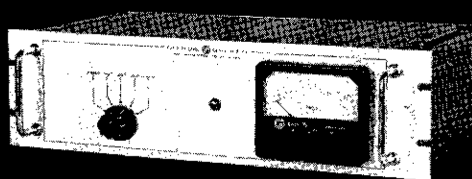

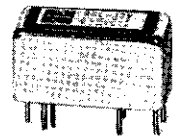

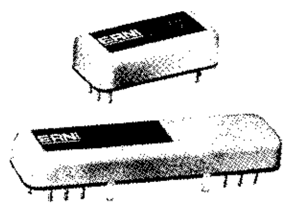

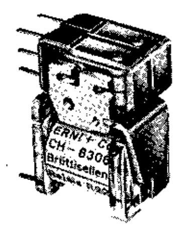

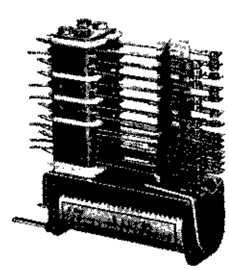

Silicon Lithium Drifted Annular Detectors

Standard Grade

Model Number	Resolution—keV at 20° C Electron	Resolution—keV at 20° C Alpha	Thickness (mm)	Active Area O.D. (mm)	Active Area I.D. (mm)	Active Area Area (mm2)	Hole Dia. (mm)
NEA 120-1	28	54	1	16	10	120	5
NE A 120-2	28	66	2	16	10	120	5
NEA 120-3	36	78	3	16	10	120	5
NEA 120-5	60	90	5	16	10	120	5
NEA 240-1	32	74	1	20	10	240	5
NEA 240-2	34	86	2	20	10	240	5
NEA 240-3	50	98	3	20	10	240	5
NEA 240-5	68	110	5	20	10	240	5
NEA 340-1	40	74	1	23	10	340	5
NEA 340-2	38	86	2	23	10	340	5
NEA 340-3	62	98	3	23	10	340	5
NEA 340-5	86	115	5	23	10	340	5
NEA 110-1	30	56	1	20	16	110	9
NEA 110-2	30	68	2	20	16	110	9
NEA 110-3	38	80	3	20	16	110	9
NEA 110-5	62	92	5	20	16	110	9
NEA 215-1	34	76	1	23	16	215	9
NEA 215-2	36	88	2	23	16	215	9
NEA 215-3	52	100	3	23	16	215	9
NEA 215-5	70	112	5	23	16	215	9

Selected Grade

Model Number	Resolution—keV at 20° C Electron	Resolution—keV at 20° C Alpha	Thickness (mm)	Active Area O.D. (mm)	Active Area I.D. (mm)	Active Area Area (mm²)	Hole Dia. (mm)
NEA 120-1A	15	38	1	16	10	120	5
NEA 120-2 A	16	42	2	16	10	120	5
NEA 120-3 A	22	45	3	16	10	120	5
NEA 120-5 A	30	48	5	16	10	120	5
NEA 240-1A	21	45	1	20	10	240	5
NEA 240-2A	23	52	2	20	10	240	5
NEA 240-3A	25	56	3	20	10	240	5
NEA 240-5A	36	64	5	20	10	240	5
NEA 340-1A	30	56	1	23	10	340	5
NEA 340-2A	25	63	2	23	10	340	5
NEA 340-3A	32	66	3	23	10	340	5
NEA 340-5A	40	75	5	23	10	340	5
NEA 110-1A	17	40	1	20	16	110	9
NEA 110-2 A	18	44	2	20	16	110	9
NEA 110-3 A	24	47	3	20	16	110	9
NEA110-5A	32	50	5	20	16	110	9
NEA 215-1A	23	47	1	23	16	215	9
NEA 215-2A	25	54	2	23	16	215	9
NEA 215-3A	27	58	3	23	16	215	9
NEA 215-5A	38	66	5	23	16	215	9

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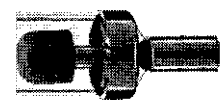

EEV flash tubes

Type	Enetgy input per flash max. (J)	Arc length (mm)	Bore diameter (mm)	Typical operating conditions Voltage (kV)	Series inductance (HH)	Flash rate	Trigger voltage (kV)
XL615/7/3	600	76	7.0	2.5	400	1 per 15 sec.	12-16
XL615/9/4	1500	102	9.0	2.5	400	1 per 30 sec.	12-16
XL615/10/5.5	3500	140	10.0	2.5	400	1 per 30 sec.	16-20
XL615/10/6.5	5000	165	10.0	2.5	800	1 per2min.	20-25
XL615/13/6.5	10000	165	13.0	2.5	800	1 per2min.	25

Send for full details of the complete range of EEV flash tubes.

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Telex: 99103 Grams: Enelectico Chelmsford
Represented by :
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Tel: (031) 44-27-11 Telex: 32-1 37

I am interested in EEV flash tubes for. . . . . (application).
Please send me data sheets on your full range.

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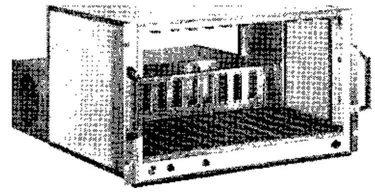
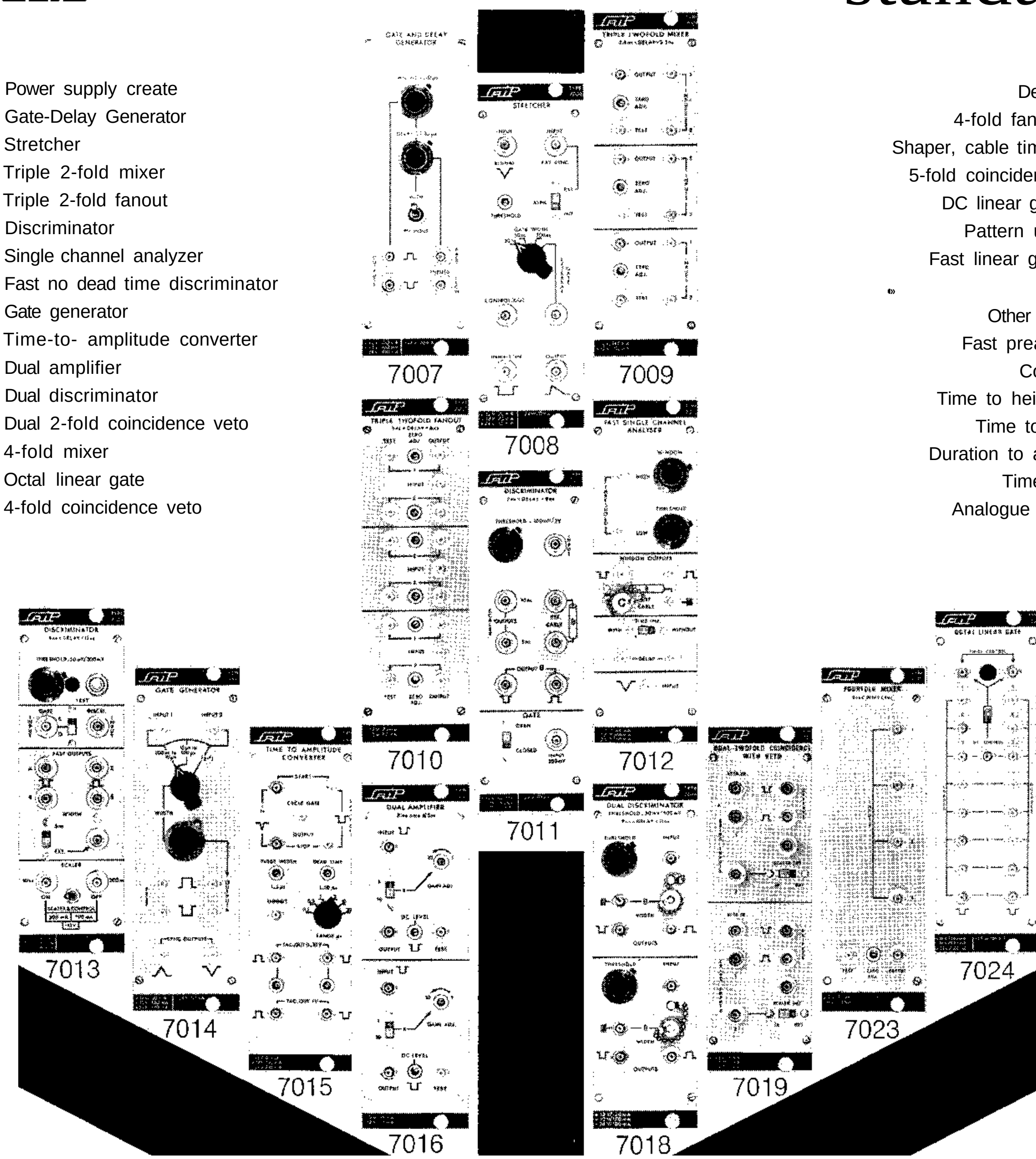


7000



7000 Power supply create
7007 Gate-Delay Generator
7008 Stretcher
7009 Triple 2-fold mixer
7010 Triple 2-fold fanout
7011 Discriminator
7012 Single channel analyzer
7013 Fast no dead time discriminator
7014 Gate generator
7015 Time-to- amplitude converter
7016 Dual amplifier
7018 Dual discriminator
7019 Dual 2-fold coincidence veto
7023 4-fold mixer
7024 Octal linear gate
7020 4-fold coincidence veto

Delay 7021
4-fold fanout 7022
Shaper, cable timed 7027
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Pattern unit 7030
Fast linear gate 7033

Other modules:
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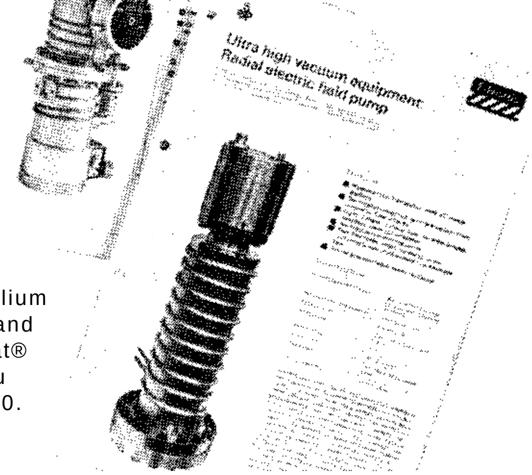
EDWARDS UHV COMPONENTS have no 'history' behind them; they start with an ultra-clean vacuum brazing process. So whether you build your own system or buy a complete plant from Edwards you get built-in advantages—initially and permanently.



When Edwards UHV components emerge from the vacuum brazing furnace they are thoroughly degassed, really clean. Their previous manufacturing and surface treatment 'history'has been completely obliterated by a degassing bake at 1050C°. System for system, that means higher vacua with lower baking temperatures, shorter cycles, and big economies in heating and control gear—whether you build your own plant, buy a standard plant from Edwards or order something custom-built with the pumps best suited to your application and budget. Edwards have no axe to grind—you can choose from sputter-ion and radial electric field pumps, liquid helium cryropumps, sublimation pumps, properly trapped vapour pumps and rotary pumps, and sorption pumps. Flanges can be either Confiât® compatible or ISO type. Leaflets are available ; we'll gladly send you a set. Or ask for the Edwards UHV Summary- Publication No. 13780.

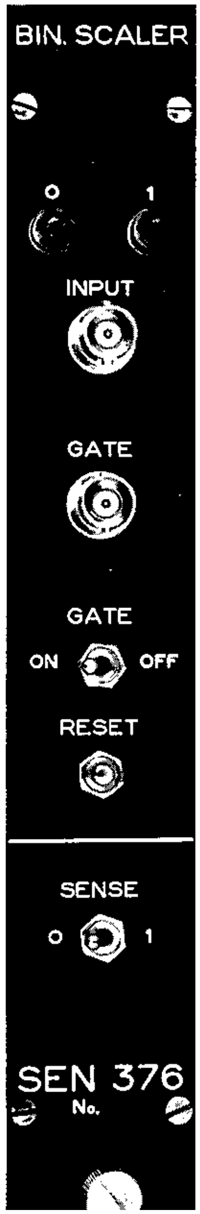
(R) *Confiât is a registered trade name of Varian Associates.*

Edwards

Edwards Vacuum Components Limited
A member of the BOC group
Manor Royal Crawley, Sussex, England
Telephone Crawley 28844 Telex 87123 Edhivac Crawley

Do you need a fast and economical binary scaler for your computerized experimental system ?

The type 376 Fast Scaler is certainly exactly what you are looking for. Just have a look on it's essential features hereafter.



- A 24 Bit, 10 ns Pulse Pair Resolution Scaler in a Single Width NIM Module.
- Input Shaper Exhibiting Schmitt Behaviour for Accepting Slow Rise Pulses.
- Input Threshold : - 300 mV
- Fast Response Input Gate, can be used as a Coincidence Circuit.
- Readout Connector for Computer Interfacing. All Output Lines allow "Wired OR Connection". The 24 Data Lines are Internally Strobed. All TTL compatible logic levels.
- Control Functions Provided : Gate Open
Gate Closed
Reset
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Sense Overflow
Sense Panel Switch

This last sense function provides operator control over the execution of the readout program.

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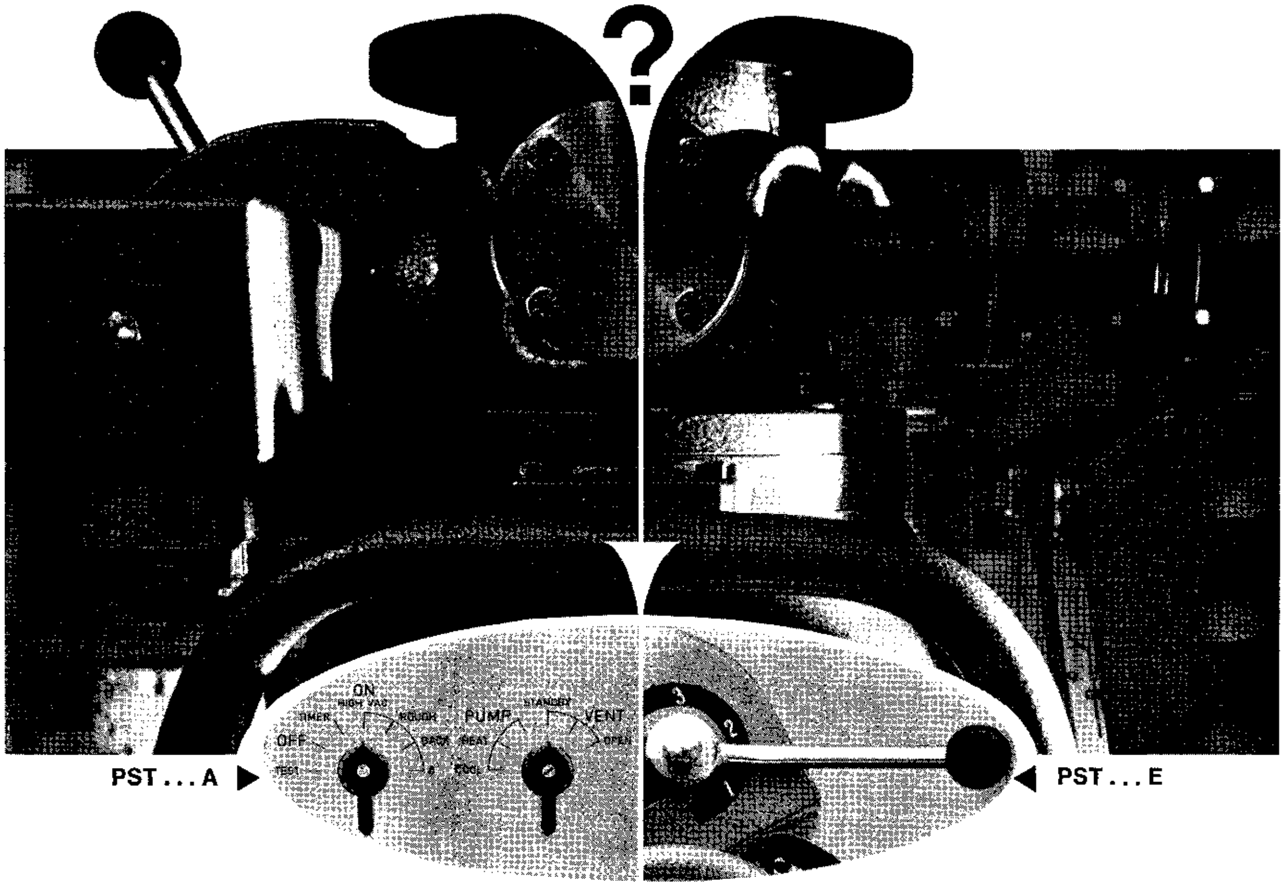
How can you concentrate to the full on your Vacuum Process and regard Vacuum Production as a side issue ?



This is quite simple . . . install a BALZERS high vacuum pumping unit, type PST.

PST . . . A automatically controlled. With the two switches provided set the pumping process required (this can include heating or cooling the vacuum chamber, also switching on the pumping unit at a preselected time) and wait until the required working pressure is reached.

PST . . . E single lever operated. The required mode of operation is selected by actuating a single lever, which controls sequential operation of the solenoid vacuum valves via a multi-pole type switch, so that errors of operation are avoided.

Other features:

- a wide range of accessories allows the simply constructed basic model to be adapted to the application;
- multi coolant baffle for use with either water or liquid nitrogen as required;
- effective safeguards to avoid the effects of breakdowns in electrical power, water or compressed air;
- individual components (pumps and valves) are all BALZERS traditional quality, carefully matched to each other to give optimum design, and assembled with care, guaranteeing a high standard of efficiency, long life and low operating costs;
- all pumping units are tested, ready for connection, and under guarantee.

Manufacturing and Sales programme

Type	pumping speed [3] l/sec.	Ultimate pressure [1] Torr.
PST 60 E 6 [2]	17	$< 2 \times 10^{-6}$
PST 60 E	17	$< 8 \times 10^{-7}$
PST 260 E	90	$< 5 \times 10^{-7}$
PST 900 E	315	$< 5 \times 10^{-7}$
PST 900 A	315	$< 5 \times 10^{-7}$
PST 1900 A	700	$< 5 \times 10^{-7}$
PST 5000 A	2150	$< 5 \times 10^{-7}$

[1]) with LN_2 cooling, ultimate pressures in the range of 10^{-8} Torr. from PST 260 E.

[2]) air cooled

[3]) for air above the plate valve

Special pumping units. We also design and build special pumping units to suit the application, and with pumping speed agreed with the customer.

If you will contact us we will be pleased to give you any further information or advice.

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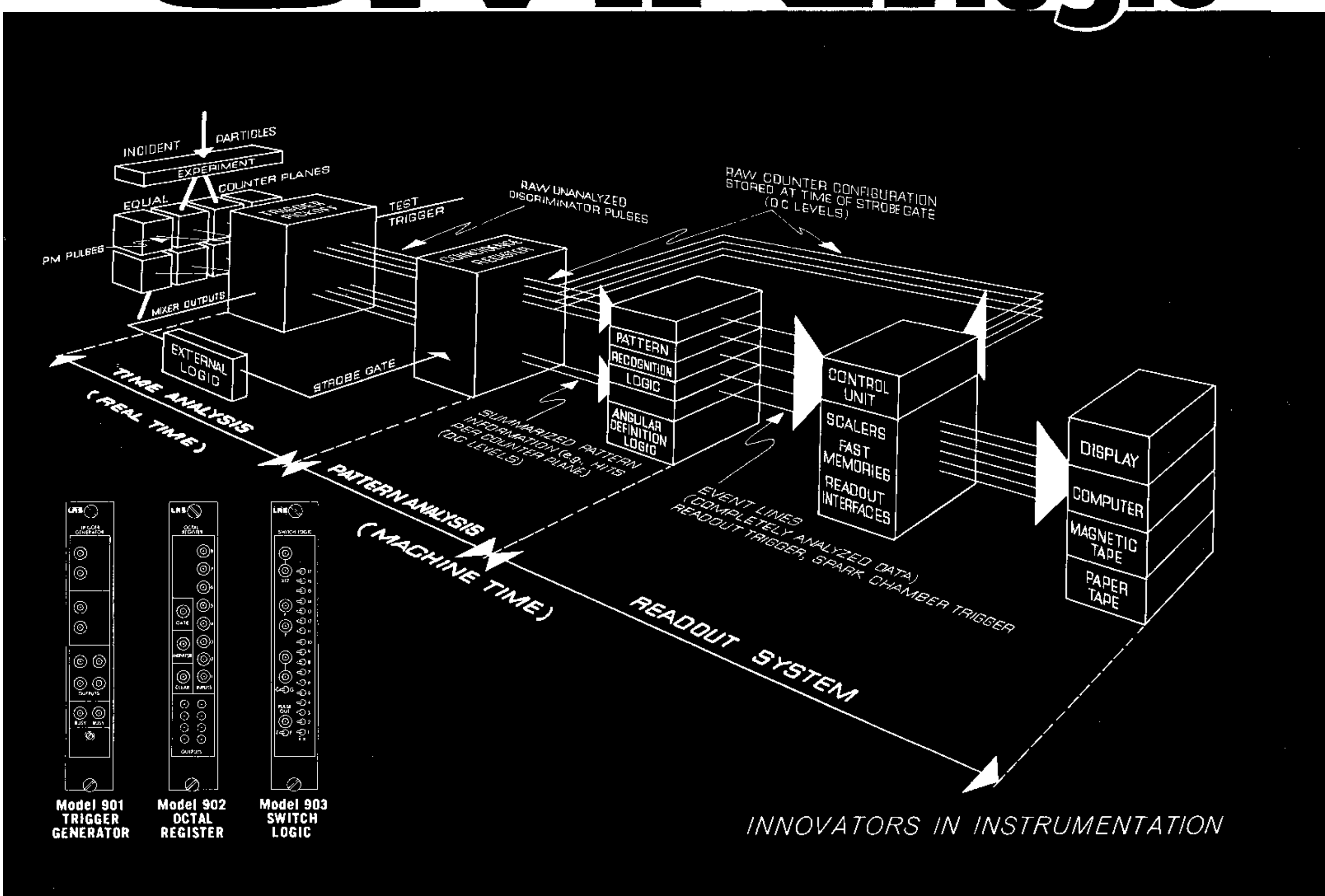
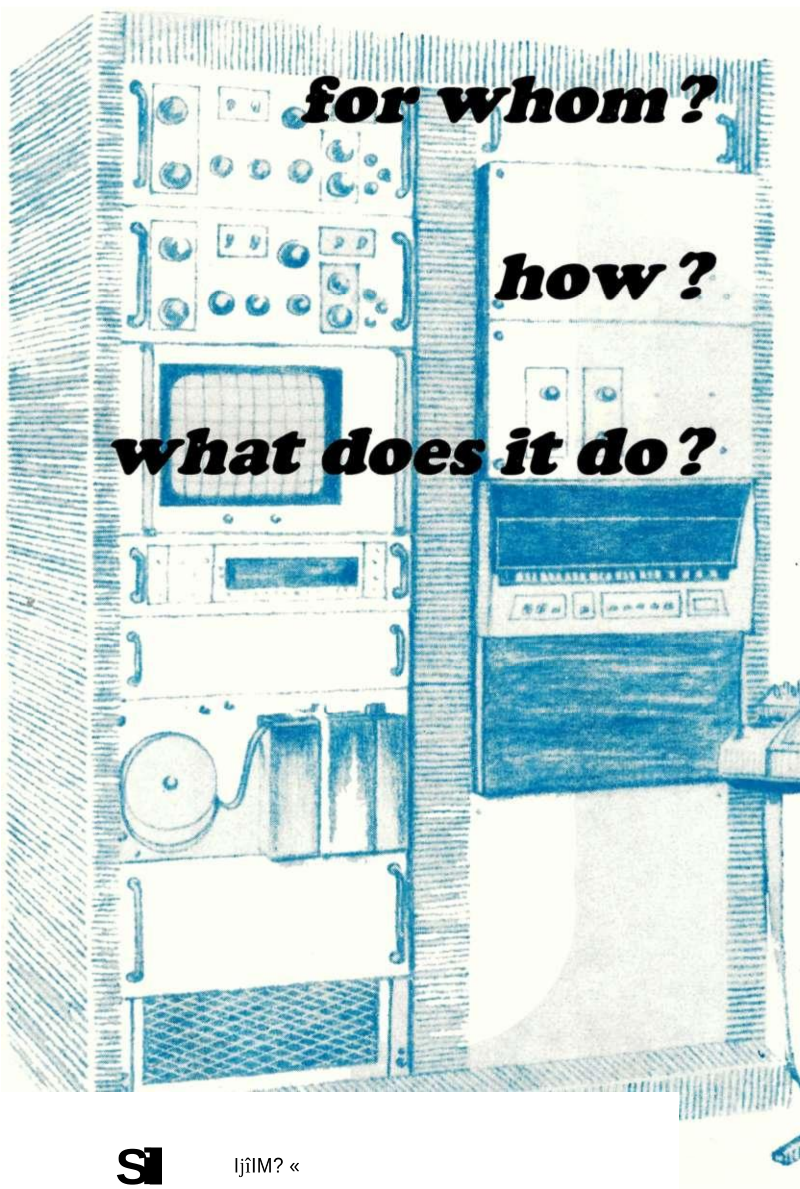


what is the NUDIAC ?

It is the DIGITAL COMPUTER which physicists have been waiting for. In fact, it is not only a digital computer, but a complete data acquisition and processing system which can be put to work immediately. It has been specially designed by nuclear instrumentation and computer specialists.

tor what?

Thesystem can be effectively employed throughout the complete range of NUCLEAR SPECTROMETRY problems.



for whom?

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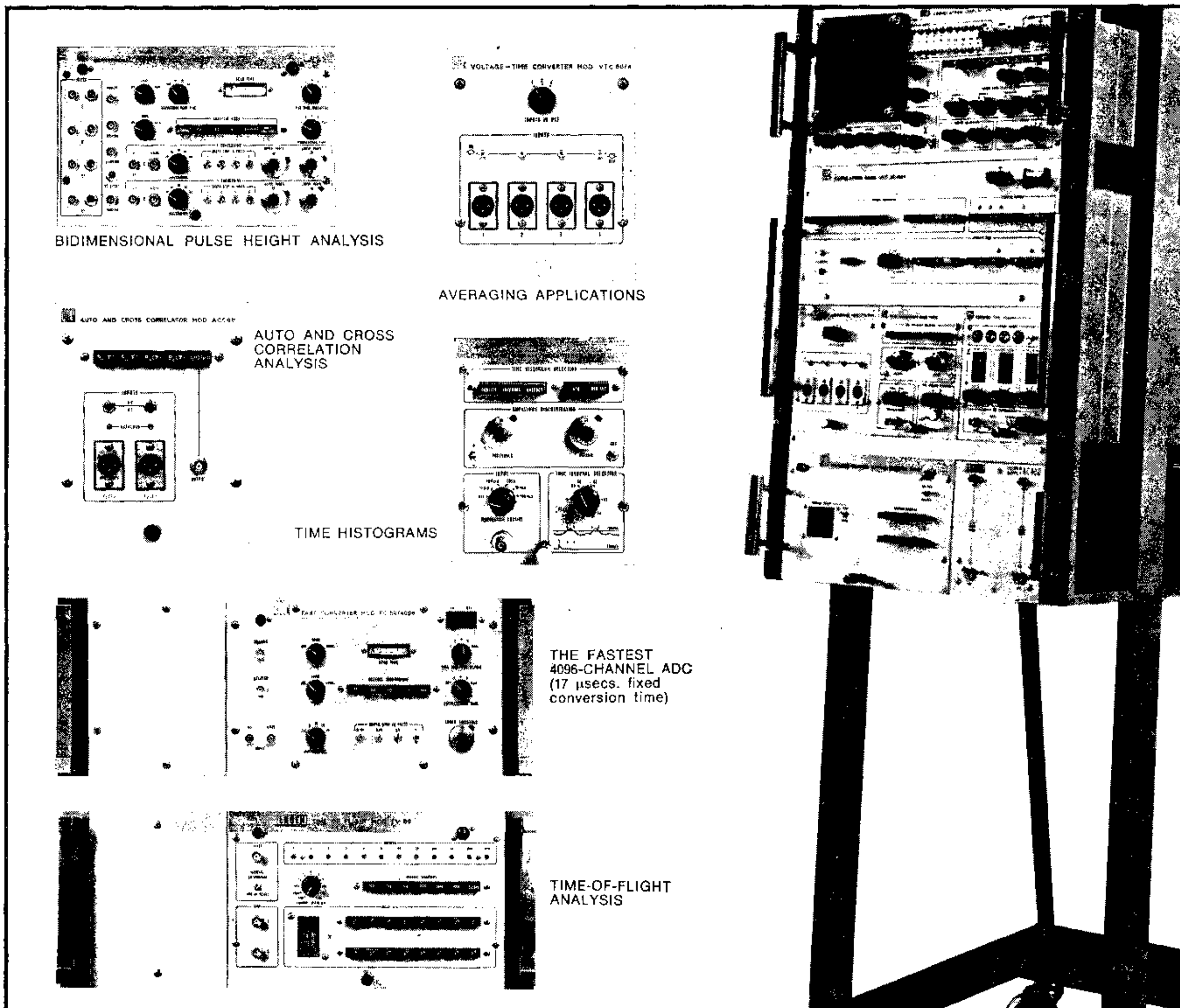

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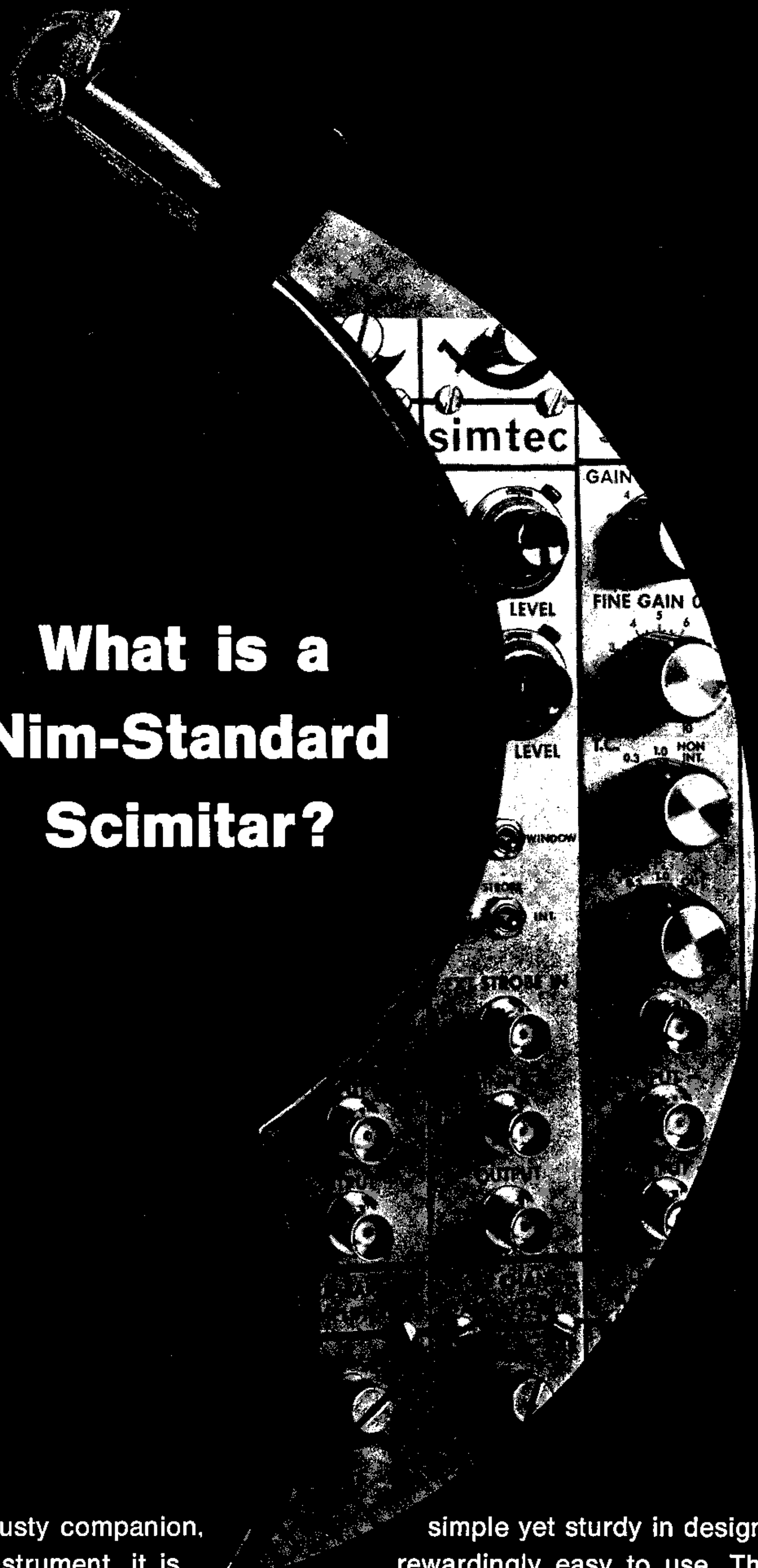

What is a Nim-Standard Scimitar?

A Scimitar is a trusty companion, simple yet sturdy in design. Constructed as a precision instrument, it is rewardingly easy to use. The clean lines conceal a wealth of engineering artistry in the tempered selection and use of materials. Scimitars accompany prudent explorers on exotic journeys of discovery. The complete line made by Simtec conforms to NIM-standards set by AEC 20893 and was developed in co-operation with AECL Chalk River Nuclear Laboratories. It is

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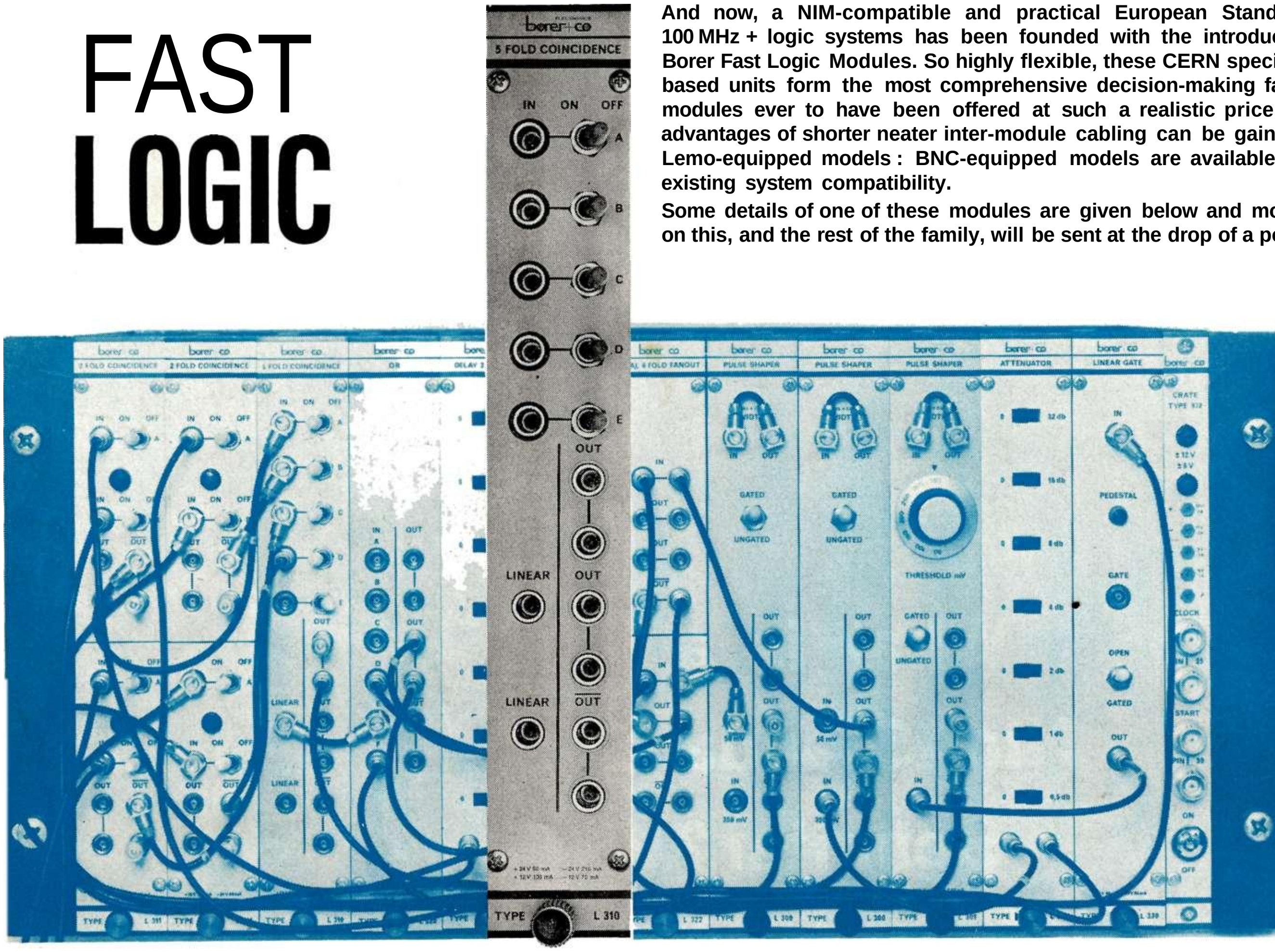
FAST LOGIC



And now, a NIM-compatible and practical European Standard for 100 MHz + logic systems has been founded with the introduction of Borer Fast Logic Modules. So highly flexible, these CERN specification based units form the most comprehensive decision-making family of modules ever to have been offered at such a realistic price. Bonus advantages of shorter neater inter-module cabling can be gained from Lemo-equipped models : BNC-equipped models are available too for existing system compatibility.

Some details of one of these modules are given below and more data on this, and the rest of the family, will be sent at the drop of a postcard.

Inputs	Impedance	50 ohms ± 2 %
	Reflections 'ON'	20 % max (capacitive)
	Reflections 'OFF'	15 % " " (inductive)
	Voltage	- 700 mV typ. }
		- 600 mV mln. } for coincidence
		- 100 mV max. for anti-coincidence
	Overlap LIN	2 ns min. for singles
		2 ns min. for 5-fold
	OUT,OUT	1.5 ns min. for singles
		1.25 ns min. for 5-fold
Linear outputs	Impedance	High, 16 mA current sources. Unused outputs need not be terminated.
	Rise Time	1.8 ns max.
	Fall Time	2.0 ns max.
	Width, equal to	(Overlap + 1.0) ns for singles
		(Overlap — 1.0) ns for 5-fold
	Rate	200 MHz max.
	Propagation delay	6 + 0.75 ns for singles
		Decreases by 0.5 ns max for 5-fold
	Feedthrough	± 15 mV max for n-1
Logic outputs	Impedance	High, 32 mA current sources, unused outputs must be terminated.
	Width OUT	8.5 + 1 ns
	Width OUT	9.0 + 1 ns
	Rise time OUT	1.5 ns max.
	Fall time OUT	2.2 ns max.
	Rise time OUT	2.0 ns max.
	Fall time OUT	2.2 ns max.
	Rate	Greater than 50 MHz
	Propagation delay	10.5 + 0.75 ns for singles
		Decreases by 0.5 ns max for 5-fold

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