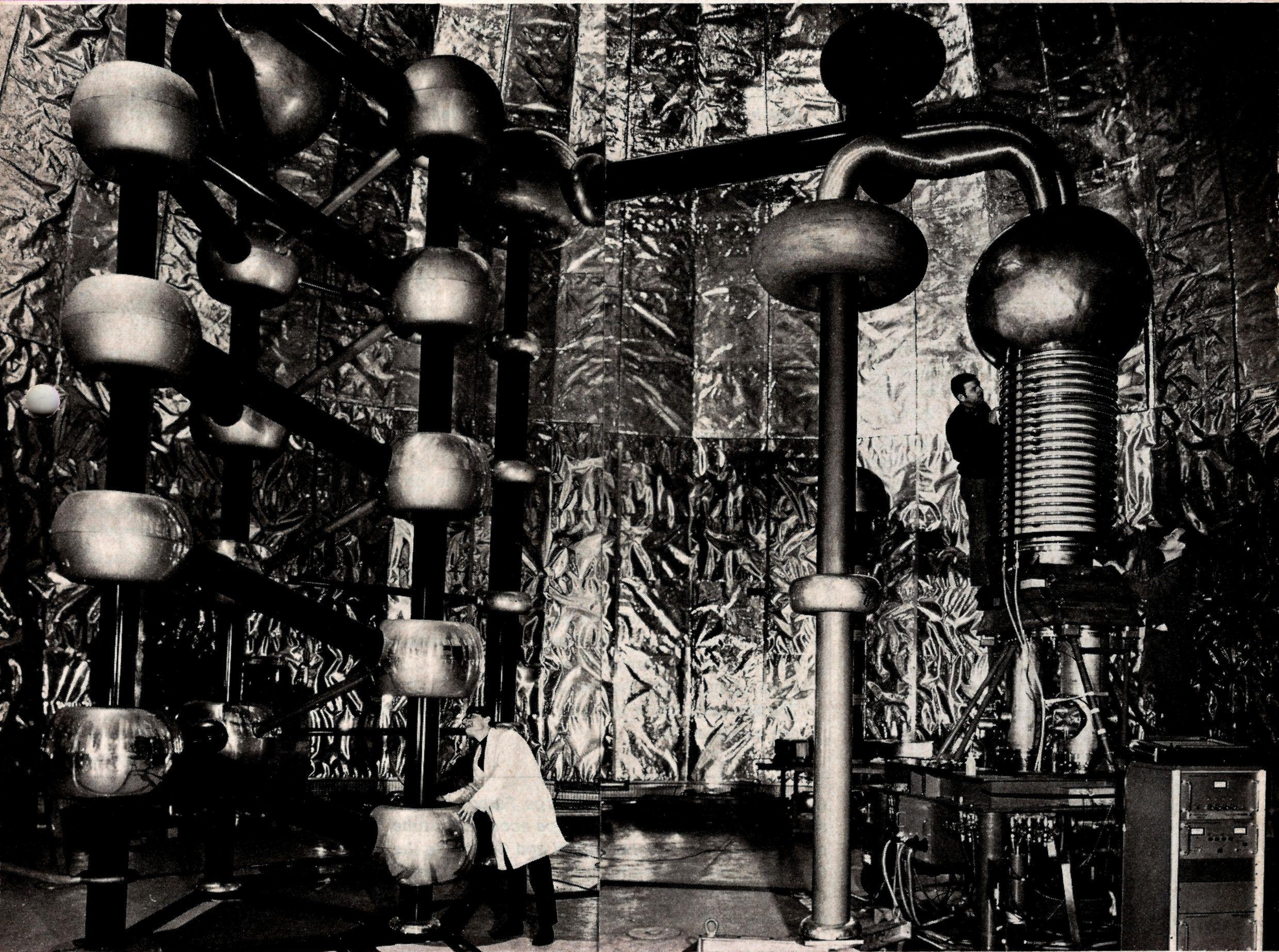
CERN COURIER

No. 3 Vol. 10 March 1970

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 450 Fellows and Visiting Scientists.

Twelve European countries participate in the work of CERN, contributing to the cost of the basic programme, 244.1 million Swiss francs in 1970, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

CERN COURIER is published monthly in English and French editions. It is distributed free to CERN employees and others interested in sub-nuclear physics.

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Printed by: Ed. Cherix et Filanosa S.A
1260 Nyon, Switzerland

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Cover photograph: Inside the large Faraday cage at the Institut de Physique Nucléaire at Lyon where tests on a prototype accelerator tube for 1.4 MeV operation are carried out in collaboration between IPN and CERN. On the left is the 1.5 MeV Haefely set. On the right is the accelerator tube during preliminary tests at 'low' voltage (850 kV). Since the photograph was taken, the tube has been enclosed for operation in sulphur hexafluoride at the full voltage. (Photo IPN)

Synchrotron injector at the half-way stage

G. Brianti
K. H. Reich

A review of progress on the synchrotron injector for the CERN proton synchrotron. The new injector, usually referred to as the PS Booster or PSB, will increase the energy at which particles are fed to the PS from 50 MeV to 800 MeV.

Booster Parameters

GENERAL	
Design kinetic energy at injection to the Booster	50 MeV
Design kinetic energy at transfer to the PS	800 MeV
Number of superposed rings	4
Mean radius	25 m
Number of protons accelerated per pulse	10^{13}
Repetition period	1.2 s
Number of focusing periods	16
Nominal working point at transfer — Q_H	4.60
Nominal working point at transfer — Q_V	4.85
Momentum compaction function	1.06 to 1.46 m
Design emittance at injection — horizontal	130 10^{-6} rad m
Design emittance at injection — vertical	40 10^{-6} rad m
MAGNET SYSTEM	
Bending magnets	
Bending radius	8.2 m
Aperture (height × width)	7 × 24 cm^2
Nominal mean magnetic flux density	1.3 to 6 kG
Magnet to magnet fluctuations (rms)	$< 5 \times 10^{-4}$
Quadrupole lenses	
Bore radius	6 cm
Maximum mean gradient	40 kG/m
Lens to lens fluctuations (rms)	$< 2 \times 10^{-3}$
R. F. SYSTEM	
Operating range of accelerating voltage	1 to 12 kV
Maximum rate of rise of voltage	100 V/μs
Frequency	2.7 to 8.2 MHz
Harmonic number	5
Maximum rate of frequency change	1 kHz/μs
VACUUM SYSTEM	
Design pressure	10^{-7} torr
Number of 400 litre pumps	35

The purpose of the PS Booster is to increase substantially the accelerated beam intensity available from the PS and the interaction rate in the colliding beams of the ISR. Its main features have been described before in CERN COURIER, vol. 8, page 3 and this article will concentrate on the present state of the projet. This is appropriate at a time when all the major contracts have been placed, practically all the machine components have been specified in detail and most of the civil engineering work has been completed.

The work reported here, concerned with the accelerator design and construction, has been carried out mainly in the Synchrotron Injector Division and in the PS Machine Division (for particular aspects of the project) through a collaboration which aims at minimizing personnel costs by avoiding duplication of groups and services as much as possible. The civil engineering work is carried out under the responsibility of the Technical Services and Buildings Division.

What the Injector looks like

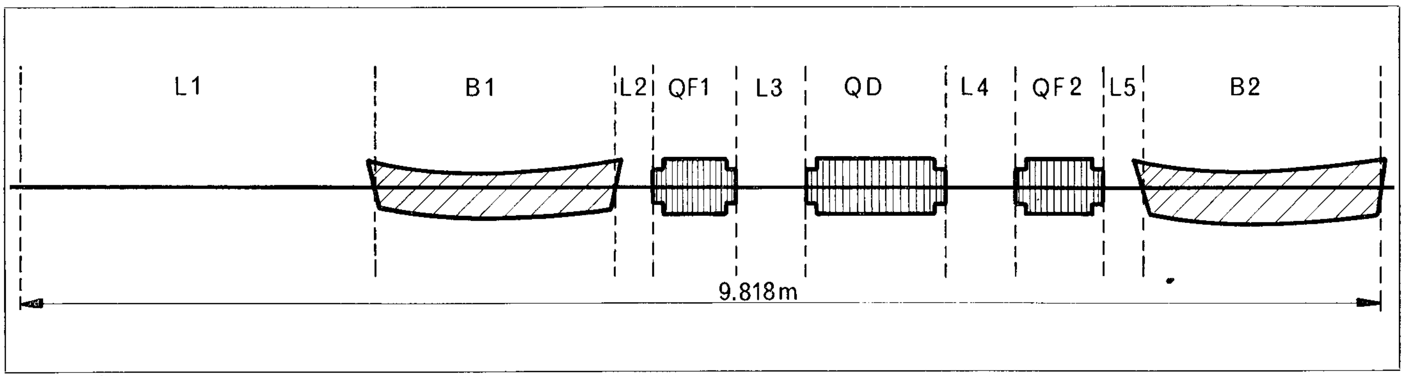
For new readers it is useful to recall the main aspects of the machine. It consists of four slow-cycling synchrotrons 50 m in diameter stacked vertically one on top of the other. The synchrotrons are filled in succession with the 50 MeV beam coming from the existing Linac. Using four rings instead of one, it should be possible to trap and accelerate a substantially greater total number of protons without altering unduly the present transverse dimensions of the final PS beam.

When the particles have been accelerated to 800 MeV the four circulating beams are extracted and recombined into a single beam for transfer into the PS. At this comparatively high energy, the space charge limit in the PS (the beam intensity at which the space charge forces in the beam itself inhibit further increase in intensity) should be well beyond the intensity of 10^{13} protons per pulse which is aimed for.

Parameters and theory

Since the time when the feasibility study was produced, work has continued in two directions:

1) to refine the proposed parameters



1.

The layout, to scale, of a Booster focusing period (there are 16 such periods in a ring). B1 and B2 are bending magnets, QF1 and QF2 are radially focusing quadrupoles and QD a radially defocusing quadrupole.

The straight sections will typically contain

L1: injection septum magnet; injection kicker magnet; correction magnets; beam observation equipment; r.f. accelerating cavity; ejection kicker magnet; ejection septum magnet; vacuum manifold and pumps (standard location).

L2: sector valve; vacuum manifold and pumps; pick-up electrode; beam scraper (standard location).

L3: multipole lens (standard location) and pick-up electrode.

L4: orbit correction dipole (standard location); dipole to deform the orbit for multiturn injection or for ejection.

L5: vacuum manifold and pumps; beam scraper (standard location).

(Standard location means that whenever possible all sixteen periods contain the same equipment).

2) to fill-in the blank spaces left in the study.

Under 1) we discuss briefly the main magnet, the r.f. accelerating system, injection and ejection, and under 2) the magnetic correction elements. We also define the machine geometry in more detail, including the layout and use of the different straight sections. The resulting parameters are listed in the Table.

Besides their required function of forcing the protons to follow the polygon-shaped orbit, the main bending magnets may have undesirable side effects due to inevitable imperfections. For example, fluctuations of the field strength on the central orbit from magnet to magnet causes orbit distortions in the horizontal plane, and imprecise magnet alignment can cause orbit distortions in the vertical plane. Deviations from the specified field can create unwanted coupling between the betatron oscillations in the horizontal and vertical planes which may then lead to proton density dilution, resonances and beam loss. To determine the admissible level of some of these non-linearities the beam behaviour has been simulated by a computer model of the Booster using the magnetic fields as measured in the bending magnet model. Similarly, the effects of imperfections in the main quadrupoles were studied and maximum admissible values determined.

Provisional values of the r.f. voltage and frequency ranges were arrived at initially on the basis of the 'zero particle' theory, and we have since looked at intensity effects. The Coulomb repulsion between the protons tends to lengthen (defocus) the bunches, when below transition energy, and a higher accelerating voltage is then required to maintain the necessary longitudinal focusing. To offset the voltage induced in the r.f. accelerating cavity by the circulating current (beam-loading) another increase of r.f. power is required. Furthermore, these induced voltages (and those induced in all sorts of equipment installed around the ring) could cause loss of beam stability. These effects are being studied (by making measurements on the PS, by using a dynamical mathematical model and by experimenting with an electronic analog model) with a view to optimizing the parameters of the final system.

Refining the injection and ejection geometries meant essentially establishing the necessary beam orbit deformations in such a way as to use a minimum of extra horizontal aperture while keeping one type of straight section free for placing multipole lenses. Subsequently the machine apertures were recalculated in detail and the vacuum chamber dimensions determined.

The magnetic correction elements are 17 dipole and 20 multipole lenses per ring. The dipoles serve to correct the closed orbit and their number was arrived at, following a detailed study, as a comprise between a 'perfect' correction and a 'minimum-cost' correction. It is intended to use them first for a point by point correction to get the beam once around the Booster, then (if necessary) to reduce any large remaining deformations, and finally to minimize all orbit deformations, particularly in the injection region. The multipole units consist of several sets of coils producing quadrupole ('skew' and normal), sextupole and octupole fields. Their number and field strengths were chosen to give the maximum possibilities in the control of the betatron oscillations of the orbiting protons.

Besides the work on the parameters, we are extending the existing theoretical knowledge of beam behaviour with a view to:

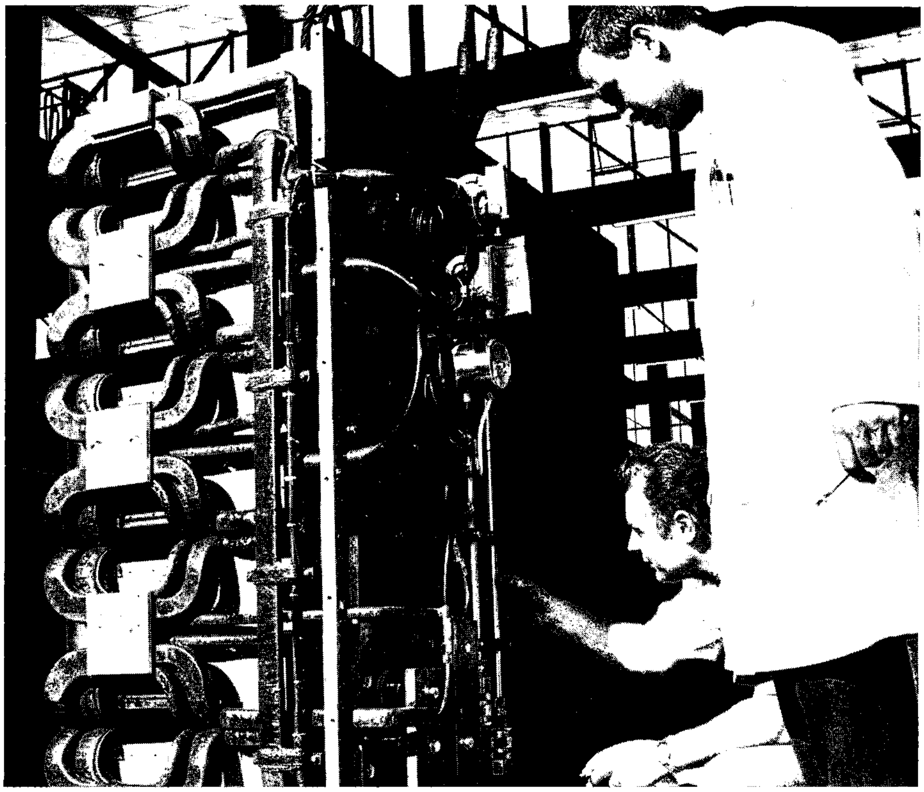
- starting Booster operation at high intensity with the best initial conditions,
- interpreting the results of the running-in measurements and,
- planning future improvements which are already possible.

Here we may mention the detailed study of (1) multiturn injection into the Booster, including the density distribution as a function of various injection parameters, (2) both stationary particle distributions and the various types of particle density dilutions and instabilities occurring under space charge conditions, and (3) the evolution of proton density from the Linac through the Booster and PS to the ISR. A partial result of some of these studies is the choice of the nominal working point at transfer as $Q_H = 4.6$, $Q_V = 4.85$.

General design

In designing a machine like the Booster, consisting of four superimposed synchrotrons, we have to solve a few additional important problems compared to a normal synchrotron.

The first one is to decide a suitable vertical spacing between the four circulating beams. From the point of view of the accelerator itself, the tendency is to have a distance as large as possible in order to accommodate with ease the r.f. cavities, the quadrupole apertures, etc. On the other hand, from the point of view of



CERN/PI 377.9.69

2.

The prototype bending magnet showing clearly the four superposed gaps. The coils are inserted from the side and kept in place by closing plates.

recombining the four beams into a single one after ejection, the incentive is to minimize the vertical distance between beams, since a large distance implies large vertical bending angles and correspondingly stringent tolerances on them. Detailed studies led to a choice of a distance only a little larger than the outer diameter (350 mm) of the ferrite rings for the r.f. cavities, namely 360 mm.

Another problem is introduced by the fact that the magnetic elements are constructed as single blocks for the four rings (the only practical construction method) so that the support and alignment system is common to all of them. This calls for stringent tolerances on the distance and relative orientation between gaps, especially for the quadrupoles, and particular requirements for the alignment system.

A further problem is the control of four rings which are intimately correlated, but for which we would like to preserve independent adjustments as far as possible. This required detailed studies of advanced control systems to marry overall economy and simplicity with the relative independence of the four synchrotrons which is necessary for their optimum performance.

Having superimposed synchrotrons brings many advantages in its wake as well as the special problems mentioned above. Certain savings are possible by comparison with the cost of a single synchrotron of four times the diameter — the circumference of the tunnel to house the machine and the overall dimensions of associated buildings are smaller; the combined magnet unit costs less than four individual units ; the combined vacuum system requires fewer and larger pumps; beam observation and control can be carried out with fewer electronic systems (observation and control being of one, or at most two, rings at a time).

Injection

As in some other cases discussed here, progress on the injection line meant going from the 'zero particle' approximation to studying the 'high intensity' solution. With respect to the beam optics this meant taking space charge forces into account. They are particularly strong at the exit of the Linac, where the bunch length is only of the order of centimetres. (Subsequently the bunches spread out rapidly to about 50 cm length, thereby reducing the proton density and hence the space charge forces). The re-optimization is well advanced; it leads to higher lens strengths and possibly a few extra lenses compared to the original design. Also, the lens strengths will depend on the Linac current, and this complication was one of the reasons for bringing in the control computer for setting the lens currents. All magnetic elements for the injection line, their supplies, and some vacuum components have been ordered.

As regards the vertical beam distributor (which distributes the linac beam to the four levels of the Booster), consideration of the effects of stray particles on the field of an electrostatic device have swung the choice to a magnetic device. Similarly a magnetic device has been adopted for the inflector, an additional reason here being the saving in space, which makes it possible to install more beam observation and correction elements in the injection straight section. Model work on these components is well advanced.

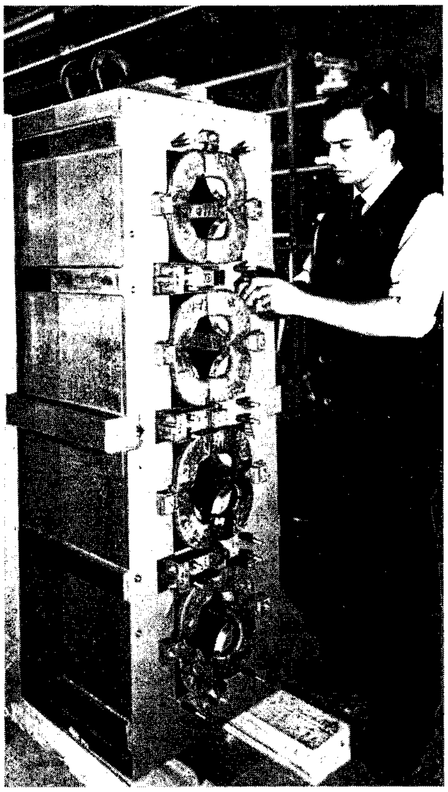
Main magnet

The main magnet system is of the 'separated function' type. It comprises 16 identical periods, with two bending magnets and a quadrupole triplet in each of them. This particular lattice has the important advantage of maintaining a relatively narrow beam both horizontally and vertically inside the bending magnets and in the long straight sections where the ejection kicker magnets are located, thus simplifying their design. A disadvantage of this lattice is that it demands rather more space around the circumference but since the Booster circumference is fixed as a quarter of that of the PS (which is very large for a 800 MeV machine) this disadvantage is not so important.

Certain features of the magnet design have been influenced by the problem of how to power and interconnect the 320 gaps belonging to four synchrotrons and to three different types of magnet (bending, horizontally focusing (F), and horizontally defocusing (D) quadrupoles).

The necessary power is considerably lower than that of the PS and this opened up the possibility of adopting a power supply not containing any rotating machinery, but with solid-state controlled rectifiers fed directly from the mains. The influence on the electricity network of taking a 10 MW active power pulse from the mains at the PS repetition rate (a pulse every 1.15 to 3 s) was carefully studied experimentally by our staff in collaboration with J.A. Fox from the Rutherford Laboratory and the Services Industriels de Genève. On the basis of the satisfactory results, it was decided to proceed with the design of a static power supply consisting of three dodecaphase rectifier sets, sequentially switched on, and of a fourth set to equalize the reactive power absorption during the cycle which is subsequently partially compensated by a capacitor bank.

In order to be able to adjust the operating conditions of the Booster, we should be able to vary the currents in the F and D quadrupoles independently from the



CERN/PI 88.12.69 3.

The prototype quadrupole being prepared for magnetic measurements. For the final version the quadrupole will have the four gaps stamped out in a single lamination.

current in the bending magnets. Given the complexity of the type of power supply described above, we came to the conclusion that it would be more economical to power all the magnet gaps of all the rings and of all types in series, thus needing only one main supply, and to vary the currents in the F and D quadrupoles (by 7 %) by means of much smaller trim supplies. Of course by such interconnections, the lengths of the magnetic elements of different types are no longer independent. The main power supply (3000 A, 2850 V peak) was ordered in October 1969 and should be completely installed by May 1971.

Considerations of peak magnetic energy and of the relatively high influence of the magnet end-fields have led to the adoption of a rather low peak field in the bending magnet (6 kG) and gradient in the quadrupoles (40 kG/m). The cost of the iron and copper represents only a fraction of the total magnet cost, and it appeared more economical to invest a modest sum in lengthening the magnets rather than to have a more stringent design. Savings are thus made on the main power supply and on the difficult compensation of the end fields. The fact that magnets will be operated in the low to medium field region suggested the use of a silicon steel.

The design is a 'window frame' configuration of the C-type (without yoke on one side). This solution is attractive not only for its intrinsic properties of magnetic field uniformity but also because of the difficulty of realizing four superimposed magnets with prominent poles. The C-shape has the advantages of allowing injection and extraction of the beams in essentially field-free regions, and of making possible lateral insertion of the coils.

A special feature is that the four gaps, even though geometrically identical, when submitted to the same excitation show slightly different magnetic fields. In fact the top and bottom gaps have a somewhat higher field at injection and a lower one at top energy that the two inner gaps, due to the different ratios of iron to air paths. (This consideration made it very important to choose a steel with low coercive force and high permeability.) To correct these effects the magnetic length of the four gaps will be made equal for top energy (where such equalization is most essential) and, to reduce the phenomenon at injection, it will be possible to take the current at the end of the cycle to a value lower than that needed at injection. The power connections of the magnet system allow a small change of the current in the outer or inner gaps, if necessary, by means of a trim supply. Auxiliary windings make it possible to equalize the field integrals of the various rings.

A complete magnet unit (figure 2) to be used as a model was delivered in September 1969 and the measurements have confirmed essentially the design assumptions. The method of construction of the block (laminations, 1 mm thick, precisely stacked in a frame and then welded together) proved to be satisfactory although special care has to be taken during welding to avoid the opening-up of the two outer gaps. The coil conductors nearest to the beam have to be accurately positioned to avoid an asymmetry of the magnetic field with respect to the median geometrical plane of each gap. We placed the contract for 34 magnets (32 in the ring, 1 as a reference unit and 1 spare) in December 1969. The first magnet of the series is expected by the end of September 1970 and the completion of the delivery by May 1971.

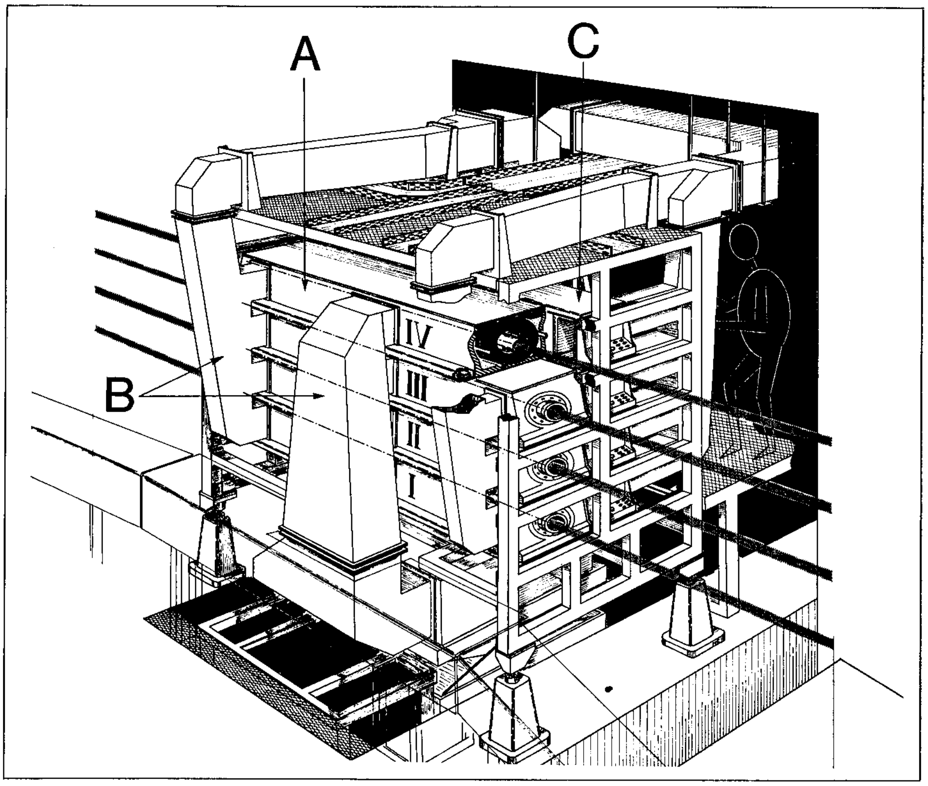
The quadrupoles of the two types, F and D, with identical cross-section but different lengths, present considerable problems. They originate from the fact that for simplicity and economy, it is quite convenient to construct the four superimposed quadrupoles as a single magnet, but this procedure imposes quite stringent tolerances not only within a particular gap but also on the distance between the magnetic centres of different gaps.

Originally it was envisaged to split the iron core into four parts and to construct the complete coils in a normal manner and insert them between the iron blocks suitably assembled. Following practical tests and more detailed studies, it has been decided to construct the quadrupole core as one single block, with laminations stamped out for the four quadrupolar apertures from one iron sheet. This procedure ensures much better tolerances between gaps but requires a different technique for the coil construction than the one mentioned above.

In fact conductors in the form of U-bars carrying the glass-tape not impregnated are introduced through the appropriate slots and then the coils are completed by means of copper bars brazed to the U-bars. The entire coil is then impregnated in situ.

Another important aspect of the quadrupole design is the compensation of end effects which are very serious if we consider the high precision required and the rather short length of the magnets. This compensation will be made by adequate shimming of the end plates, which is being tackled by means of computations and experimental work on a prototype (figure 3) which was received in November 1969.

In February 1970, the contract for the construction of 48 quadrupole units and some spares was placed. The first unit is expected by January 1971 and the completion of the delivery by August 1971.



Artist's impression of the group of four superposed accelerating cavities (A) with their air cooling system. The four ring levels are indicated I, II, III, IV.

The air ducts (B) can be disconnected to enable the cavities to be moved out for servicing. Part of cavity IV has been cut away to show the ferrite rings. The r.f. power amplifiers (C) are visible at the rear.

4.

R.f. accelerating system

As a result of three years of theoretical and experimental study including model work, the design of the r.f. accelerating system is now frozen. Each cavity consists of two quarter-wave ferrite-loaded resonators, one of which is excited by an r.f. generator. After the ring separation was increased to 360 mm it was found possible to combine the four cavities in a single unit as shown in figure 4. (A second straight section located diametrically opposite in the Booster is reserved for a further unit).

The two times twenty-five ferrite rings per cavity (350 mm outside diameter, 200 mm inside diameter, 30 mm thick) are air-cooled. This type of cooling was chosen for its simplicity: in contrast to some cooling fluids, air does not influence the r.f. fields, does not attack the ferrites chemically, is not toxic, does not present a problem in case of small leaks — and it does not have long delivery times, nor does it present a large budget item! Apart from the bulkiness of air ducts (and the limited cooling capacity), the main drawback is the possibility of 'thermal run-away' of individual ferrite rings which are no longer closely coupled thermally to a large-capacity heat sink. This potential danger was avoided by specifying close tolerances on the relevant ferrite properties from ring to ring and by working with a conservative maximum temperature (about 30° C).

The ferrites are biased by means of two 'figure of eight' loops (rather than by means of an external magnet yoke), which at the same time couple the two half-cavities. We finally decided to locate the final stage of the power amplifier at the cavity which makes it possible to achieve better control of beam-cavity interactions. Each cavity will be equipped with a double unit, one active and one in reserve which can be switched in remotely. The pre-amplifier and driver stages as well as the tuning amplifier will be located in the central r.f. room (outside the radiation environment), thereby increasing their lifetime and facilitating their servicing.

Like all alternating gradient proton synchrotrons, the Booster will be equipped with an automatic beam control system for the control of the r.f. phase and frequency (i.e. radial beam position). In the design of this system due regard is being given to the anticipated effects of the intense beam. The main electronic circuits, which are of advanced design, have been finalized. A complete phase lock servo loop has been constructed and successfully tested on the PS. Good progress is also being made on the problem of synchronizing the four rings.

The delicate problem of transferring the 20 bunches from the Booster to the PS r.f. 'buckets' without unacceptable dilution of longitudinal phase space density has been studied and a promising solution found, at least for the more normal running conditions.

Vacuum

The beam in the Booster can be accelerated slowly, since all the time between two successive PS pulses is available for accelerating the beam up to only 800 MeV. This makes it possible to have rather cheap r.f. and main magnet power supply systems, but implies that the 50 MeV beam from the Linac spends a relatively long time in the Booster at low energy when scattering by residual gas molecules in the vacuum chamber can be particularly troublesome. Fixing a limit of about 10 % to the tolerable increase in emittance due to gas scattering, the average pressure around the ring needs to be of the order of 10^{-7} torr. Fortunately, such pressures can be obtained nowadays using standard ion pumps and metal joints without further complications such as baking of vacuum chambers.

As has been pointed out before, the four machines are kept as independent as possible for most of the systems, but for vacuum it appeared much more convenient to have a single system, which is more economical and involves a considerably smaller number of components. Thirty two 400 l/s ion pumps (two per magnet period) will be used and about 10 mechanical and turbomolecular pump groups will complete the installation.

The most tricky vacuum chamber to design, is that located in the gap of the bending magnet, for which we require that the distortion of the magnetic field due to eddy-currents in the chamber should be sufficiently small not to need correction by pole-face windings. All requirements are met by a thin walled metal chamber adequately corrugated for mechanical strength. We plan to use Inconel-X as material, with a thickness of 0.4 mm and corrugations of about 3 mm height. The other vacuum chambers are all of the thick walled type and rather conventional.

A special case is posed by the large tanks containing the kicker magnets for ejection where a considerable pumping speed is required and here a sublimation pump will be used in addition to the normal ion pump.

Transfer to the PS

The transfer beam-line from the Booster to the PS is one of the most intricate transport systems for intense particle beams that has ever been designed. It has to accomplish several tasks in a rather limited space and to preserve as far as possible the quality of the beams circulating in the Booster.

After a rather straightforward (at least in principle) fast ejection of the beams in the four horizontal planes correspond-

The 'optics' for the recombination of the beams from the four rings (I, II, III, IV) of the Booster for transfer to the PS in the 20 bunch mode (five bunches from each ring being transferred in sequence). Without moving any element this can be changed to the 10 bunch mode (the twenty bunches from the Booster being transferred as ten vertically stacked pairs) by adding DSM — a double septum magnet. The other units are: ESM — ejection septum magnet, VBM — vertical bending magnet, VSM — vertical septum magnet, K — kicker magnet, Q — quadrupole, D — vertical deflector.

A sketch of the Booster buildings. There are three levels, the lowest one being that taken by the machine tunnel itself. Above is the service tunnel for cabling, some electronics, etc., and on top is the entrance, water-cooling plant, air-conditioning plant and power supplies.

ing to the four Booster rings, we have to recombine the beams into one at the PS plane, to match this beam to the PS acceptances (both for betatron oscillations and momentum), and finally to inject the beam on the PS closed orbit.

A further complication stems from the fact that several recombination modes of the four beams can be envisaged, namely:

a) 20 bunch modes — where beams are sequentially extracted one after the other from the Booster rings;

b) 10 bunch modes — where two bunches are stacked into the same PS bucket either horizontally by two-turn injection into the PS or vertically by merging the bunches in the transfer line itself;

c) 5 bunch modes — where a beam with vertically merged bunches in the transfer line is then two-turn injected into the PS.

Several optical arrangements for the recombination have been considered by the study group prior to the authorization to build the machine. More recently, the final scheme has been determined (figure 5). It requires a minimum number of magnetic elements and has the advantage of not needing any physical displacement of elements when changing from one of the above modes to another. Only one double septum magnet needs to be powered additionally when it is required to recombine bunches in the same bucket.

The part of the transfer line where the beam from the Booster is matched to the PS uses a 10° bending magnet and seven quadrupoles.

A spectrometer is to be installed in a branch-off from the transfer line so that the mean energy of each bunch can be measured and the beam recombination system can be set up and beam emittances measured independently from the operation of the PS. This facility will be very useful especially during the running-in period.

The main elements for the injection of the recombined beam into the PS are one septum magnet and one (or two in the case of two-turn injection) full aperture kicker magnet. The exact injection path required considerable detailed study.

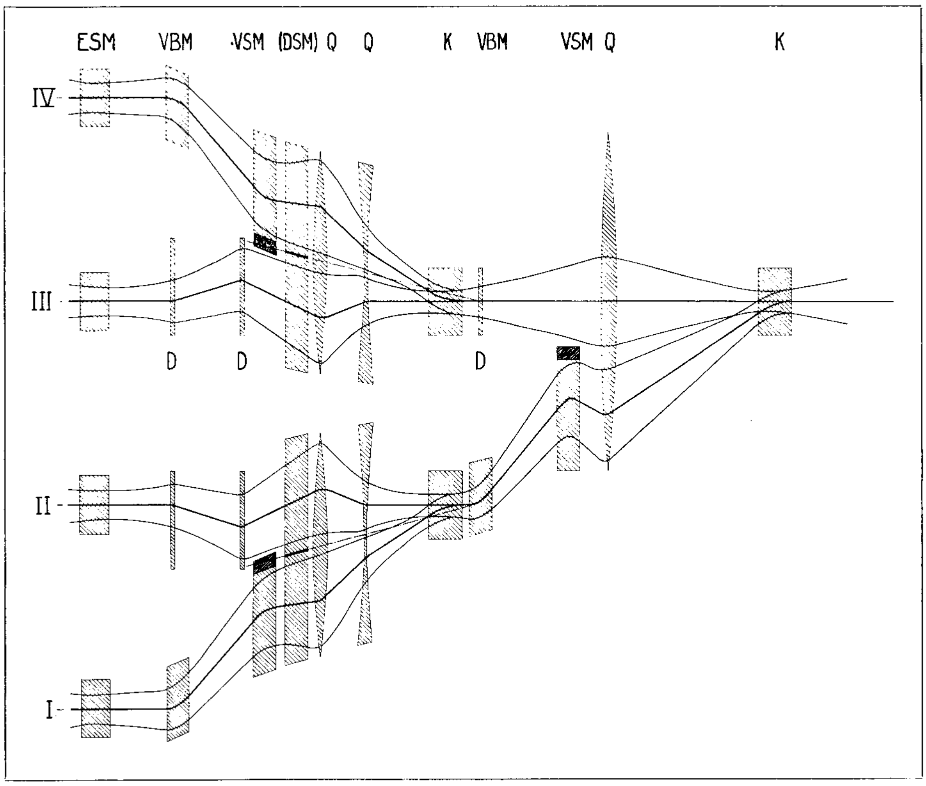
From the hardware point of view, the most critical components are the eight kicker magnets needed for extraction from the Booster, recombination and injection into the PS. Full aperture kickers, based on a modular system from which magnets of various strengths can be built, have been developed, tested and finalized. The pulses of power to the kickers need a very short rise-time (50 ns). Jitter-free deuterium thyratrons have been successfully used as switches coupled with a non-linear pulse-sharpening network to adequately shorten the relatively slow pulse from the thyratrons (see CERN COURIER vol. 8, page 24).

The final kicker magnets are now in production. All other magnetic elements of the transfer-line — septum magnets, quadrupole and bending magnets — are either ordered or being tested in prototype form. A contract for all the d.c. power supplies was placed in December 1969.

Beam Observation and Measurement

Adequate equipment for beam observation and measurement is particularly important in an accelerator which has to deliver its high intensity soon after commissioning. In most of the existing accelerators, it has taken years to bring up the intensity to the levels specifield for the Booster.

The strategy adopted is to monitor the relevant beam properties at each stage of the beam's journey, in particular at the important 'frontiers'. Thus, quite elaborate devices are being constructed to measure the beam emittance and energy spread as well as the beam position and intensity before injection into the Booster and before transfer into the PS. In the Booster itself, 18 pick-up electrodes per ring (mostly located concentrically inside the multipole lenses) will make it possible to observe and measure the proton orbit. An 'Ionization Beam Scanner' (IBS) and possibly a 'Gas Curtain' are planned for the measurement of the transverse density distribution of the protons. An automatic Q-measurement device will serve to measure betatron frequencies every three milliseconds. In addition we shall have the more conventional collection of scintillator screens, current transformers, wide-band pick up stations, targets (for beam 'shaving' and IBS calibration) and



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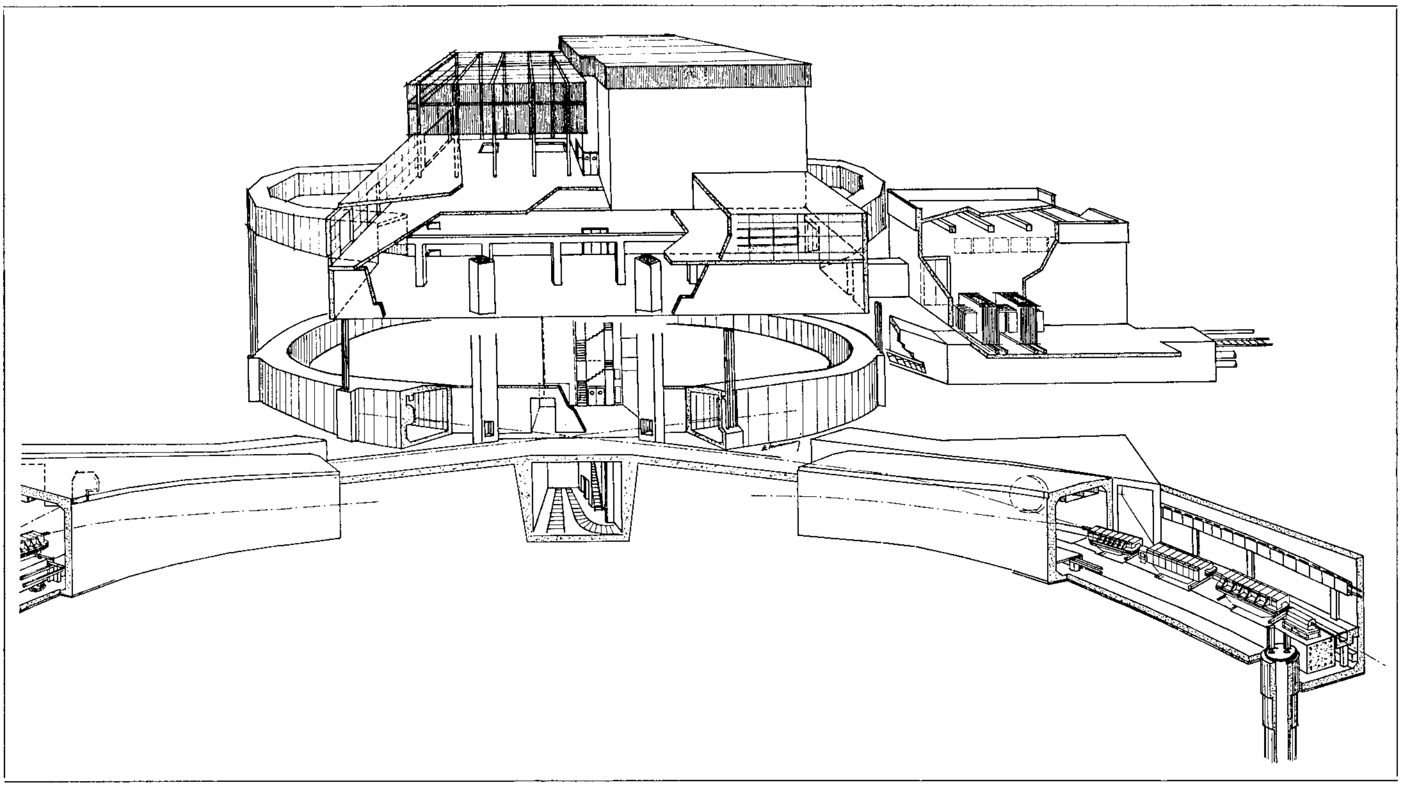


6.

beam loss detectors. All of these have been specified in detail and the design is well advanced on some of them.

Controls

A number of difficult decisions had to be taken as regards the controls. Firstly there was the question of the location of the Booster controls — should it be in the Booster building or in the Main Control Room of the PS. The latter solution was adopted to ensure the best operational integration between the Linac, the Booster and the PS, to minimize the total cost in terms of the manpower needed for operation and in terms of the capital outlay, and to make the transition from the running-in period to normal Booster operation easier. However, the number of racks available in the MCR is rather restricted and their optimum use requires careful planning. The layout of these racks has been worked out and the MCR is being rearranged accordingly.

Secondly we had to decide on the degree of involvement of a control computer and subsequently whether to enlarge the capacity of the existing IBM 1800 in the MCR or to buy a new computer. Ideas have evolved to the point where we decided recently, in collaboration with the MPS Controls Group, to entrust a considerable number of controls to an enlarged IBM 1800 (without any independent manual back up) and to buy a satellite computer for the generation of most time-variable control functions. The detailed specifications for the majority of controls are well advanced and their design is about to start.

Good progress has been made with the more classical controls and with the rather tricky Booster timing system, as well as with the audio intercommunication and radiation security systems.

Buildings

The location of the Booster has been indicated and commented upon in CERN COURIER vol. 8, page 5.

The buildings are at three different levels (figure 6). At the bottom are the main tunnel and the connections with the PS for the injected and ejected beams. The civil engineering work on this part was completed in the Spring of 1969 and, since the Summer, the main tunnel is covered by earth shielding.

The next level comprises a service tunnel to contain cabling, certain power supplies and some local electronics, and a central electronic room to house all the electronics for detailed control of the major components of the machine. At the same level, but separate from the main building structure, there is the power house for the main magnet power supply and the electricity substation. The work on this level is progressing satisfactorily.

At the top are located the entrance and the access to the vertical shaft to transport machine components to the lower levels (for economy no road is provided at tunnel level), the water cooling and air-conditioning plants and the power supplies for the beam transport to and from the PS.

All buildings are scheduled to be ready for occupancy and for the start of machine installation by the end of this year.

Collaboration with industry

It is worth noting that 80 to 90 % of the components of the Booster will be produced by European industry. Despite the present boom in industry, which could have led to lack of interest in CERN's rather special and difficult technical requirements, and to problems in achieving tight delivery schedules, we have found the, by now, traditional good-will and interest in our problems.

It is therefore a pleasure to record our appreciation of the cooperation we are receiving from the many firms participating in our project, in particular:

Alsthom (France) — bending magnets, d.c. power supplies; Asea (Sweden) — bending magnet, quadrupole; BBC (Federal Republic of Germany) — main quadrupoles; BOA (Switzerland) — vacuum system; Calorstat (France) — vacuum system; Kabel und Metallwerke (Federal Republic of Germany) — water-cooled power cables; Lintott (UK) — d.c. bending magnets; Oerlikon (Switzerland) — d.c. magnet lenses; Passoni e Villa (Italy) — high voltage supplies; Pfeiffer (Federal Republic of Germany) — turbomolecular vacuum pumps; Philips (Netherlands) — r.f. cavity ferrite; Siemens (Federal Republic of Germany) — main magnet power supply; Smit (Netherlands) — d.c. quadrupoles; Varian (Switzerland/Italy) — ion vacuum pumps.

The general progress of the project and the delivery dates agreed by industry give every hope, at this stage, that the original time schedule for construction can be held. The Booster should provide its first beams to the PS in 1972.

Studying heavy mesons CERN/Serpukhov experiment No. 2

The story of the second experiment to be carried out by a joint team of physicists from CERN and from the Institute of High Energy Physics Serpukhov, on the 76 GeV proton synchrotron at Serpukhov.

We had intended this month to record, fairly briefly, the dispatch of equipment to Serpukhov for the second joint experiment and to say something about the aims of the experiment. But there is so much of interest in connection with this topic, that it merits telling in more detail. Some of the things we have to try to cover are: The experiment is Chapter 3 of a story which began about five years ago. Chapter 1 was written at CERN where seven negatively charged mesons were identified for the first time using a new technique known as the 'missing mass' technique. Chapter 2 has recently emerged in print. It has extended these results in a CERN experiment using a different approach and a higher energy. Nine further heavy mesons have been identified and it has been found that new particles are lying so thick on the ground at higher energies that it is becoming difficult to distinguish one from another.

Chapter 1 revealed that a particle known as A 2 (in view of the recent epidemics, we hasten to add that this has nothing to do with the influenza virus !) is in fact two particles of almost identical mass. A controversy as to whether these were two radically different particles or two particles having the same quantum numbers has been convincingly resolved in favour of the second alternative.

The experiment at Serpukhov will study the newly observed particles in more detail and later will have a look at what is around at still higher energies. The 200 tons of equipment en route for Serpukhov is quite exceptional in its sophistication and versatility. The problem is not how to stretch its performance to gain more information but rather how to restrain the inclination to do a dozen other interesting experiments which are easily possible. The huge Antonov 22 plane (bigger even than the Boeing jumbo jet) is coming to Geneva airport for the first time to take 50 tons of the more delicate equipment, adding spice to the equipment removal.

Chapter I:
The Massing Mass Spectrometer

At the end of 1966, the missing mass spectrometer experiment (see CERN COURIER vol. 7, page 31) concluded its run on the CERN PS. It searched for negative mesons over the mass range from 0.5 to 2.5 GeV and spotted seven for the first time. It also demonstrated the success of the missing mass technique which was described by its originator, B. Maglic, as rather like fishing for particles with a net rather than a hook.

The experiment went as follows. A beam of negative pions from the PS was fired at a hydrogen target and the detection equipment recorded parameters of the emerging proton when the following interaction took place:

$$\pi^- + p \rightarrow p + (X^-)$$

One has enough information about the incoming pion, the target proton and the emerging proton to be able to calculate the missing mass (written in the interaction as X^-). It was found that the missing mass preferred particular values — corresponding to particles with sharply defined masses. The nature of the other particles participating in the interaction (pion, proton, proton) tells us that the X^- particle is a negative meson.

A distinctive feature of the experiment was the way in which it looked at the emerging proton. The array of detectors for the proton could be moved on a turn-table through angles with respect to the direction of the incoming pion beam. Associated with each meson produced, there is an angle at which a high percentage of the protons emerge. (Such angles are known as 'Jacobian peaks' in the angular distribution). Thus as the detector was moved through a range of angles, the number of protons recorded rose sharply at those angles corresponding to production of a meson. The meson itself lives only for about 10^{-23} seconds before decaying, predominantly into pions, and the decay products could be observed in a detection system immediately following the target.

This first net caught the following fish — δ (0.962), R_1 (1.630), R_2 (1.700), R_3 (1.750), S (1.929), T (2.195) and U (2.384) where the figures in brackets are masses in units of GeV. There is a remarkable regularity in the mass spectrum of the particles, the squares of their masses lying neatly on a straight line. This ties in nicely with the hypothesis that every meson is composed of a quark and an anti-quark (like a molecule made up of a quark and an anti-quark rotating around one another).

Another observation from Chapter I was that the A 2 meson, which was known as a single peak prior to the experiment, is 'split' — it consists of two particles (now referred to as A 2 high and A 2 low) of almost identical mass.

Chapter II:
CERN Boson Spectrometer

In 1968 and 1969 a CERN, Geneva, Munich collaboration carried out the CERN Boson Spectrometer experiment (see CERN COURIER vol. 9, pages 8 and 233). This also used the missing mass technique but in a different way. Whereas the Missing Mass Spectrometer specified the missing mass by observing the Jacobian peaks in the distribution of the protons coming off at an angle (let's call it the MMS method), the CERN Boson Spectrometer specified the missing mass by measuring the momentum of the protons coming off from the target within a small angle in the forward direction (the CBS method).

('Boson' incidentally is a global term for those particles (including all the mesons) which have an integral value for their spin (0, 1, 2...) and thus obey Bose-Einstein statistics; their counterpart is 'fermion' meaning particles which have a half-integer value for their spin ($^1/_2$, $^3/_2$...) and thus obey Fermi-Dirac statistics.)

The CBS used wide gap spark chambers and a large magnet to measure the forward proton and was able to look at different mass ranges by varying the energy of the incoming pions. The detection system also caught the decay products of the mesons which were produced but, since the system was essentially for measuring the proton, the decay products could not be studied as thoroughly as in an MMS set-up. The great advantage of the CBS was to be able to investigate about 1 GeV higher masses than the MMS for a given energy pion beam using the forward proton. The experiment did two things — first it confirmed with its different approach) the A 2 splitting; second, it extended the search for mesons from 2.5 to 4 GeV.

The A 2 controvesy centred on whether A 2 high and A 2 low have the same total spin (J) and parity (P) quantum numbers. The observed symmetric shape of the double peaked A 2 suggested that this was so — it looked like interference between two particles of the same quantum numbers. This question is important because if the quantum numbers take certain different values it destroys the quark model of the mesons as we know it.

To explain briefly what could be happening with regard to the A 2 we need to think back to the days of atomic spectroscopy when observed electron energy levels in the atoms were beautifully explained by considering the energy that electrons has by virtue of their angular momentum in orbit around the nucleus (with orbital quantum number L), their intrinsic spins (spin quantum number s), and the way these could couple together. We have a similar situation with the two quarks orbiting around one another in the meson. Possible values could be assigned for the spin and parity of the A 2 as $J^P = 2^+$. Then A 2 high and A 2 low could be explained as belonging one to the top of the L = 1 group of energy levels and one to the bottom of the L = 3 group. (This rather complicated story is explained more fully in CERN COURIER vol. 9, page 233.) The quark model still has to be stretched to explain how the L = 3 group can come down by about a GeV in mass compared with where they are expected and it is not very satisfying to accept that the two particles fall on top of one another by accident.

Results from the USA had suggested that for A 2 low $J^P = 1^-$, which would spell death to the simple quark model. The CBS experiment studied the quantum numbers of the A 2 in two independent ways. One was by examining over 3000 events giving three pions ($X^- \to \pi^+ + \pi^- + \pi^-$) in the region of the A 2 mass. Two of the pions can result from the prior formation of a rho meson. Then the interactions go

$$X^- \to \varrho^0 + \pi^-$$
$$\varrho^0 \to \pi^+ + \pi^-$$

The decays where it could be shown that a rho and a pion were produced were then submitted to what is called a 'Dalitz plot' and various hypotheses for the possible spin and parity quantum numbers were compared with the results. No difference was detected between the decays coming from A 2 high and those from A 2 low and $J^P = 2^+$ fitted the experimental results best.

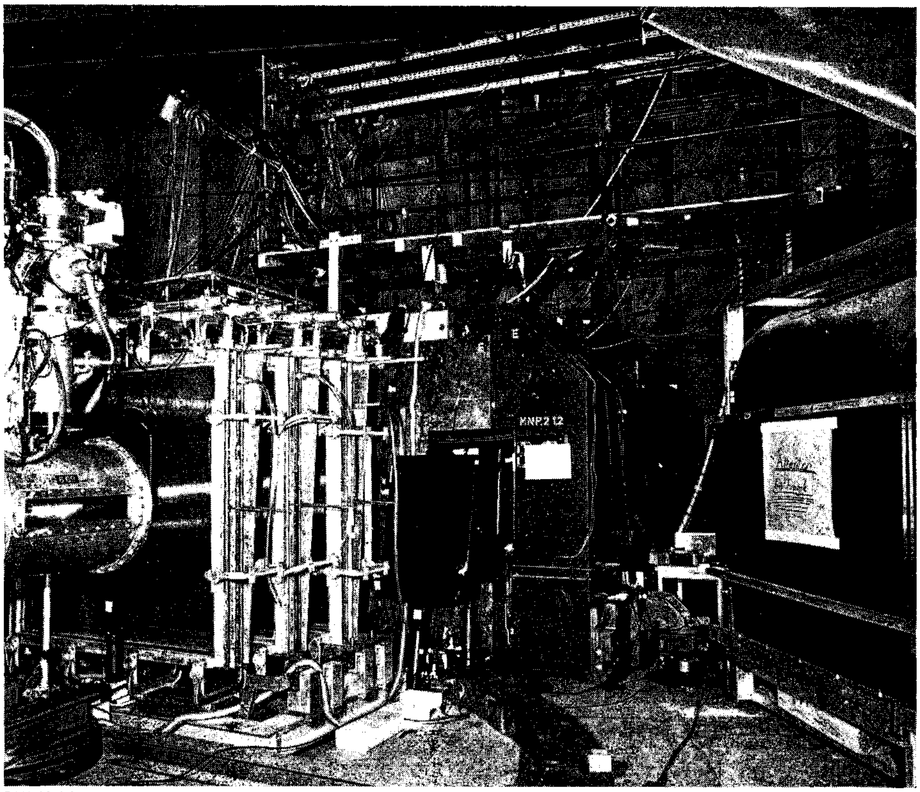
The other way was to look at the comparatively rare decays of the A 2 into a neutral kaon and a negative kaon

$$A\,2^- \to K^0_1 + K^-$$

which occurs in about 4 % of all the possible decays. 251 events of this type were identified. Again the data showed a deeply split A 2 with no difference between A 2 high and A 2 low. By indirect argument the most probable quantum numbers are then $J^P = 2^+$. The programme for the 'Conference on Experimental Meson Spectroscopy' to be held in Philadelphia at the beginning of May contains the question 'Does anyone wish to claim that J^P for the A 2 is not equal to 2^+?'.

The experiment involved the extensive collaboration of the Universities of Geneva and Munich (Sektion Physik) with CERN. Their contribution included the provision of equipment, computing time, and finance in addition to the teams of physicists. From Geneva came R. Baud, M. N. Focacci, P. Lecomte, M. Martin (team leader) and C. Nef. From Munich came H. Benz, B. Bosnjakovic, H. Jostlein and A. Weitsch (team leader). The remaining members of the team were H. Blumenfeld, D. R. Botterill, G. Damgaard, W. Kienzle (team leader), R. Klanner, C. Lechanoine, V. Roinishvili and P. Schubelin.

Now let us turn to look at the nine new fishes that the CBS net has caught. The search for negative mesons was extended over the mass range from 2.5 to 4 GeV,



Equipment for the CERN/Serpukhov experiment photographed during final tests at the beginning of March before being dismantled for dispatch to the Soviet Union. On the left is the new type of hydrogen target, followed by a series of three wide gap spark chambers (light can be seen reflecting from the planes of wires), followed by the large aperture magnet. Also in the picture are scintillators wrapped in black tape to shield them from the light. Note in particular the huge scintillator on the right marked 'Attention très fragile'. Part of the turn-table on which the proton detector can be moved is seen at the bottom of the photograph.

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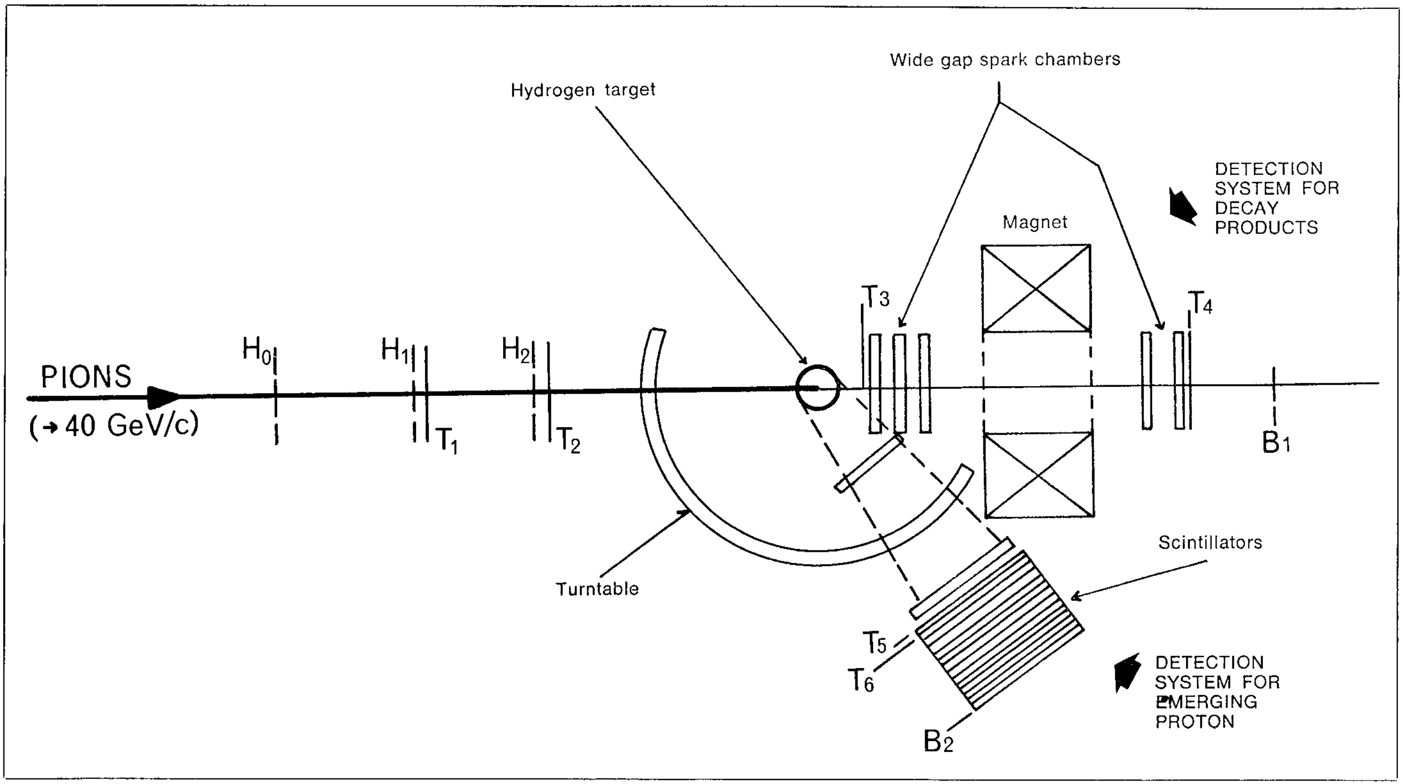


setting the energy of the incoming pion beam at energies going from about 8 to 15 GeV and measuring the forward proton as described above. Unfortunately we are running out of alphabet so the newly observed particles are known simply by their masses (in GeV) as follows: X^- (2.620), X^- (2.800), X^- (2.880), X^- (3.025), X^- (3.075), X^- (3.145), X^- (3.180), X^- (3.475) and X^- (3.545). Most of them are peaks of narrow width. Their cross-sections do not decrease rapidly with energy, contrary to expectation.

The first few fit on the straight line plotted from the MMS particles but the higher we go in mass the more difficult it becomes to assign a meson to its position since there are more particles found than are required by extrapolating the line. Near 4 GeV the mesons are tumbling on top of one another; the space between neighbouring peaks becomes so small that they are difficult to distinguish even though the CBS has a very good mass resolution.

In conclusion the experiment has shown that the mass region from 2.5 to 4 GeV is also rich in interest. Years of experimentation with still more sophisticated equipment, sensitive to the decays of the heavy mesons, will be needed to understand their properties.

Chapter III:

The CERN/Serpukhov Experiment

The experiment in Serpukhov will be in two stages. The first will study some of the higher mass mesons recently identified whose properties have not been found.

Thanks to the higher energy of the pion beam (20 to 40 GeV) available from the Serpukhov machine, it is possible to use the MMS method again to detect the proton at an angle (even for the mesons of mass above 4 GeV) leaving the forward direction free for a detection system tuned to measure the decay products of the mesons.

The system is so versatile that several interesting studies can be carried out at the same time. The first is of course the missing mass study of negative mesons as before

$$\pi^- + p \to p + (X^-)$$

The second is the study of neutral mesons by a 'double missing mass' measurement when the X^- decays. The detectors can measure emerging negative pions precisely so as to identify neutral mesons (X°) in the decay

$$X^- \to \pi^- + (X^\circ)$$

where the X° may for instance decay into pions which are also measured

$$X^\circ \to \pi^+ + \pi^-$$

In other words what is done is to measure a negative pion and to see if the 'missing mass' predominantly takes up particular values corresponding to neutral mesons. (The rho meson coming from the decay of the A 2 as mentioned above is an example of this type and has been seen clearly in recent tests.)

The third is the study of the possibility of doubly charged negative mesons (X^{--}) by measuring the positive pion from the X^- decays. If it were shown that the missing mass took up particular values

$$X^- \to \pi^+ + (X^{--})$$

there really would be a flutter in the theoretical dovecotes. The quark theory of the mesons forbids a doubly charged meson — in no way can a quark and an anti-quark (each carrying a charge of $^1/_3$ or $^2/_3$ e) be combined to yield two integral charges.

After the investigation of the heavy meson decays by the MMS method, the experiment will turn to a search for mesons of still higher mass (above 4 GeV). Again it is the higher energy of the pion beams from the Serpukhov machine which makes it possible to look for particles as heavy as 8 GeV. Here the experiment will revert to the CBS method measuring the forward proton and will not have as much evidence on the decays of these heavy mesons.

Let us now run through the way in which the experiment (Part 1) will be carried out and en route we can get a good idea of the complex of equipment involved. The sketch of the layout may help in understanding what follows.

The pion beam-line, known as Channel 4B, will probably be set at a momentum of 25 GeV/c while using the 'double missing mass' method. It is a beam of excellent quality providing 500 000 pions per pulse lasting one second (there is one pulse every 7.5 seconds). It is expected to record about 25 events per pulse (about 200 000 per day). Counter hodoscopes H_0, H_1 and H_2 will monitor this beam and scintillation counters T_1 and T_2 will pick out a single pion. (Despite there being 500 000 pions per second, the counters can distinguish between charged particles

A schematic representation of the layout of the experiment as it will be for its first stage. H_0, H_1, H_2 are hodoscopes monitoring the incoming pion beam. T_1, T_2, T_3, T_4, T_5, T_6 are trigger counters which must record charged particles and B_1, B_2 are trigger counters which must not record charged particles before the whole detection system switches on to record an 'event'.

arriving at times as short as two or three nanoseconds apart.) T_1 and T_2 are trigger counters — the whole system will not switch on to record an event unless T_1 and T_2 tell the electronics that they have picked out a pion.

The target is a small cylinder of liquid hydrogen, 43 cm long, 4 cm in diameter. It is of the new type (described on page 84), developed by L. Mazzone at CERN, which needs almost no attention.

The detection system for the proton is mounted on a turn-table so that it can be moved around to pick out the Jacobian peaks. Initially it will be swept right around into the pion beam for a thorough study of the beam properties and calibration of the spark chambers. It consists of two wide gap spark chambers and a bank of scintillation counters. The scintillators are 2 × 1 m² and 10 mm thick. They serve as rough range counters, measuring the energy of a proton by seeing how far it travels through the bank. The first two, T_5 and T_6 are trigger counters (they must see a particle before the whole system will switch on) and the last scintillator B 2 is an 'anti-coincidence' counter (no proton from the interaction we are interested in should reach it) — if it sees a charged particle the whole system does not switch on. Further scintillators T_3 and T_4 must record a charged particle passing through the spark chambers and magnet before the whole system switches on. They have an opening along the beam direction so as not to record beam particles. Finally an anticoincidence counter B_1 must not record a beam pion selected downstream to ensure that there was in fact an interaction in the target.

Thus when trigger counters T_1 to T_6 all fire while B_1 and B_2 do not fire, the electronics switch on the spark chambers and the event is recorded.

Observing the proton direction in the spark chambers the proton angle is measured to an accuracy of ± 3 mrad and its momentum to ± 1 %. Since the proton momenta are quite low (about 500 MeV/c) scattering of the proton on its way out of the target is a major worry. Also to reduce scattering the spaces where the proton travels between equipment will be filled with large polythene bags containing helium, which will cause less scatter than air.

The detection system for the decay products consists of five wide-gap spark chambers arranged on either side of a large magnet which has an aperture 1.5 m wide, 1 m deep and 50 cm high, and a field of 10 kG. This will bend the tracks of the charged particles and enable their momenta and the sign of their charge to be determined. The spark chambers are 1.5 × 1.5 m² with a gap of 5 cm and they have been developed in the course of the MMS and CBS experiments. This began under the late G. E. Chikovani from the Georgian Academy of Science in Tbilisi who spent several years with the CBS experiment. The tradition of his expertise has been carried on by V. Roinishvili, also from Tbilisi, who has participated in the CBS experiment and who will be in the CERN/Serpukhov team as a member of the Serpukhov staff.

The whole system has been thoroughly tested at CERN in exactly the form which will be installed at Serpukhov. These tests came to an end on 6 March. Ideally a supernatural power would then have picked up the equipment as it was and deposited it in the experimental hall at Serpukhov where a special concrete base about 1 m high (known as the CERN platform) awaits it — effectively raising the floor so that the beam height is the same as at CERN. In the absence of such a power, the equipment has been dismantled and dispatched in pieces. Dismantling and packing took until 20 March.

On 22 March the 110 ton magnet left Geneva by train. It travels by Swiss railway to the Russian border at Tchop and from there by Russian railway right into the experimental hall. The total transit time is 3 weeks.

On 31 March an Antonov 22 cargo plane is scheduled to land at Cointrin airport Geneva to pick up over 50 tons of delicate equipment. It has a capacity of 500 m³ and this will be taken up by three large containers (two for an IBM 1800 computer which will be used on-line in the experiment and one for the fast electronics units) and other items including the spark chambers, the hydrogen target and the scintillators. Loading will take place overnight and the plane will leave for Moscow on 1 April. On arrival at an airport between Moscow and Serpukhov, a convoy of trucks will take over and travel at slow speed to the Laboratory. The trucks will halt in the experimental hall itself and unloading, customs checking and installation will begin. The headaches of this exercise on the CERN side have been particularly those of E. Leya who is responsible for the transport. The associated documents stand some 20 cm high on his desk.

The CERN members of the team (with their particular responsibilities indicated in brackets) are as follows: W. Kienzle (the team leader), R. Klanner (beam), P. Lecomte (target), G. Damgaard (scintillators and trigger logic), A. Weitsch (spark chambers), M. Martin and G. Laverrière (data acquisition), R. Baud, A. Lacourt and an IBM engineer (computer), M. N. Focacci-Kienzle and C. Lechanoine (data analysis). Other specialists will go to Serpukhlov for a time until the equipment settles down, for instance, V. Beck and R. Schillsott (mechanical work), C. Brand and G. Coubra (target). The Serpukhov component of the team will be led G. Lansberg and will have four other physicists and four technicians.

The team members, with their families, are moving to Serpukhov in stages and are due to have their first joint group meeting there on 6 April. They will stay in a new apartment block in the nearby village of Protvino and a kindergarten will be available for the young children.

The experiment is scheduled to start on 1 June 1970 and to finish about the end of 1971.

CERN News

1.4 MeV pre-injector

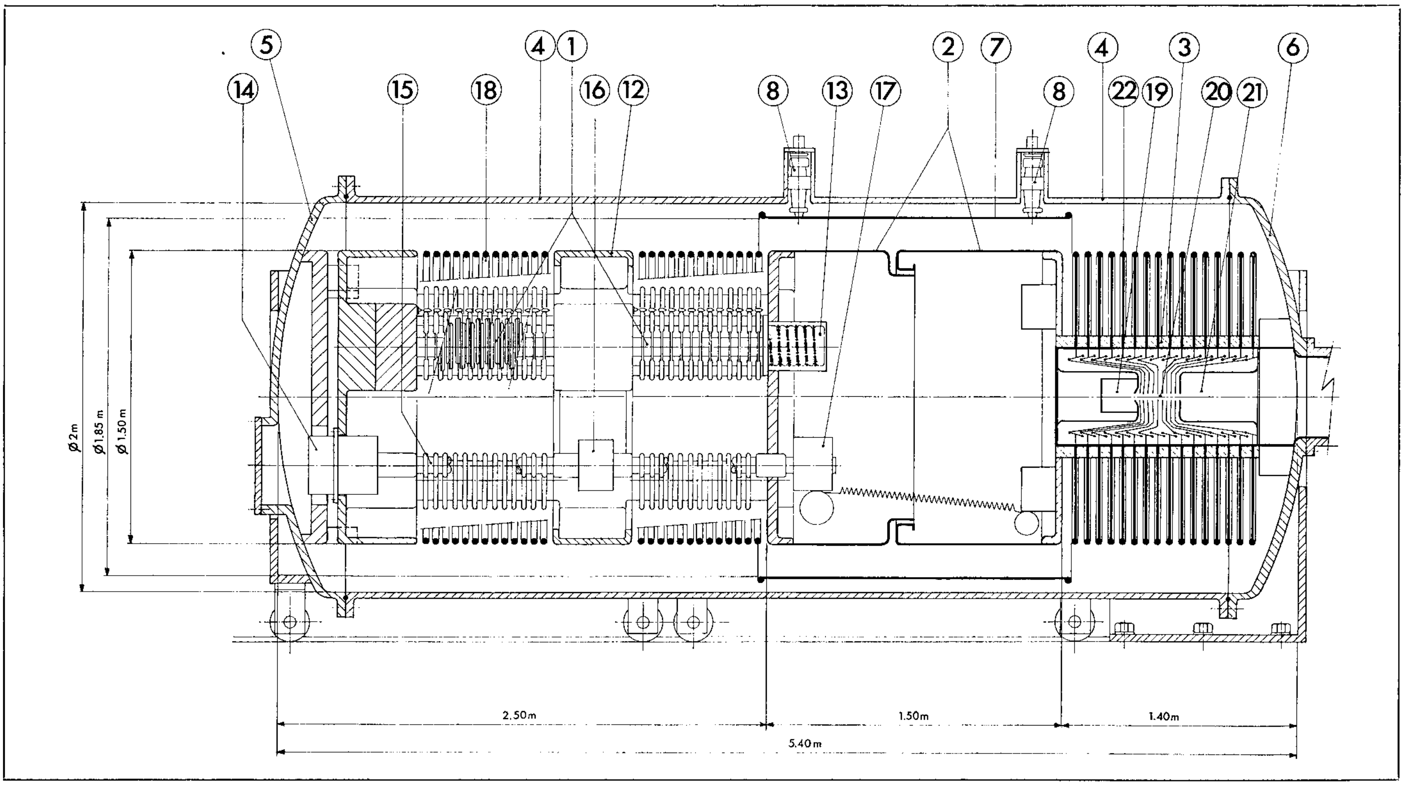
When thought was being given to the programme of improvements at the 28 GeV proton synchrotron, the performance of the Linac feeding the accelerator was, of course, one of the items examined. The 'bottleneck' in terms of Linac performance was considered to be the first part of Tank 1 — the first of the three large r.f. cavities in which proton beams are accelerated to a final energy of 50 MeV. The present ion source, one of the most powerful operating on a proton accelerator, delivers a higher quality beam than can be exploited. A redesign of Tank 1 was therefore considered and it was also realized that achieving higher intensities would be easier if the beams into Tank 1 were of higher energy than those provided by the existing 500 keV pre-injector. This possibility was also considered interesting in connection with the 300 GeV project. Studies have been carried out by a team from the Linac group in close collaboration with the Institut de Physique Nucléaire, Lyon, and with Saclay. They have now advanced to the stage where a project for a pre-injector of energy 1.4 MeV can be formulated.

The collaboration with Lyon enabled CERN to use a high voltage installation at IPN (constructed in connection with a French heavy ion linac project with a 1 MeV electrostatic injector) for testing high gradient accelerating structures, while enabling Lyon to benefit from the CERN experience in accelerating tube construction and running. (The high cleanliness CERN tube design and assembly technique has been adapted by Brookhaven and commercialized recently by HVEC to cope with the demand of the Heidelberg heavy ion linac group who ordered three of them.) The collaboration with Saclay arose spontaneously from the close relationship between the two Laboratories and enabled CERN to benefit from the experience accumulated at Saclay during the construction of their well engineered new injector for Saturne (see CERN COURIER vol. 9, page 138).

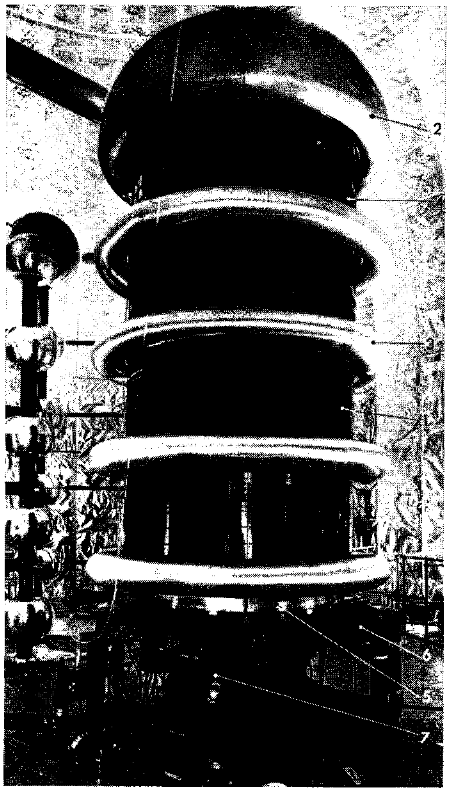
The size of the present Faraday cage at the PS prohibits moving to higher energies with an 'open air' design — the cage is not big enough to contain, without breakdown, equipment taken to much higher voltages. Thus a design for an enclosed pressurized system as used at Saclay was chosen. As far as possible, well-proven techniques were selected for the various components. For example, the ion source and accelerator tube are similar to those used on the PS and the high voltage generator consists of two Saclay-type units in series. It is for this reason also that the energy is limited to 1.4 MeV. Higher energies could have involved considerable development work on new techniques and have resulted in a more expensive project. The major features of the proposed design are as follows:

Pressurized tank

All the major units of the pre-injector are grouped together inside a pressurized tank containing sulphur hexafluoride under a pressure of seven atmospheres. The tank (a horizontal cylinder 5.4 m long and 2 m diameter) contains the high voltage generator (two 750 kV generators



A diagram of the proposed pre-injector. The tank contains sulphur hexafluoride gas at a pressure of seven atmospheres with the exception of the volume centre right where the beam energes. The different components are: 1. High voltage generator; 2. High voltage electrode; 3. Accelerator tube; 4. Central cylinder; 5. and 6. Base-plates; 7. Capacitive screen; 8. Insulating supports; 12. Intermediate electrode; 13. Protective resistor; 14. Motor; 15. Insulating shaft; 16. 2000 Hz alternator; 17. 400 Hz alternator; 18. Equipotential rings; 19. Anode (containing the ion source); 20. Accelerating electrodes; 21. Cathode containing a focusing triplet; 22. Equipotential rings.



The prototype accelerator tube was tested under a cylindrical container filled with sulphur hexafluoride at atmospheric pressure. The units indicated are: 1. Insulating casing; 2. Upper high voltage electrode; 3. Anti-corona rings; 4. Resistor; 5. Lower cone; 6. Chassis; 7. Pumping set. (Photo IPN)

Installation of the dome forming the roof of the large Faraday cage at the Institut de Physique Nucléaire, Lyon, where the prototype accelerator tube was tested. The construction of the Faraday cage involved novel and inexpensive techniques. (Photo Huguenin)

in series), the ion source, the accelerator tube and almost all their associated equipment.

A 2000 Hz alternator, driven by an insulating shaft, provides the power required for one of the generators (the first is supplied from a source at earth potential), and another 400 Hz alternator, driven by the same shaft, provides power for the various components of the ion source.

The tank opens at the joint between the baseplates and the central body. The accelerator tube sub-assembly is fixed in relation to the Linac, while the central body is movable on rails, as also is the generator sub-assembly.

Ion source

The ion source is required to provide a current of about 500 mA for 100 μs with a current density of about 200 mA/cm^2 at a repetition frequency of 2 Hz. This performance is already achieved by the present PS source (see CERN COURIER vol. 6, page 88) which can therefore be used almost as it stands with the exception of the electronic circuitry which is miniaturized.

The hydrogen feeding the source is stored inside the tank in a light-metal bottle containing enough gas for 3000 hours of operation. Monitoring and control of the source is carried out via an infra-red link by a method already in use at CERN (see CERN COURIER vol. 9, page 103).

Accelerator tube

This part of the project required the most thorough experimental investigation in view of the very high voltage and voltage gradients. Experiments have been carried out (the 'Berthe' tests described below).

The accelerating structure is not finally decided but may be of the Pierce hybrid type which offers considerable flexibility and is satisfactory from the beam optics point of view. The electrodes are made of titanium alloy.

The central apertures are machined to be as close as possible in profile to the theoretical equipotential. They are supported by three oval-shaped bars leaving plenty of room for vacuum pumping. This is important because of the leakage of hydrogen from the source, and degassing of the electrodes during high voltage hardening.

A pump with a speed of at least 1000 l/s designed to cope with the hydrogen leaking from the source, is to provide the vacuum, which must reach 2×10^{-4} torr. Several types are now on test.

High voltage generators

There are two 750 kV generators, almost exactly like that used in the Saclay pre-injector. They must be capable of providing 500 μA d.c. and an instantaneous current of ten times this value. They are of the series cascade type with selenium rectifiers and ceramic capacitors. A protective resistor is provided to limit the power in case of a breakdown.

The negative terminal of the first generator is earthed, and it can therefore be supplied from an external unit. A 2000 Hz alternator at a potential of +750 kV driven by the insulating shaft provides the supply for the second generator.

'Berthe' tests

Prototype tests on the accelerator tube, known as the 'Berthe' tests, have started in Lyon. CERN has provided a high voltage test facility to be used in a Faraday cage constructed by IPN who also provided a 1.5 MV generator (Haefely set). Scientists from both centres participated in the tests.

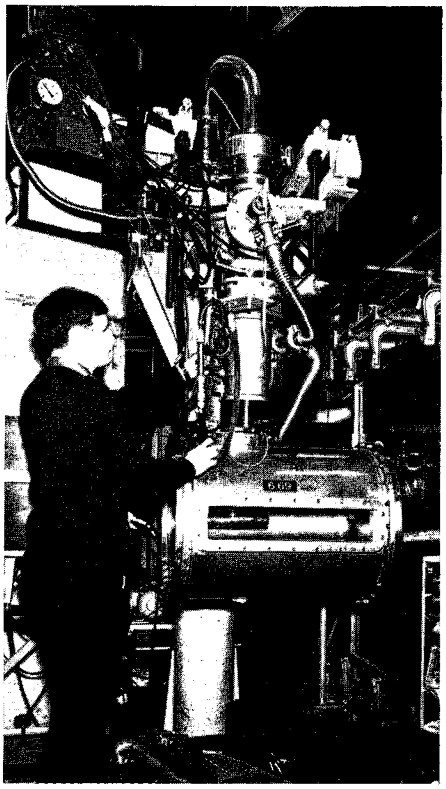
The Faraday cage is of novel construction. It is topped by a large dome 16 m in diameter and 12 m high the inside of which is coated with aluminium. The dome is made from a very light metal framework and glass fibre reinforced polyester foam. This provides a very light structure at a low cost.

The prototype accelerator tube is of the type used at the CERN PS. The cathode, anode and intermediate electrodes are all adjustable in position for test purposes. For tests above 850 kV it was placed in an insulating environment of sulphur hexafluoride at atmospheric pressure.

The tests were concerned first of all with the voltage holding properties in vacuum of titanium alloy electrodes as the distance between two electrodes is varied. Average voltage gradients of 200 kV/cm over 1 cm and of 130 kV/cm over 6 cm could be achieved. A model accelerator tube structure with five electrodes (anode, cathode, three intermediate electrodes with a central aperture where the proton beam would pass) was then put under voltage. On 20 January 1970, the summit of 1 MV was topped with great joy, the first time this had been achieved with such a system. A week later, after adjustments 1230 kV was achieved without difficulty. The d.c. inter-electrode current was less than 0.01 μA and gave rise to X-radiation below 0.1 mR/h at 10 m distance. After a shutdown over Easter when several modifications will be carried out, the tests are scheduled to begin again until next summer.

The results so far have confirmed that the advanced technology of accelerator tube construction, the use of titanium electrodes, and of a very clean vacuum system (turbo-molecular pumps were used in the tests) make it feasible to construct a high energy pre-injector.

The new type of hydrogen target, which will be used in the CERN/Serpukhov experiment, photographed in the actual experimental conditions during tests at CERN in February. Inside the vacuum tank (the horizontal cylinder in the foreground) a small black horizontal cylinder filled with liquid hydrogen forming the target proper may be seen through the Mylar window. The liquefier is visible at the top left of the photograph, standing on a concrete block.



CERN/PI 1.2.70

Hydrogen target

Liquid hydrogen targets are used in many experiments carried out with particle accelerators, taking advantage of the simplicity of the hydrogen nucleus of a single proton. An experiment then looks at the collision of an incident particle (an accelerated proton or a secondary particle such as a pion or a kaon) with a proton in the target. If the target nucleus was complex (consisting of several protons and neutrons), the effects of the very strong binding force between the protons and neutrons would make it much more difficult to study the interaction between the incident particle and a particle in the nucleus.

Liquid hydrogen (providing a much denser concentration of the target nuclei than gaseous hydrogen) is usually contained in a small cylindrical flask located horizontally in the path of the beam. Hydrogen becomes liquid, at normal pressure, at a temperature of 20.4° K. In spite of the heat insulation provided around the target system, some hydrogen will gradually evaporate away, and the liquid hydrogen in the target has periodically to be replenished. Large dewars of hydrogen are thus generally to be found alongside a target, connected to the target by pipes.

A mixture of hydrogen and air is inflammable (explosive) and the hydrogen system has to be treated with great care especially during changing from a dewar to another containing about 200 litres of liquid. Any escaping gas is encouraged to find its way out into the open air. In addition to the explosion hazard, escaping hydrogen represents a considerable financial loss.

In order to simplify the safety problems, hydrogen targets have been developed in which the hydrogen is in a closed circuit — when it changes to the gaseous state it is recondensed in a heat exchanger from which the excess heat is removed by a circuit containing helium, which is not explosive. This does mean, however, that the hydrogen loss is replaced by a leakage of helium (even more expensive than hydrogen) and, even if the problems of safety are thereby simplified, there is still the inconvenience of the periodic change-over of dewars. The ideal solution, therefore, is to find some way of becoming totally independent of any need for replenishment from outside.

These problems have been solved in a new target design which is, for example, being used for the target of the new CERN/Serpukhov experiment to be carried out on the Serpukhov 76 GeV accelerator. It contains only a litre of hydrogen and is very simple to operate.

The target (constructed at CERN under the responsibility of the group of L. Mazzone) consists of two sections — the target proper surrounded by a vacuum tank with very thin Mylar windows (0.12 mm) to allow particles to pass through the front and sides with very low probability of scattering; a liquefier, similar to that of a refrigerator, which uses helium as the medium fluid and is designed to recondense the gaseous hydrogen leaving the target. The two sections are interconnected by vacuum-insulated pipes through which the hydrogen is circulated by gravity. The vacuum providing the insulation for the liquefier and for the target and connecting pipes is produced by an oil diffusion pump generating about 10^{-6} torr. Both the helium and hydrogen circuits are closed systems and neither needs regular replenishment.

The experimental physicists are very satisfied with the performance of this new type of target. It has proved so reliable as to become part of the equipment they can forget about.

Computer takes over

On 29 January, a rather unusual test was made during one of the machine development periods on the CERN proton synchrotron.

All the dipolar corrections guiding the beam in the horizontal plane were switched off and it was then impossible to accelerate the beam to full energy. The beam would make only thirty revolutions in the machine (lasting about 200 μs). The IBM 1800 machine control computer was then asked (politely and in a language it understands) to bring the beam back on. After successive optimization procedures, the computer succeeded in accelerating a beam with an intensity of 96×10^{10} protons per pulse. The intensity before beginning the tests had been about 80×10^{10} protons per pulse.

The program used optimizes the beam intensity at one point in the machine cycle by altering parameters which define the horizontal injection trajectory (involving 28 dipolar windings and 3 electrostatic inflectors).

The test was part of the research programme of the controls group concerning the use of on-line computers in accelerator control. Though the experiment does not foreshadow computer controlled operation in the near future, it does show how the use of computers can help in accelerator control. Similar work is being done in several other Laboratories (see CERN COURIER vol. 9, pages 166 and 381) but this is believed to be the first time that the intensity of an accelerator in use for physics has been optimized by computer.

The 2 metre hydrogen bubble chamber opened out into its major component parts. It has now been reassembled to begin operation again after a long shutdown during which it had its first thorough cleaning since it came into operation in 1964.

Important modifications which have been carried out were — shortening of the vacuum tank, where it is in the path of the beam, to allow final beam-line magnets to be installed closer to the chamber thus improving operation with low energy beams; repolishing of the windows and marking of new fiducial lines better adapted to HPD film measurement; installation of mirrors so that laser beams can be used to study optical distortion. The magnetic field has also been remeasured with the chamber completely assembled.

Slow ejection developments

Some most encouraging tests have recently taken place in the proton synchrotron on the use of an electrostatic septum deflector to improve further the efficiency of slow ejection. The idea of adding an electrostatic unit to a slow ejection system has been considered for a long time at CERN but at the prevailing PS intensities (when high slow ejection efficiency was not essential) there was no wish to increase the difficulties encountered in the operation of the slow ejection by this addition. But it was shown by A. W. Maschke at Batavia to be an essential element in achieving very high slow ejection efficiency which is a crucial factor in the design philosophy of the 200 GeV accelerator.

The completion of the improvement programme yielding much higher PS intensities will make the electrostatic septum an essential element in slow ejection systems at CERN also. The construction of a first prototype of such a septum was recently undertaken in the electrostatic separator group (led by C. Germain) who have considerable experience in the required techniques (see CERN COURIER vol. 9, page 132).

The advantage of an electrostatic unit is that it is possible to have a very thin septum while still achieving a field high enough to give an adequate deflection to the protons. The septum, which shields the beam orbiting in the synchrotron from the field which bends the particles out of the synchrotron, will inevitably intercept some of the particles. These are then lost from the ejected beam. The efficiency of the ejection system is inversely proportional to the thickness of the septum. In a 'conventional' septum magnet, as the septum is made progressively thinner, the field which can be attained in the magnet becomes lower. An electrostatic deflector, which can have a very thin septum since no current is flowing in it, then becomes a more attractive proposition for the first unit of the slow ejection system.

The unit built at CERN is about a metre long and has a septum less than 0.2 mm thick. The electrodes are a stainless steel anode, forming the septum, and an anodized aluminium alloy cathode. It was installed in the PS in association with the system slow ejecting beams from straight section 62. It was positioned upstream of the first conventional septum magnet and powered to deflect the beam so that it would not collide with the septum of this magnet.

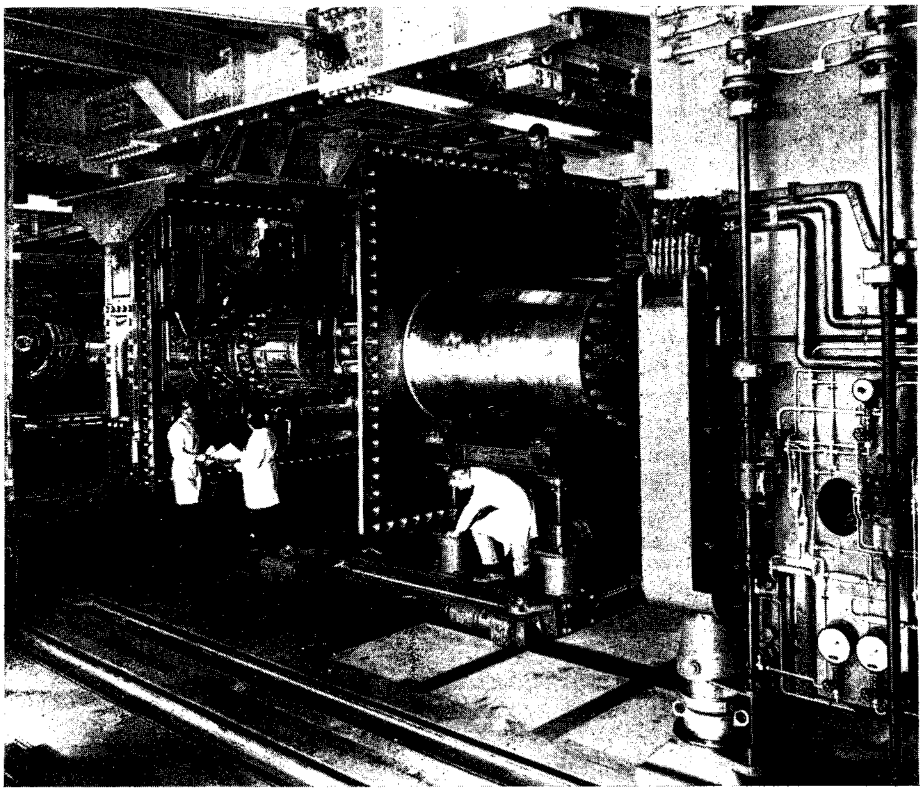
In the absence of a beam, the electrostatic septum withstood a voltage of 160 kV over 10 mm without breakdown. Preliminary tests have been carried out with the PS beam, varying parameters such as beam energy and intensity, position of the septum, cathode voltage, etc., all of which influence the capability of the septum to withstand the high voltage applied to the gap. The orbiting beam could affect the high voltage supply powering the electrostatic septum deflector when the level of radiation became high, because of beam losses in the neighbourhood, and protection against this needs to be fitted. Nevertheless, despite the fact that conditions were not optimized, it proved possible to achieve the following result.

With a beam energy of 24 GeV and intensity. It is intended to include an powering the septum (with the gap set at 26 mm) with a pulsed current of 50 µA at a voltage of 110 kV, an efficiency of 95 % ± 2 % was achieved.

Later, good results were obtained when trying to reduce the influence of the proton beam on the septum capability to withstand high voltage. Slow ejection tests will start again soon at a higher beam intensity. It is intended to include an electrostatic septum in the slow ejection system sending beams to the West hall which is to come into operation in 1972.

Installation of a test beam-line

To carry out quite detailed studies on a slow ejected beam (involving for example measurements of size and emittance) without interfering with the beam-line feeding the experiments, it is an advantage to have a test beam-line branching off the main beam-line. Such a beam-line has been installed as part of the slow ejection system at Brookhaven. It is then



CERN/PI 76.3.70

possible to study slow ejection using the best possible observation techniques.

Work is now under way on a test beam-line at the CERN proton synchrotron for the slow ejected beam from straight section 62. The beam is deflected into the test beam-line by reversing the polarity of a magnet. The beam-line is 17 m long and it is intended to install a closed-circuit TV camera and screens, a mini-scanner, a secondary emission chamber and a topo-scope.

Because the beam has to pass through windows, its characteristics will be slightly modified and calculations will have to be made to correct for the effect that this will have on the emittance.

The test beam-line will give an additional means of studying slow ejection.

Fire-inhibiting paint

Flashovers can occur in polyethylene-insulated cables carrying high-voltage and high-intensity pulsed currents, and because fuses cannot be inserted in such circuits, the repetition of these flashovers during many pulses can cause the polyethylene to catch fire. It burns like tinder and the flame can travel considerable distances along the cable. Moreover, it is difficult to extinguish (as was demonstrated during the recent fire in the neutrino tunnel where there is a large number of cables running side-by-side).

At the end of February, CERN's firemen carried out some tests on a new fire-inhibiting paint which proved capable of halting the propagation of the flame along polyethylene cable. It has a double action under the effect of heat. In the first place, it releases gaseous carbon dioxide, and secondly it swells occluding carbon dioxide molecules, thus constituting an excellent heat-shield by reason of its poor heat conductivity. To provide full protection, the cable must be completely coated with the paint and this can be achieved using an electrostatic spray-gun.

The use of this paint on all pulsed high-voltage lines already in use is therefore to be highly recommended. For new polyethylene cables, use could also be made of a sheath of a substance like PVC or polychloroprene, which is also a good way of preventing fire from spreading. The paint could also be successfully used on other combustible materials.

Tests being carried out on fire inhibiting paint. The fire did not spread to the right along the cables where the insulation had been coated with the paint.

CERN/PI 452.1.70

Feeding the PS with nitrogen

Following successful tests carried out on sector 4 of the PS vacuum chamber, it has been decided to use dry nitrogen, before atmospheric air, to fill the vacuum chambers when the vacuum has to be broken for maintenance or modification of equipment. This trick, which is already in use in other Laboratories and by certain CERN groups, has the advantage of shortening pumping time by a factor of more than three when the high vacuum has to be restablished.

The reduction in pumping time is due to absorption of dry nitrogen by the chamber walls which inhibits the subsequent absorption of water vapour when atmospheric air is allowed in. This is of special importance since the PS oil diffusion pumps are at present being replaced by ion pumps, which are particularly sensitive to moisture.

Two sectors of the synchrotron, 2 and 6, are already fitted with the necessary connections, and this will be extended to the other sectors as the ion pumps are installed.

1970 CERN School

The 1970 CERN School of Physics marks a new departure in this series of summer schools for young experimental physicists. This year the school is being organized in collaboration with the Joint Institute for Nuclear Research, Dubna, USSR.

The school will be held at Loma-Koli in North Karelia in Finland (530 km north-east of Helsinki) from 21 June to 5 July, and replaces the Liperi School of Physics normally arranged each summer by the Research Institute for Theoretical Physics, Helsinki. It is intended for physicists from the twelve Member States of CERN (about 50 students), from the twelve Member States of Dubna (about 40 students) and from Finland (about 10 students).

The Organizing Committee is chaired by O. Kofoed-Hansen (CERN) and members are M. Brenner (Abo Akademi, Turku), Ch. Christov (Dubna), K.V. Laurikainen (University of Helsinki), W.O. Lock (CERN), P. Tarjanne (University of Helsinki), A.N. Tavkhelidze (Dubna), L. Van Hove (CERN).

The programme of the school will concentrate on the following topics: Modern developments in hadron physics (lectures to be given by A. Donnachie, University of Manchester, and K. Kajantie, CERN/Helsinki); weak interactions (B.A. Arbusov, Serpukhov) and electromagnetic interactions (S.B. Gerasimov, Dubna). In addition there will be lectures on the research programmes of CERN (B.P. Gregory), of Dubna (Ch. Christov) and of Serpukhov (S.P. Denisov). Special lectures will include one on the CERN muon experiment (E. Picasso) and on the Cabibbo theory in weak interactions (P. Tarjanne). Informal discussion groups will be led by N. Brene, P.N. Bogolubov, C. Michael and E. Picasso.

Around the Laboratories

EPS New Divisions and Group

At the Council Session of the European Physical Society held in Paris on 12, 13 February, two new specialized Divisions and an Inter-Divisional Group were constituted. The Divisions are 'High Energy and Elementary Particle Physics' and 'Nuclear Physics'; the Group is 'Computational Physics'.

The functions of the High Energy and Elementary Particle Physics Division were formulated by a Steering Committee which met in Geneva on 5 February. They are:

1. The Division should serve as a forum for discussion of professional problems in high energy physics, and should endeavour to express general opinions, and to take appropriate action, based on the views of the physicists working in the field.

2. Concerning the general aims and activities of the Division, the Steering Committee proposes:

a) to establish a body within the Division for the purpose of furthering co-ordination in the development and use of the research facilities in all aspects of high energy physics in Europe;

b) to improve the organization and co-ordination of conferences in this field in Europe, and in particular to promote small conferences on specialized topics;

c) to further the co-ordination of advanced education in high energy physics and related fields, and to promote new activities where needed.

An interim Board, composed of A. Berthelot, R. H. Dalitz, W. Paul, P. Preiswerk (Chairman) and A. Zichichi, was invited to bring the Division into operation. Since the Paris Meeting A. M. Baldin has joined the Board.

The Nuclear Physics Division has as interim Board — L. L. Green (Chairman), N. Cindro, E. Cotton, W. Gentner, H. Schmidt-Rohr, G. H. Stafford, R. van Lieshout and V. V. Volkov. The Computational Physics Group (so constituted since its speciality crosses the frontiers of all the Divisions) has as interim Board — G. R. Macleod (Chairman), J. B. Adams, H. Bross, K. Differt, M. R. Feix, B. H. Flowers, E. Knighting, B. McNamara, C. Moser, R. S. Pease, C. L. Pekeris, K. V. Roberts, A. Vaciago, L. Van Hove and V. Verlet.

From left to right: R. Hildebrand, R. Stiening, and J. Klems, the physicists who have carried out the neutrino neutral current experiment at Berkeley. The entire detection apparatus, which is unusually simple and compact for a high energy physics experiment, is shown behind them.

(Photo LRL)

BERKELEY

Important experiment on the cheap

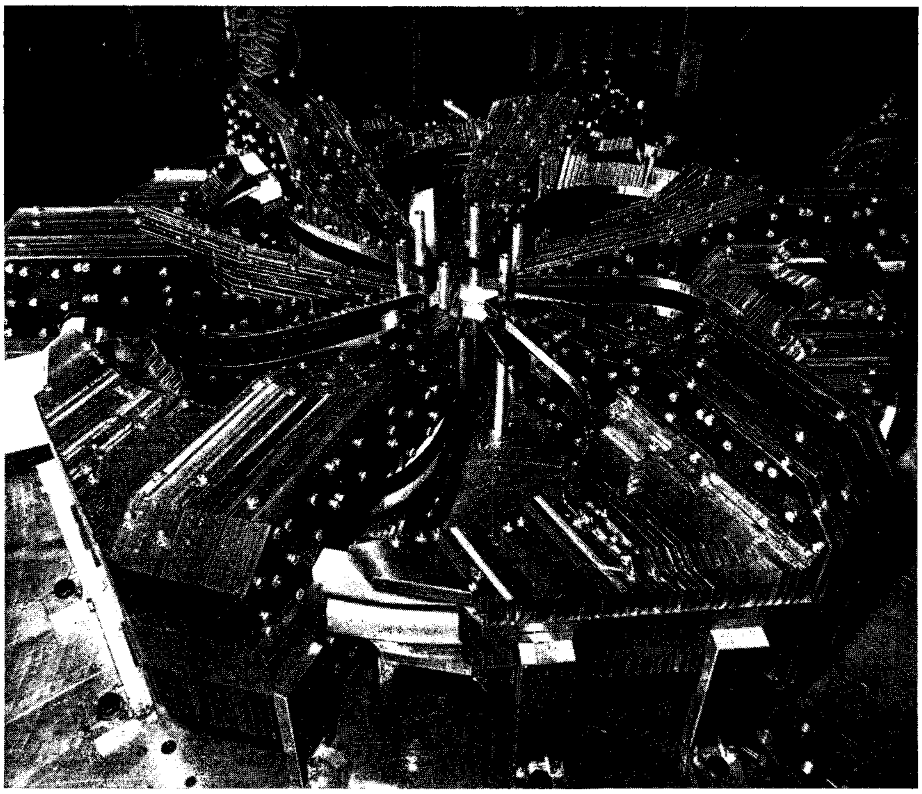
On 5 December the University of Chicago-Berkeley neutrino neutral current experiment concluded its run at the 6 GeV Bevatron. The experimenters looked for the reaction $K^+ \rightarrow \pi^+ + \nu + \bar{\nu}$, which, had it been observed, would have been evidence of the existence of such currents. During the course of the experiment a total of 1.5×10^9 positive kaons decayed within the detecting apparatus but no example of the neutral current reaction was observed.

Preliminary analysis of the data indicates that the branching ratio for K^+ decay in this manner is less than 1.2×10^{-6}. The experiment is important because the absence of this decay mode (and of the related mode $K^+ \rightarrow \pi^+ + e^+ + e^-$) is an unsolved puzzle in weak interaction theory. One possible interpretation of this observation is that electrons and neutrinos carry a quantum number which forbids the creation of isolated electron or neutrino pairs by weak interactions.

An unusual feature of the Berkeley experiment is that the apparatus was put together by the experimenters almost entirely from 'odds and ends'. One crucial part of the apparatus consisted of two fifteen year old oscilloscopes which were used to display the $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay sequence. No computers, either on-line or off-line, were used in the reduction of the data.

Medical and biological applications of wire chambers

Wire spark chambers, with magnetostrictive delay line readout for recording the coordinates of charged particles, have been in use at Berkeley for the past few years. The versatility inherent in this electronic readout method has prompted the use of these devices in medicine and biology. In medicine they are being de-



The most recent magnet model (at a scale of 1 : 20) for the TRIUMF cyclotron in Canada. The model scaled down exactly the design drawings of the consulting engineering firm including all bolts and other mechanical details necessary for the magnet fabrication and the cyclotron assembly. The resulting magnetic field from the model matched the desired field to better than 1 %.

(Photo TRIUMF)

veloped for imaging distributions of X-rays emitted by radioactive isotopes used to locate tumors and other abnormalities in human organs. (L. Kaufman, V. Perez-Mendez — Nuc. Inst. & Methods 62, 105 and M. Powell, D. Price, L. Kaufman, D. Mack, V. Perez-Mendez — J. Nuc. Med. 9 (1968) 342.) In biology they are being developed for rapid scanning of paper chromatographs in which beta-emitting radioisotopes are used as tracers.

Proportional wire chambers (developed at CERN) coupled with the electromagnetic delay line readout (developed at Berkeley by A. Rindi, V. Perez-Mendez and R. L. Wallace) will also be used. They have the advantages of simpler operation and of counting rates up to 10^5 per second. The poorer positional accuracy of these proportional chambers (locating particles to within 1 to 2 mm compared to the 0.2 to 0.3 mm for the wire spark chambers) is not of importance for these applications.

One recent use of wire chambers is of interest in the application of negative pion beams for cancer therapy. An experiment was recently carried out by A. J. Miller, V. Perez-Mendez, M. R. Raju, A. Rindi, and J. Sperinde at the 184 inch Berkeley cyclotron where a low energy negative pion beam was stopped in tissue-simulating plastic. The spatial distribution of the stopping pions was determined by observing the distribution of gamma rays (2 %) produced in the capture process when viewed by the wire chamber through a slotted collimator.

TRIUMF

Magnet contract placed

An important stage in the TRIUMF project (see CERN COURIER vol. 8, page 136) was reached in February with the placing of the contract for the manufacture of the 4000 ton magnet for the cyclotron. The contract went to Davie Shipbuilding Ltd. of Lauzon, Quebec, the largest shipbuilding company in Canada, for a cost of $ 1.94 million.

This follows more than three years study of the complex magnet, in a team led by E. G. Auld, which has culminated in a highly efficient design. The latest model magnet (exactly scaled to a twentieth of the magnet for the machine) achieved the desired field to better than 1 %. The firm of Dilworth, Secord, Meagher and Associates, Vancouver, has been responsible for the structural design.

The magnet has six spiral sectors. The horizontal return yoke will be built up from low carbon steel plates 3 inches and 5 inches thick (0.15 and 0.25 inches on the model); the vertical return yoke will be built up from 10 inch plate (one solid piece on the model). The pole piece consists of three separate plates contoured by flame cutting and machining to a final thickness of 10.8 inches.

The Steel Company of Canada, Hamilton, will supply the 3 inch plate for about $ 400 000 and the Lukens Steel Company, Coastville (the largest steel mill in the world) will supply the 5 and 10 inch plate for about $ 600 000. The plate ranges in length from 1 foot to over 31 feet. It will be shipped to Davie for cutting and machining.

TRIUMF — the joint project of the University of Alberta, Simon Frazer University, the University of Victoria and the University of British Columbia — hopes to produce its first beams in 1973 and to be the first of the new generation of cyclotrons to begin meson physics.

BATAVIA

Preparation for experiments

It is intended eventually to make extensive use of superconducting magnets in the beam-lines into the experimental areas of the 200 GeV accelerator. Model superconducting magnets are therefore being built. Mark II bending magnet, which has a 'picture frame' iron yoke, reached a field of 21 kG and was charged from zero field to 20 kG in about 5 minutes. During tests the superconducting coil was deliberately quenched eleven times without affecting subsequent performance. A 10 foot dipole is to be built by 1 July 1970 to give a field of 35 kG. A superconducting quadrupole (7 foot long, to give a field gradient of 10 kG/inch) is under study.

The third 'Experimental facilities workshop' was held on 13 March to discuss Experimental Area 1 (the area being designed for neutrino beams and bubble chambers). The annual meeting of the

Summer School in Medium Energy Nuclear Physics at Banff, Alberta

The School is sponsored by the Division of Nuclear and Theoretical Physics of the Canadian Association of Physicists, with support from the North Atlantic Treaty Organization, Atomic Energy of Canada Limited, and from the University of Alberta. The purpose of the School is to study the important aspects of nuclear and meson physics at intermediate energies. The subjects covered will be: (1) Pion-Nucleus Scattering (2) Proton-Nucleus Scattering (3) Diffraction Theory (4) Interaction of μ Meson with Nuclei (5) Nuclear Structure Studies.

There will be six guest speakers covering these topics in a two-week period. The School is limited to 80-100 participants.

Applications are invited from interested persons to attend the Summer School. Successful applicants may be able to obtain full or partial financial support. Apply to:

Dr. G.C. Neilson, Chairman
Division of Nuclear Physics
Canadian Association of Physicists
Nuclear Research Centre
The University of Alberta
Edmonton, Alberta, Canada

August 17-28 1970

NAL Users Organization is scheduled for 10, 11 April.

As another step in the preparation for the experimental programme, a 'Program Committee' has been set up including Laboratory Staff and scientists from outside (O. Chamberlain, T. H. Fields, V. L. Fitch, M. Gell-Mann, T. D. Lee, W. K. H. Panofsky, R. G. Sachs, N. P. Samios and W. J. Willis). The Committee is calling for experimental proposals in the near future since plans for the first experiments need to be sufficiently well defined by the autumn of this year to allow apparatus to be ordered. Experiments will then be ready to use the machine as from 1 July 1972. The Committee met for the first time on 6 March. It will meet again in August to consider proposals.

Construction progress

The Booster tunnel was ready for occupancy on the scheduled date of 26 February and the first of the 48 modules was moved into position. Booster magnets are now arriving at the Laboratory at a rate of about three magnets per week. The first prototype r.f. cavity for the Booster has been successfully operated to full power.

To help preserve the quality of the beam in the Booster when passing through transition energy, a system is being installed to enable the transition energy to be shifted as the beam crosses it. This trick was successfully developed at CERN in the proton synchrotron (see CERN COURIER vol. 9, page 230).

The first production bending magnet for the main ring was completed on 23 January and was powered to fields of 22.5 kG. It has the new coil design described in CERN COURIER vol. 10, page 14. Detailed measurements of the fields then began. A modified pole shape has been adopted using tapered sides to improve the quality of the field at high fields. Computations predict that the field shape will then be acceptable without further correction up to 21 kG (corresponding to 467 GeV). By the end of February, four magnets had been installed in the main ring prototype tunnel. Tunnel sections are already in place in the excavation for the main ring.

President Nixon's budget request to Congress included construction money for the 200 GeV accelerator of $ 65 million for fiscal year 1971 (beginning 1 July 1970) plus $ 17 million for operation and equipment. In the next fiscal year it is hoped to begin construction of the 'Core Building' which is intended to be an impressive 'high rise' structure containing offices, laboratories, computer centre, library, auditorium for 500 people, restaurant, etc. Leading architects have put forward conceptual designs.

LUND Conference Proceedings

The fifth in the series of 'odd-year conferences', which started in Aix-en-Provence in 1961, was held in Lund, Sweden, from 25 June to 2 July 1969. A short review of some of the major topics from the Conference appeared in CERN COURIER vol. 9, page 232. The Proceedings of the Conference has now appeared and has been distributed to the participants.

The Proceedings opens with an article commemorating Gunnar Källén, who was Professor of Theoretical Physics in Lund, and who died tragically in an airplane accident before the Conference. The Proceedings contains the full talks of the rapporteurs, reporting on the parallel sessions of the Conference, and the discussions which ensued. A novel feature of this Conference was a series of introductory review talks; they give extremely useful introductions to the main subjects covered. As usual the Proceedings gives a list of participants and the titles of the contributions to the parallel sessions.

The Proceedings may be ordered directly from the printer, Berlingska Boktryckeriet, St. Gråbrödersgaten 17, 222 22 Lund, Sweden, against advance payment of 100 Swiss francs (postal account 3 04 90).

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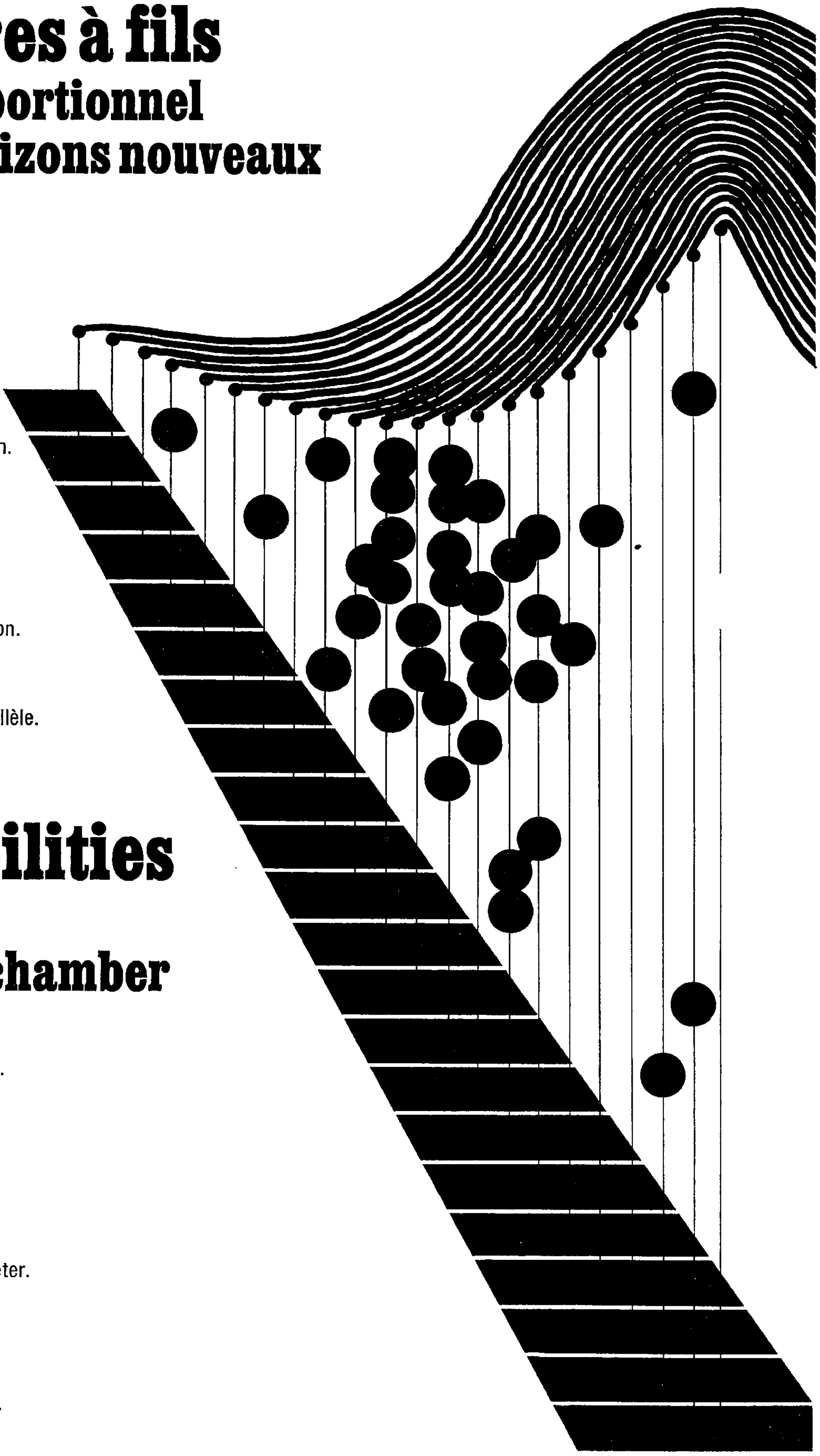
CARACTÉRISTIQUES
Temps mort inférieur à 10^{-6} seconde par fil.
Auto-déclenchement.
Sorties logiques fil par fil.
Possibilité de coïncidences avec une autre chambre ou un détecteur.
APPLICATIONS
Détection sélective des particules en fonction de leur pouvoir d'ionisation.
Basses énergies :
Plan focal de spectromètre.
Localisation spatiale de rayons X et de neutrons.
Chromatographie β.
Hautes énergies :
Localisation de traces.
Hodoscope à faible pouvoir d'absorption.
Electronique :
Résolution : 40 ns
Temps mort total : 200 ns
Vitesse de lecture : 4 MHz en code parallèle.



new possibilities
with multiwire proportionnal chamber

CHARACTERISTICS
Dead time below 10^{-6} second per wire.
No triggering DC high voltage.
Logical output for each wire.
Possibility of use in coincidence with other chamber or detector.
APPLICATIONS
Detection selectivity for particles of different ionizing power.
Low energy physics :
Localisation in focal plan of spectrometer.
Mapping in spatial distribution of X-rays and neutrons.
β chromatography.
High energy physics :
Localisation of particle trajectories.
Hodoscope with low superficial weight.
Electronics :
Resolution : 40 ns
Total dead time : 200 ns
Reading speed : 4 MHz in parallel code.

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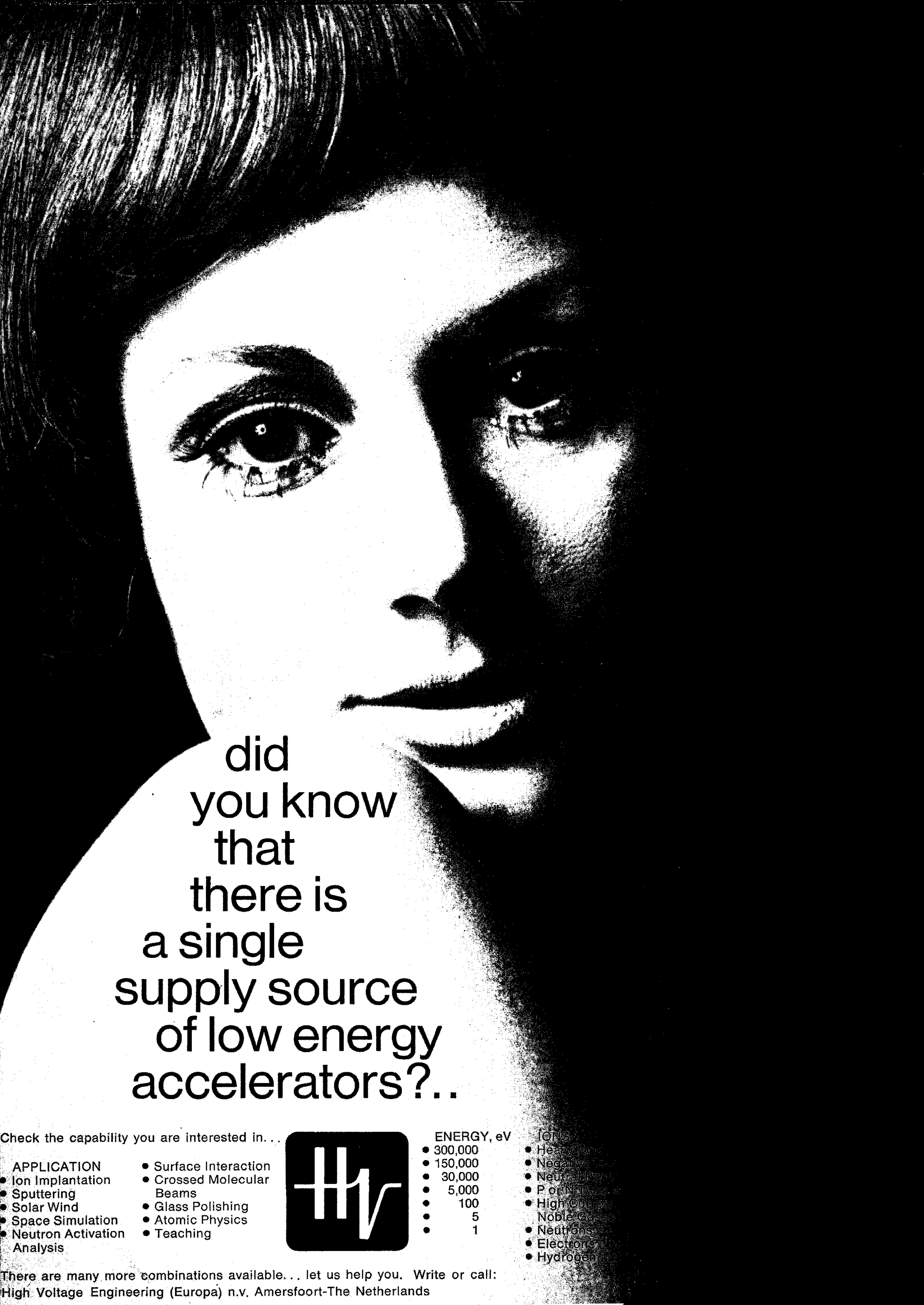

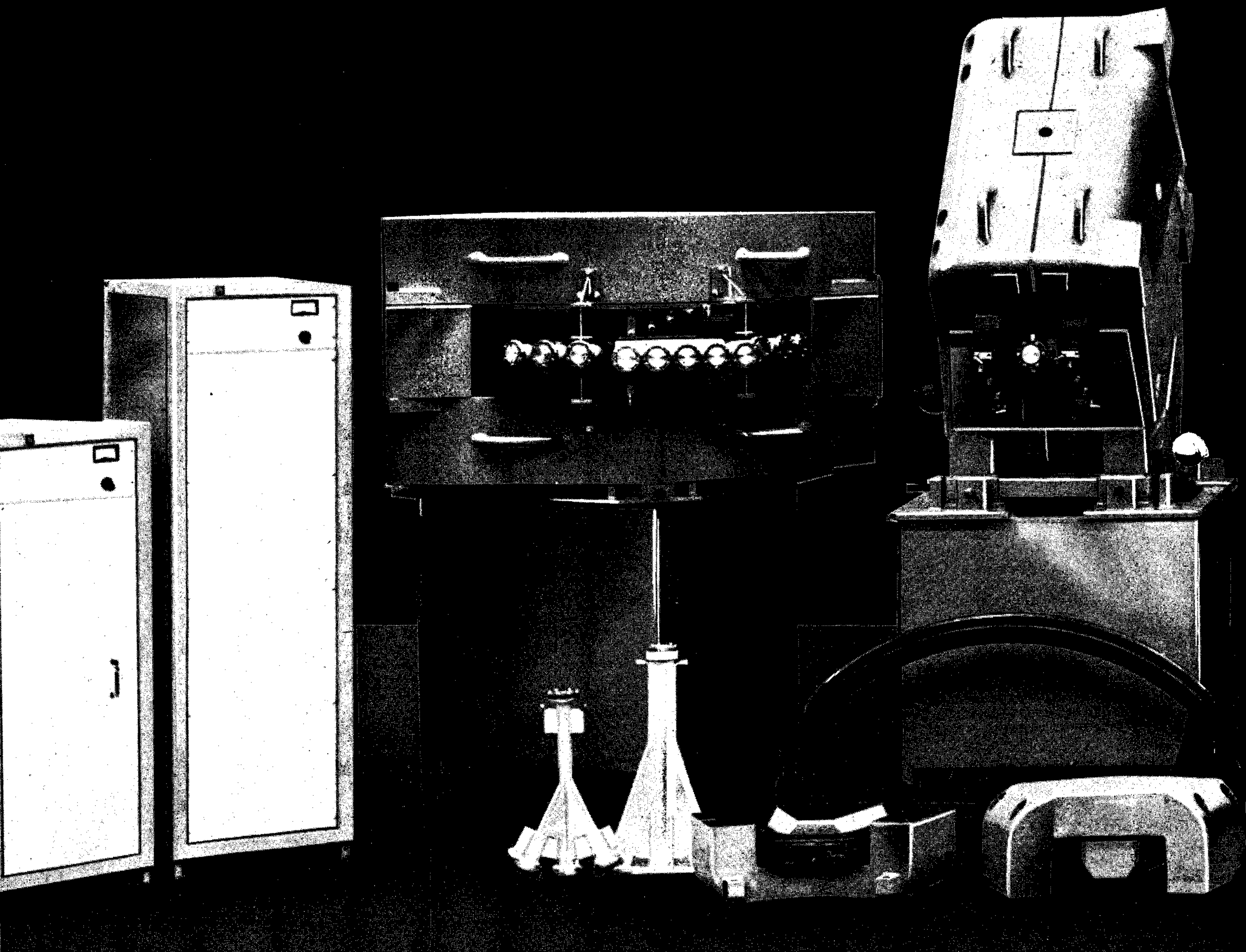

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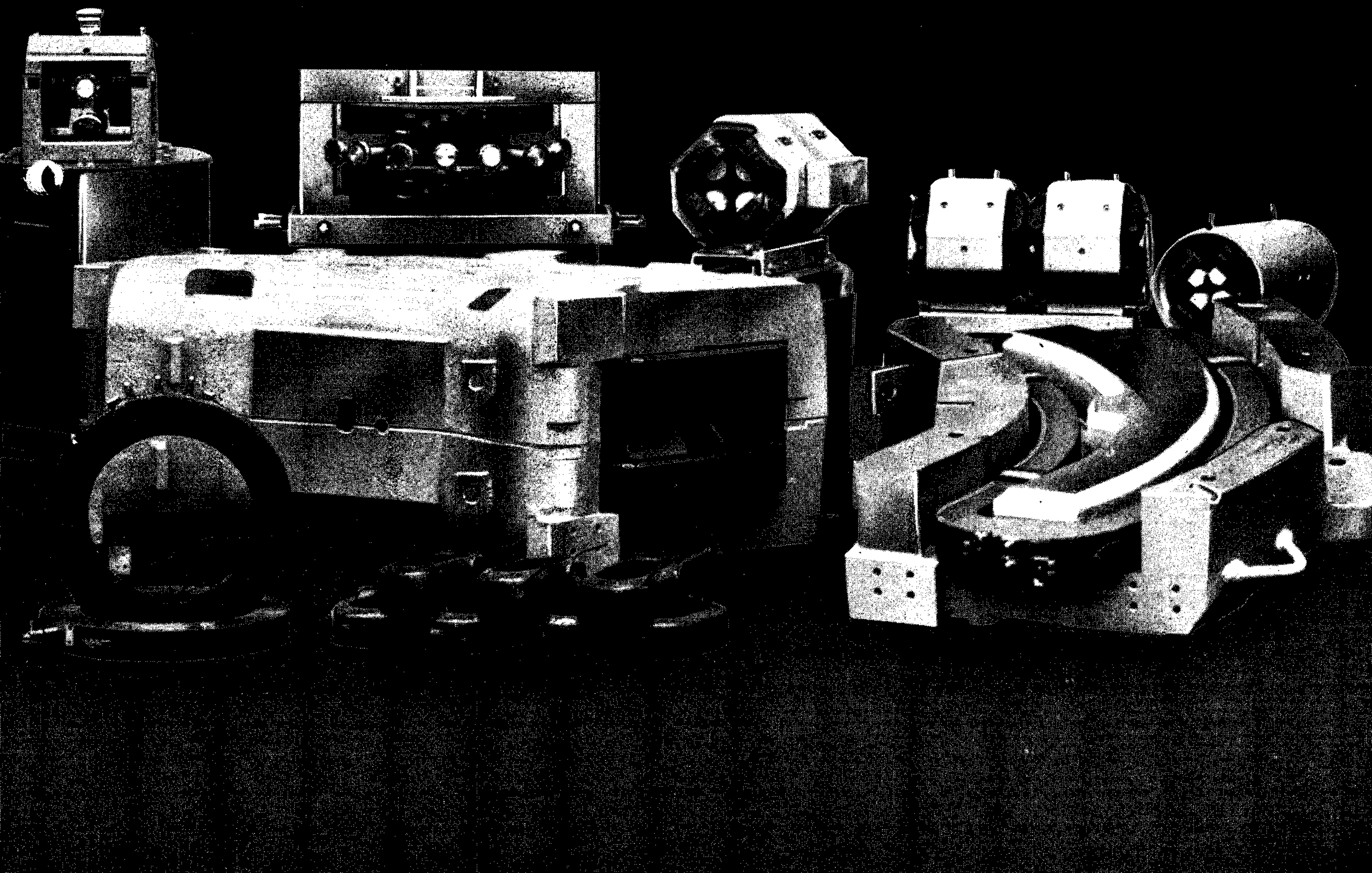

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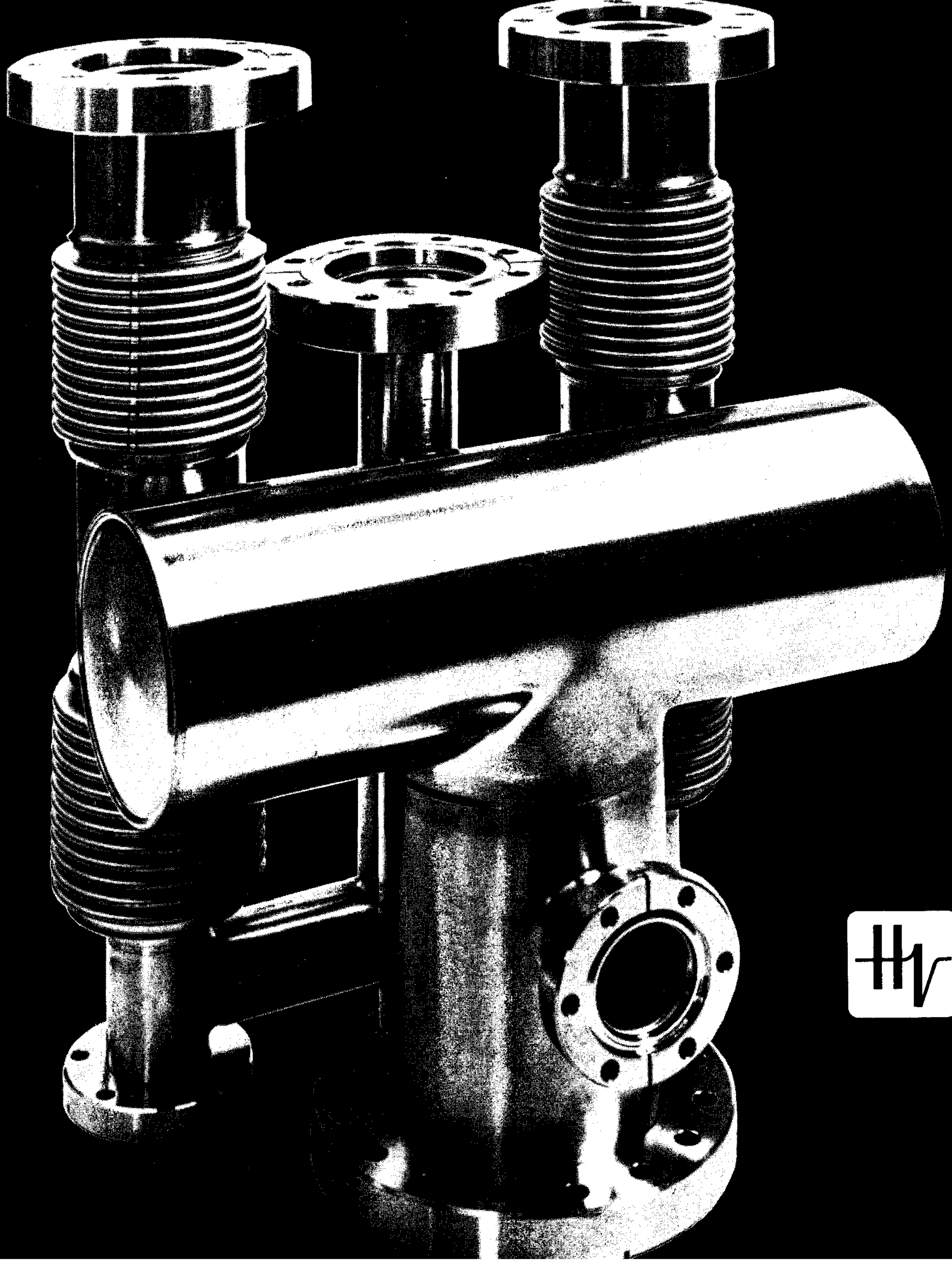

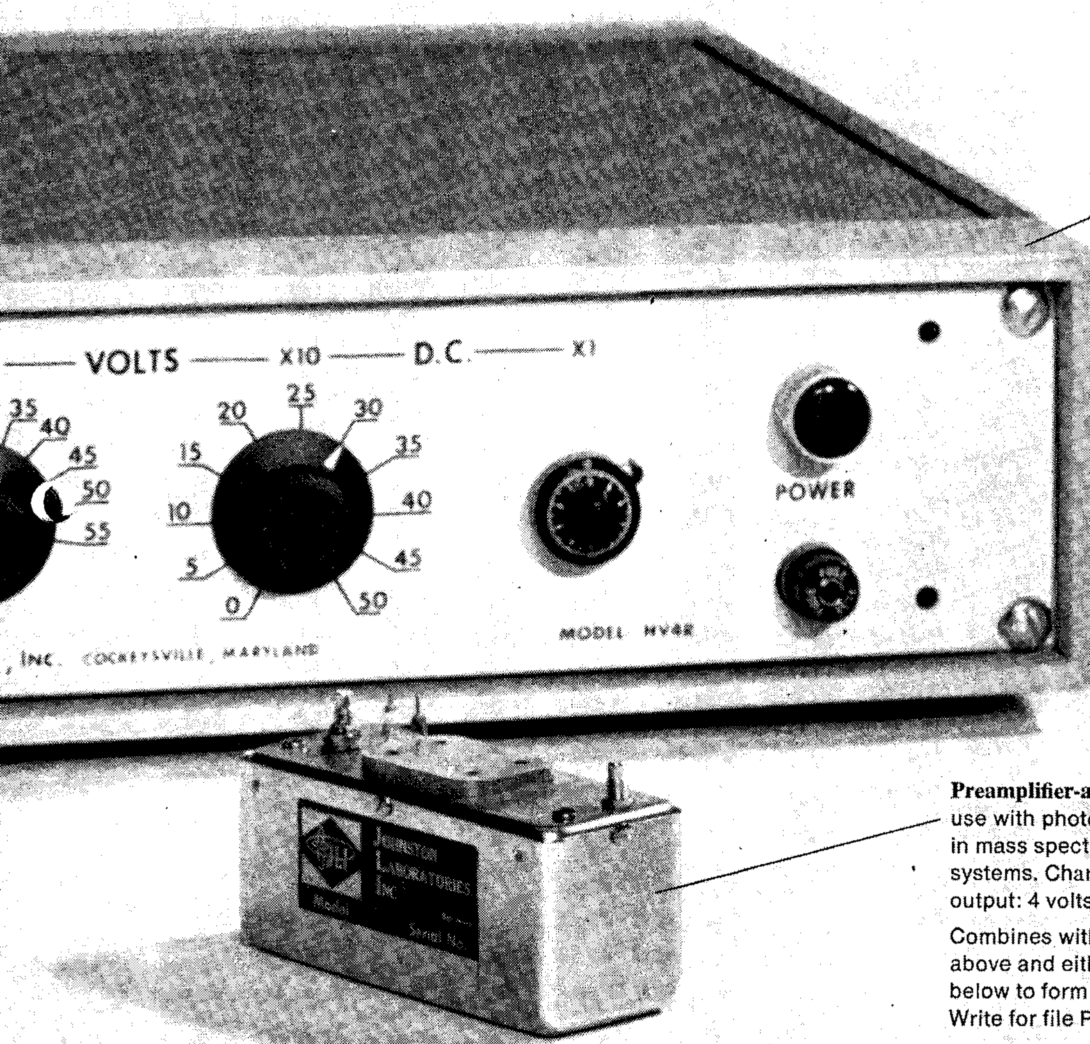
VOLTS
X10
D.C.
X1
35
40
45
50
55
20
25
30
15
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10
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0
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POWER
MODEL HV4R
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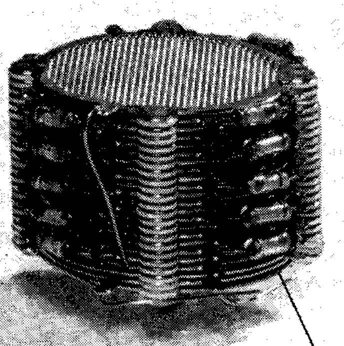

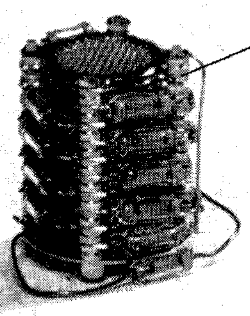

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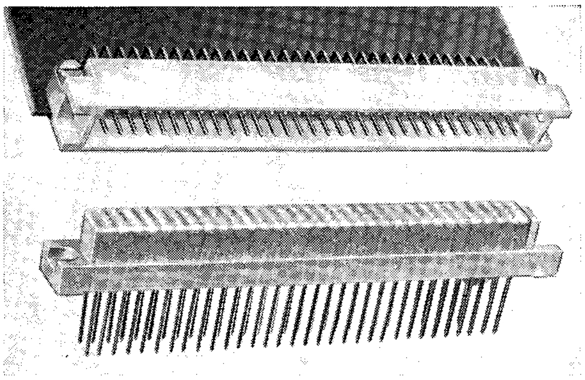

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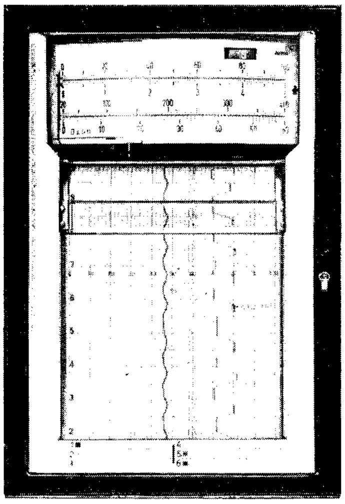
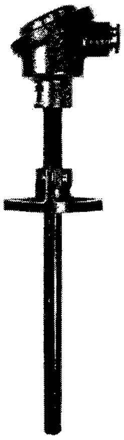
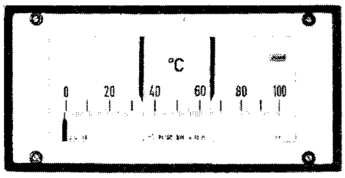


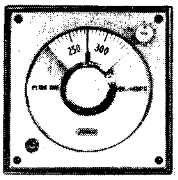
Punktschreiber



Thermoelemente
Widerstandsthermometer
Feuchtegeber



Thermoelektrische Regler und Anzeiger



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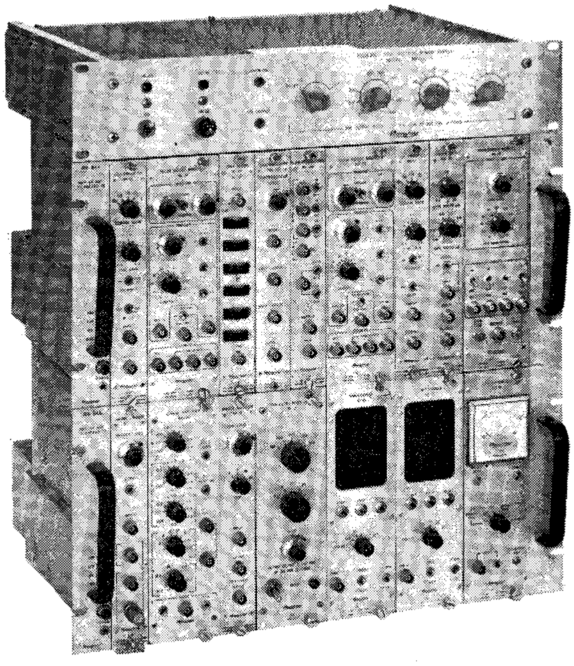

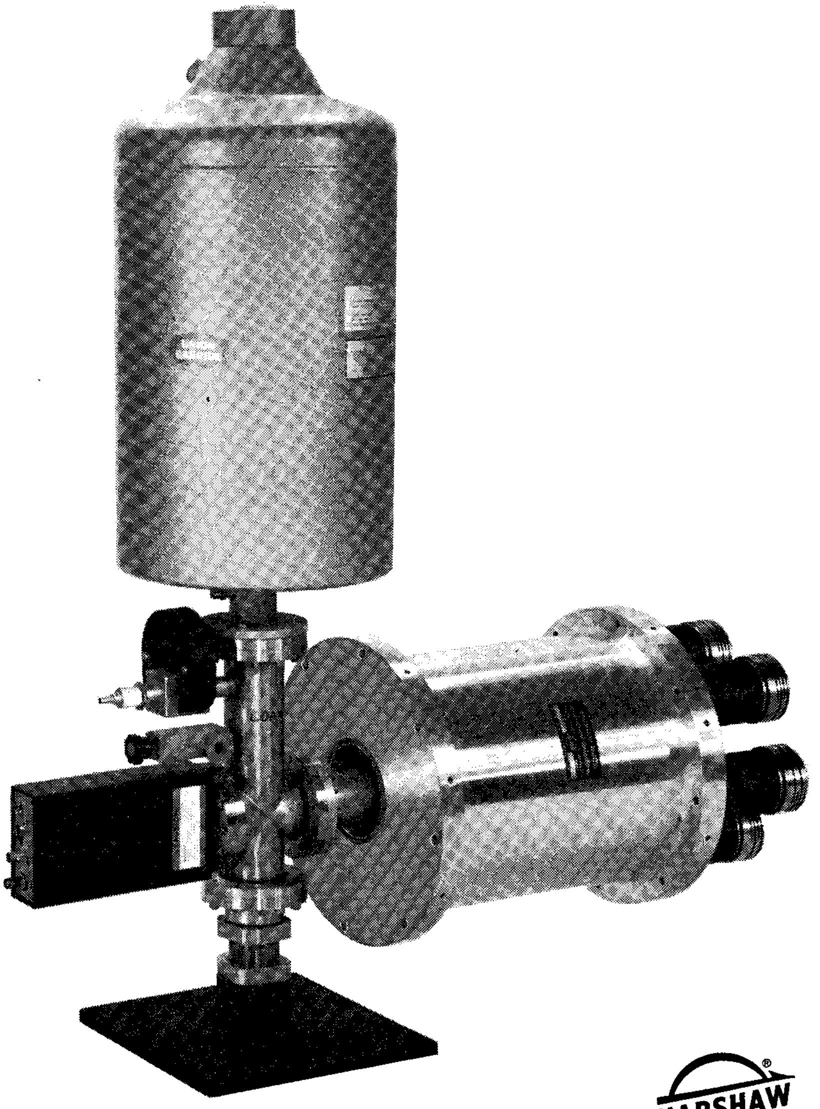

First, we'll tell you something about medium-sized computers, you know already.

They're a pain in the neck.

Because all the ones you've ever seen up to now come with big price tags and nothing like the kind of versatility you want, unless you're willing to fork out a fortune to get them tailor-made to your requirements.

Hence, the new Digital PDP-15 medium-sized computer. Really four medium-sized computers for you to choose from. Not just one. All costing you far less than any comparable competitive computers.

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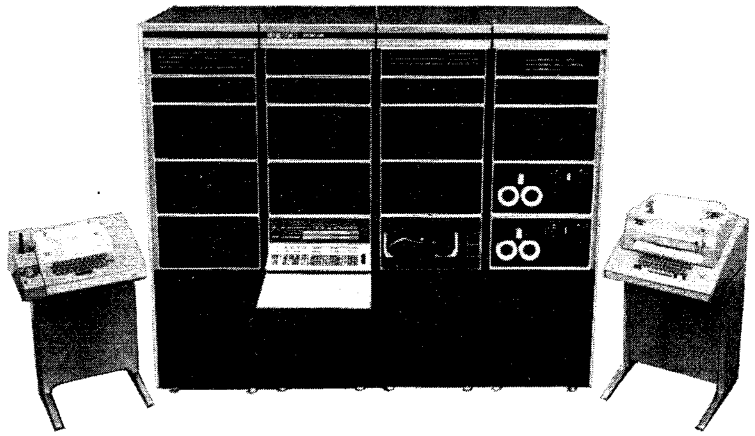
PDP-15/10 4,096 18-bit words of 800-nanosecond core memory, Teletype Model ASR-33 console teleprinter. COMPACT Software System including assembler, editor, debugging aids, and mathematical and utility routines.

PDP-15/20 Advanced Monitor System: 8,192 words of core memory, KSR-35 Teletype for extra reliability, two DECtape transports and control units, high-speed paper tape reader/punch, Extended Arithmetic Element for high-speed arithmetic operations and register manipulation. Advanced Monitor System with FORTRAN IV, FOCAL-15, MACRO-15 macro assembler, linking loader, batch processor, system generator, scientific library, and comprehensive debugging and utility routines.

PDP-15/30 Background/Foreground System: 16,384 words of core memory, KSR-35 Teletype, Extended Arithmetic Element, Automatic Priority Interrupt System, Memory Protect System, high-speed paper tape reader/punch, three DECtape transports and control unit, real-time clock,.and a second on-line Teletype for background use. Background/Foreground Monitor System combining all Advanced Monitor functions with concurrent execution of real-time foreground tasks and program development or other lower-priority background computation.

PDP-15/40 Disk-Oriented Background/Foreground System: 24,576 words of core memory, KSR-35 Teletype, Automatic Priority Interrupt System, Memory Protect System, high-speed paper tape reader/punch, two DECtape transports and control unit, RF15 DEC-disk control and two RS09 random-access disk files, real-time clock, and a second on-line Teletype for background use. Disk-oriented version of the Background/Foreground Monitor System, allowing concurrent execution of real-time tasks and background computation, in addition to all standard Advanced Monitor functions.



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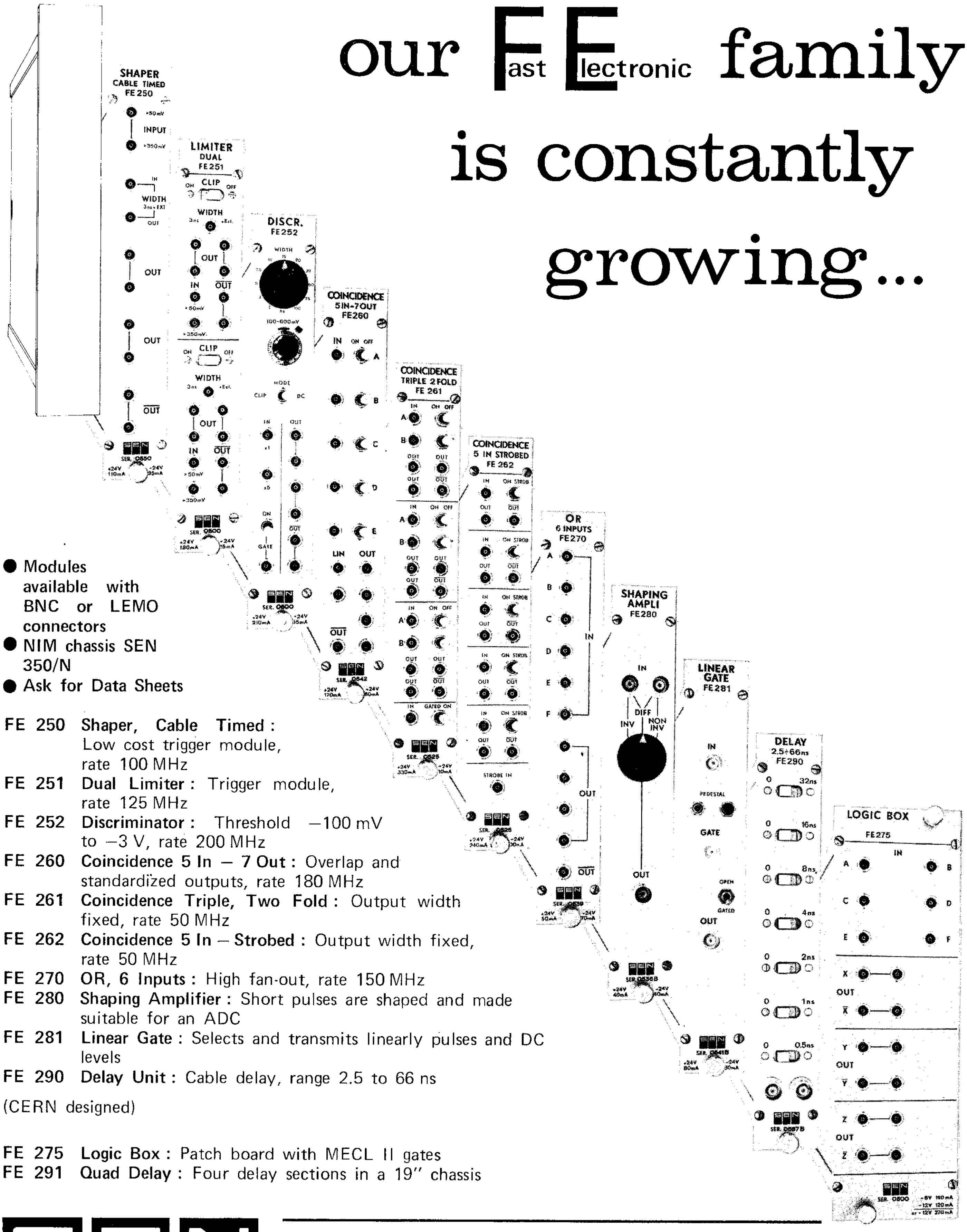

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- NIM chassis SEN 350/N
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FE 252	**Discriminator :** Threshold −100 mV to −3 V, rate 200 MHz
FE 260	**Coincidence 5 In — 7 Out :** Overlap and standardized outputs, rate 180 MHz
FE 261	**Coincidence Triple, Two Fold :** Output width fixed, rate 50 MHz
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FE 270	**OR, 6 Inputs :** High fan-out, rate 150 MHz
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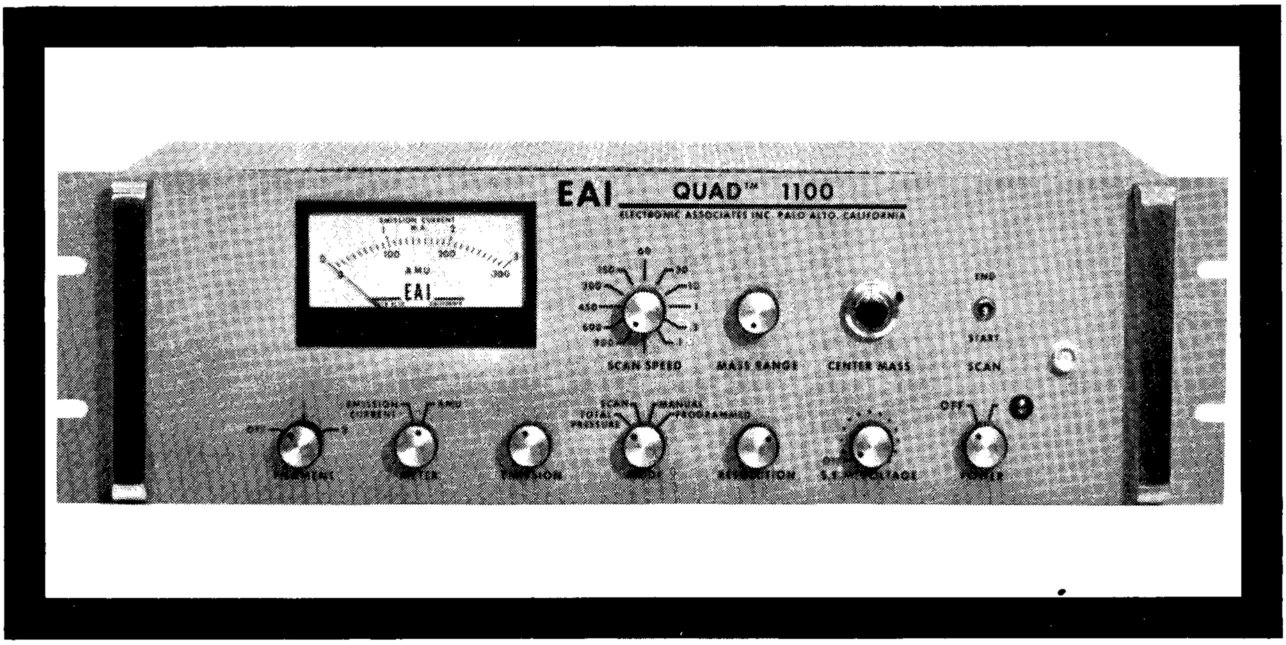
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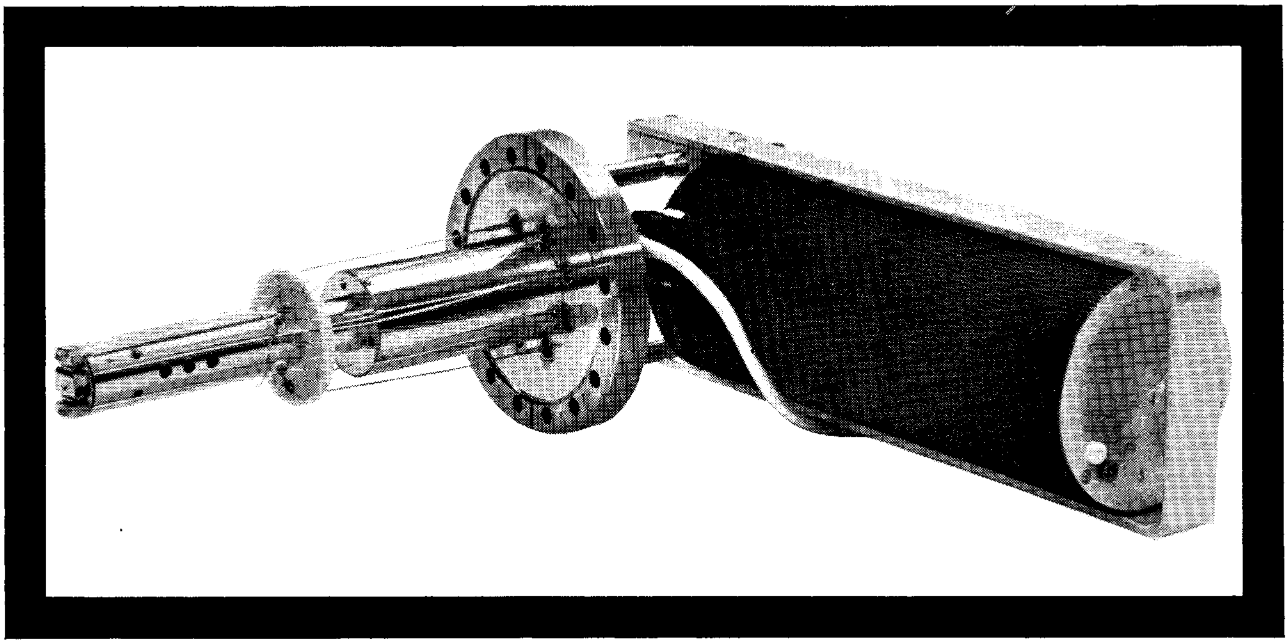
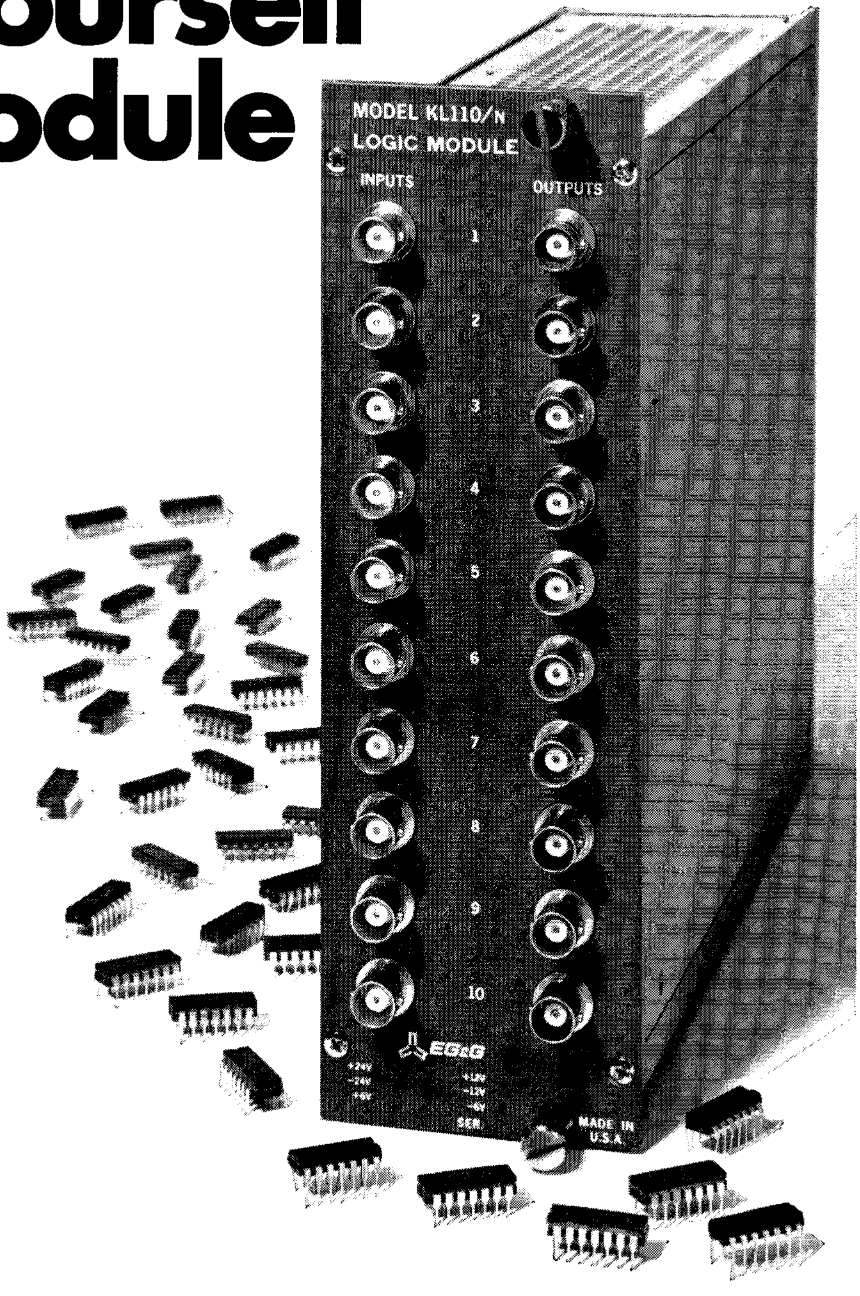
EMISSION CURRENT
AMU
SCAN
MANUAL
TOTAL PRESSURE
PROGRAMMED
OFF
RESOLUTION



The do-it-yourself logic module



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You can build them when there's no standard module available. And you can avoid obsolescence by reconfiguring them again and again.

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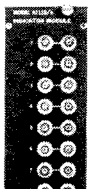

This module indicates presence of NIM standard fast logic signals. A light flashes whenever such a pulse is sent through the bridging input. KI110/N Indicator Module supplied ready to run. Write for all the facts.

For complete details on how this can save you money, write EG&G, Inc., Nuclear Instrumentation Division, 35 Congress Street, Salem, Massachusetts 01970. Phone: (617) 745-5200. Cables: EGGINC-SALEM. TWX: 710-347-6741. TELEX: 949469.

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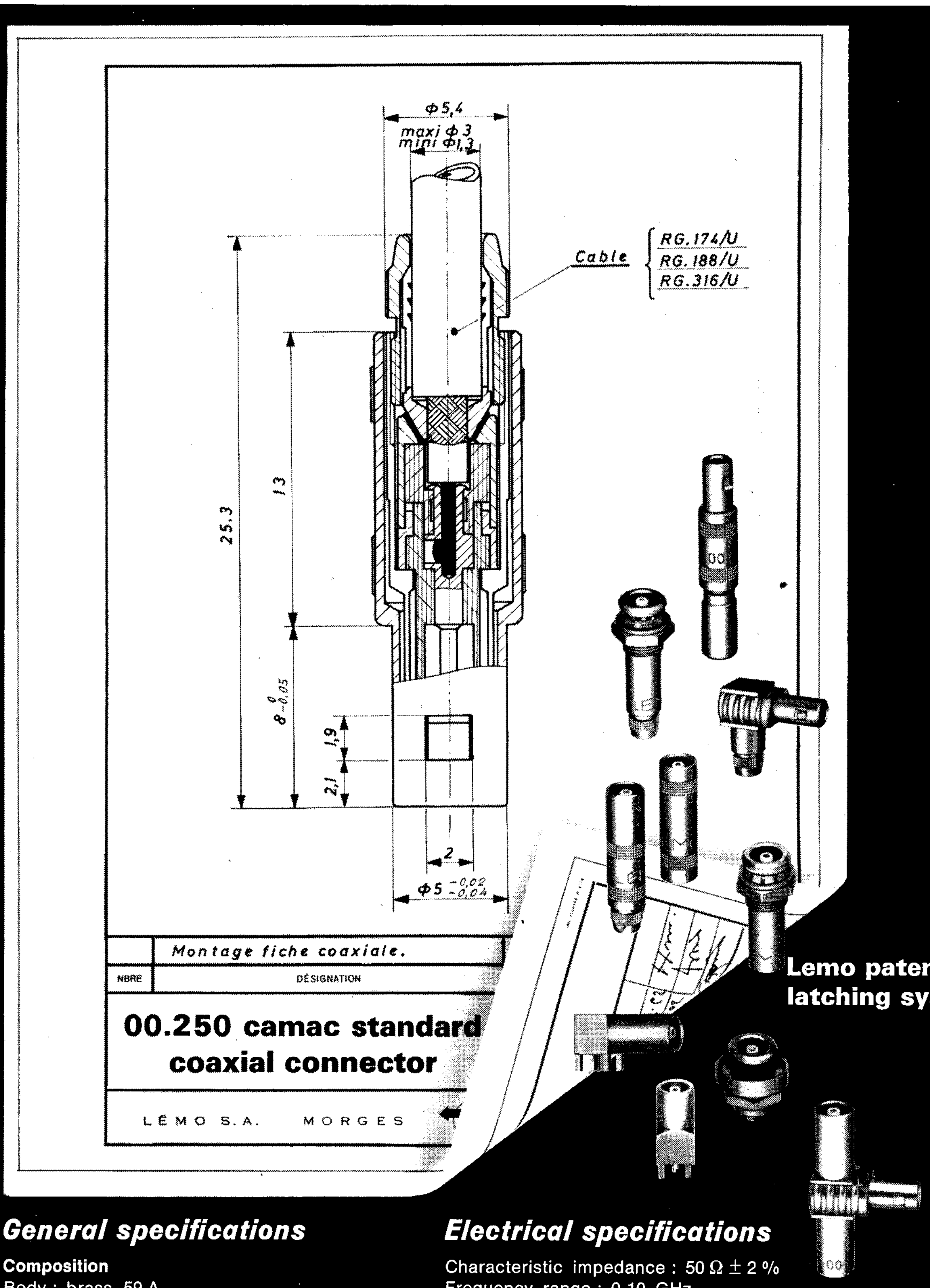
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