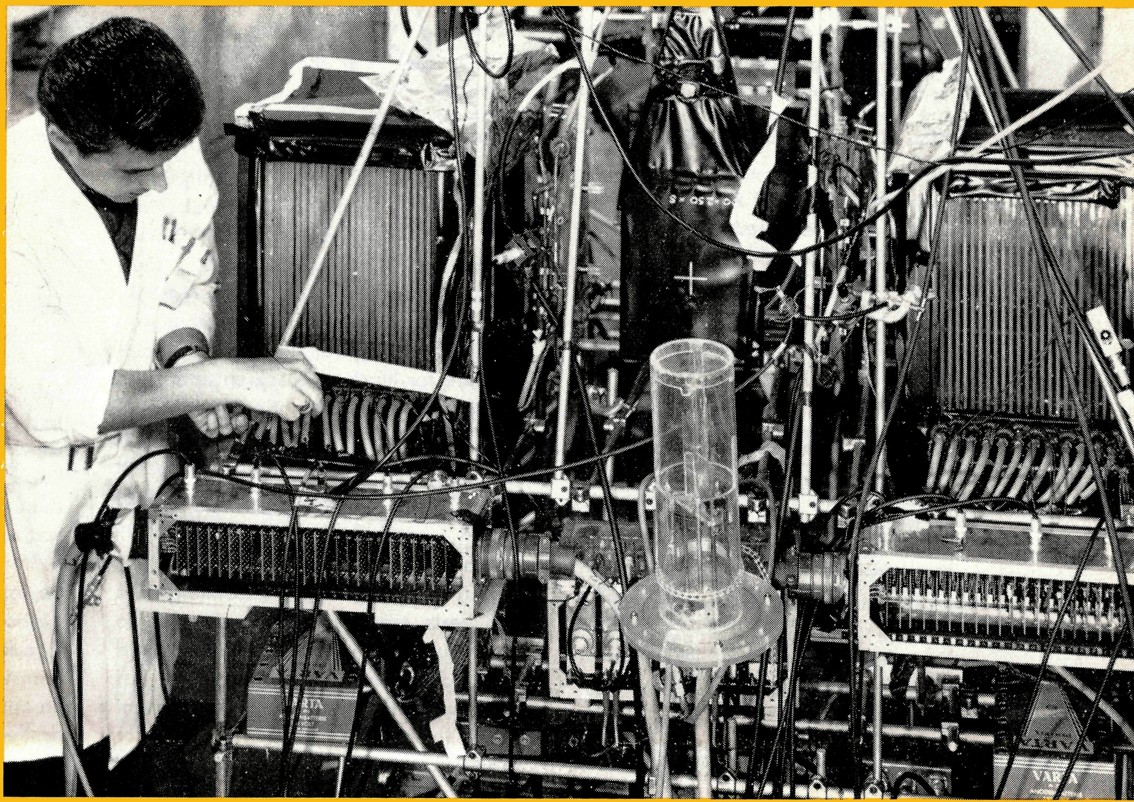
CERN COURIER



CERN/PI 99.8.64

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

The European Organization for Nuclear Research (CERN) came into being in 1954 as a co-operative enterprise among European governments in order to regain a first-rank position in nuclear science. At present it is supported by 13 Member States, with contributions according to their national revenues: Austria (1.96%), Belgium (3.85), Denmark (2.09), Federal Republic of Germany (22.86), France (18.66), Greece (0.60), Italy (10.83), Netherlands (3.94), Norway (1.48), Spain (1.68), Sweden (4.25), Switzerland (3.20), United Kingdom (24.60).
Contributions for 1964 total 107.2 million Swiss francs.

The character and aims of the Organization are defined in its Convention as follows :

'The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.'

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The cover photograph illustrates the fact that not all the experiments at CERN require massive equipment. At the synchro-cyclotron two interesting new kinds of spark chamber, giving direct electronic information instead of photographs, are being tested in an experiment on the energy levels of helium-4. A lithium-6 nucleus struck by a 100-MeV pion gives two protons and a helium-4 nucleus. Each proton passes through two pairs of 'current-measuring' chambers, which locate its path in space, and enters a 'range chamber', which indicates where it comes to rest. The data obtained are recorded on punched paper tape and then fed to a computer to calculate the energy and angle of emission of each proton and hence the energy state of the residual nucleus. In the range chambers (seen on each side of the photograph), the plates are each connected through a magnetic 'memory' core so that, after each trigger, those that actually sparked can be identified. In the current-measuring chambers (difficult to see here) only two plates are used and the earthed one has two separate connecting wires, from opposite edges, each passing through a magnetic core. The difference in the currents flowing through the two cores, measured simply by having two secondary windings in opposition around the cores, gives a measure of the position of the spark with respect to the edge connexions; for example, if these edges are vertical, a horizontal co-ordinate is obtained.
The plastic container in the foreground of the photograph (out of its operating position) contains the lithium target.

CERN COURIER

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Last month at CERN

Dubna Conference

Early in August, 23 CERN physicists, including the Director General, Prof. V.F. Weisskopf, and the Directorate Member for Research, Prof. B.P. Gregory, travelled to Dubna, in the U.S.S.R., for the 12th International conference on high-energy physics, held at the Joint Institute for Nuclear Research under the auspices of the International Union of Pure and Applied Physics. A number of other physicists currently at CERN went as representatives of their own laboratories.

The conference, which took place during 5-15 August, fell essentially into two parts, most of it being devoted to the results of experiments in this field of fundamental research and the last two days to the methods and equipment used. In this sense it was the successor to the two separate conferences held at CERN in July 1962.

Fundamental law doubted

One of the most discussed topics at Dubna was the result of an experiment carried out at the 33-GeV alternating-gradient synchrotron in Brookhaven, U.S.A., by four physicists from Princeton University (one of them on leave from the Centre d'Etudes Nucléaires at Saclay)[*]. To the uninitiated, their discovery seemed of no special interest — a so-called K^0_2 (K-nought-two) meson had been found to decay sometimes into two particles (pions), instead of into the more usual three particles (pion + muon + neutrino, three pions, etc.). To many high-energy physicists, however, and specialists in weak interactions in particular, the result was startling, because it seemed to disprove one of the fundamental rules that are believed to cover the behaviour of matter, a rule known as 'CP invariance'.

This rule is connected with a number of others by the so-called CPT invariance theorem. C represents the mathematical operation of 'charge conjugation', changing the wave function of a particle into that of its corresponding antiparticle (or vice-versa) ; P is the parity operator, reversing the sign of all the space co-ordinates in the wave function ; T represents the operation of changing the sign of the time co-ordinate — running time backwards. Physically, CPT invariance implies that antiparticles (or particles), viewed upside down in a mirror and with time running backwards are subject to exactly the same forces and interactions as particles (or antiparticles) in the normal world. Moreover, for strong and electromagnetic interactions, systems of fundamental particles are invariant under C, P and T operations separately : for example (considering C alone) the force between an antiproton and a positron is the same as the force between a proton and an electron, so that an 'anti' hydrogen atom would behave in exactly the same way as a normal hydrogen atom ; considering P, the shape of the electron cloud is symmetrical about the proton nucleus so that the atom has no left and right or top and bottom. For weak interactions, however, P invariance does not hold : a particle undergoing spontaneous decay does show a kind of left and right side. But the 'left' side of a particle is the 'right' side of an antiparticle, so that until now it was accepted that it was the double operation represented by CP that introduced no change in any system. This was the principle that was put in doubt by the Princeton / Brookhaven experiment.

By implication, since it appeared impossible to believe that CPT invariance was not true, time reversal by itself could no longer be assumed to have no effect, at least in the case of the weak interactions. In other words, the laws governing such interactions could no longer be assumed independent of the direction of time, and all the theories including this assumption would have to be looked at afresh.

Briefly, the experiment had involved an investigation of the decay of neutral

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[*] J.H. Christenson, J.W. Cronin, V.L. Fitch and R. Turlay, Physical Review Letters, vol. 13, p. 138 (27 July 1964).

mesons. These decays (spontaneous disintegration into other particles) were thought to be of two kinds, one corresponding to the decay of a K°_1 meson, the other to the decay of a K°_2 meson (as explained below). In particular, if CP invariance were true the K°_1 meson could decay into two pions (one positive, one negative) but the K°_2 could not. The Princeton experimenters had arranged their apparatus to ensure that only the decays of K°_2 mesons would be detected and had then found that about two in every thousand in fact produced the 'impossible' pair of pions.

A new force in the universe !

The results were published just before the Dubna conference, and at the conference another group (from Illinois University) gave further evidence for the effect. There followed, as the rapporteur of the theoretical plenary session remarked, a great deal of agitated discussion, especially over the clinking sound of vodka glasses, about the experiments and their implications. Afterwards, at CERN and in many other laboratories, by letter and by telephone, the discussion continued and new ideas were developed. At an early stage, three possibilities emerged :

a) the experimental results were wrong ;

b) CP invariance could no longer be assumed to occur in all cases ;

c) an unknown effect had transformed some of the K°_2 mesons in the experiment into K°_1 mesons, which had then decayed into pions in the normal way.

The first explanation could be safely ruled out ; the second was intriguing to many theoreticians, who busily began working out the possible consequences or tried to explain the cause in various ways ; the third rapidly produced at least two independent postulates of a new, hitherto unsuspected, fundamental force in the universe.

At Stanford University (U.S.A.), such an idea came from J.S. Bell, a CERN physicist on leave, and J.K. Perring (on leave from the Atomic Energy Research Establishment in England) *. At CERN, J. Bernstein (on leave from New York University), N. Cabibbo and T.D. Lee (on leave from Columbia University) evolved a similar notion. It seems that, apart from the four known forces (strong, electromagnetic, weak and gravitational) in the universe, there may be a fifth, extremely weak but long-range, force that is different for antiparticles and particles. An antiparticle acted on by all the particles in, say, our own galaxy would thus have a slightly different energy to a particle in the same circumstances. As a result, K°_2 mesons would sometimes be changed to K°_1 mesons and the experimental results could be explained without having to give up the principle of CP invariance. The effect would be very small, involving an energy difference of only 10^{-8} eV. This would be much too small to be detected if it were not for the peculiar properties of the K° mesons, which make them particularly sensitive to such small forces.

An exciting aspect of the new theories was that, if they were true, the fraction of K°_2 mesons apparently decaying into two pions would depend on the velocity of the mesons. Moves were immediately made to see whether the experiment could be repeated with K-mesons of much higher energy, and such an investigation is now under active preparation at CERN.

K°_1 and K°_2, or K° and $\bar{K}^\circ$

Why, though, should a force distinguishing between particles and antiparticles turn a K°_2 into a K°_1, and what are these particles anyway ? To answer such questions fully would be a complicated mathematical exercise, but more briefly the situation arises from the rather peculiar position that the K meson (or kaon) occupies among elementary particles. In its uncharged, neutral, form the distinction between particle and antiparticle seems to be ill-defined. Whereas a neutral pion, for example is identical to a neutral antipion, so that there is no way of telling the difference, whilst a neutron is quite distinct from an antineutron, having a magnetic moment of opposite sign, the neutral kaon seems to be capable of transforming itself into a neutral antikaon even though the latter has quite different (strong) interactions with other particles. This seeming paradox has been resolved by distinguishing sharply between the strong interactions responsible for the production of the K mesons and the weak interactions by which they decay. The objects formed by the strong interaction are taken to be the kaon, K°, or antikaon, $\bar{K}^\circ$, whilst the ones that decay have become known as K°_1 and K°_2. At its formation the K° consists of a certain combination of the two particles K°_1 and K°_2; the $\bar{K}^\circ$ consists of a different combination of the same two particles. It follows, similarly, that the K°_1 consists of a certain proportion of K° and $\bar{K}^\circ$ and the K°_2 consists of a different proportion ; more generally, any mixture of K°_1 and K°_2 can always be treated as a mixture of K° and $\bar{K}^\circ$, and vice-versa.

Since the K°_1 and K°_2 have different lifetimes (about 10^{-10} second and 5×10^{-8} second respectively), it is clear that the composition of any mixture will change with time, producing a corresponding change in the proportion of K° to $\bar{K}^\circ$ and hence an apparent conversion of particle into antiparticle and vice-versa.

Perhaps even stranger is the 'regeneration' of the K°_1, in the presence of matter. In a pure vacuum, (more specifically, in the absence of any force which acts differently on particles and antiparticles) a beam of K° particles, say, soon comes to consist only of K°_2, owing to the decay of the K°_1 component. But the K°_2 consists of K° and $\bar{K}^\circ$, and in passing through matter the $\bar{K}^\circ$ interacts much more often than the K°, thus changing the proportions of the mixture again and seemingly 'putting back' K°_1 into the beam.*

The different lifetimes of the K°_1 and K°_2 arise from their different modes of decay, which (at least until the recent experiment) have been assumed to be quite distinct. In fact one of the reasons for postulating these two particles was to enable the observed decay modes of the K° to be explained without violating the CP invariance principle.

The CP invariance of the forces responsible for an interaction can be expressed in a simple way by assigning a kind of 'quantum number' for C and for P to each 'object' (particle or antiparticle) taking part. These quantum numbers have one of two values, + 1

Continued on p. 124

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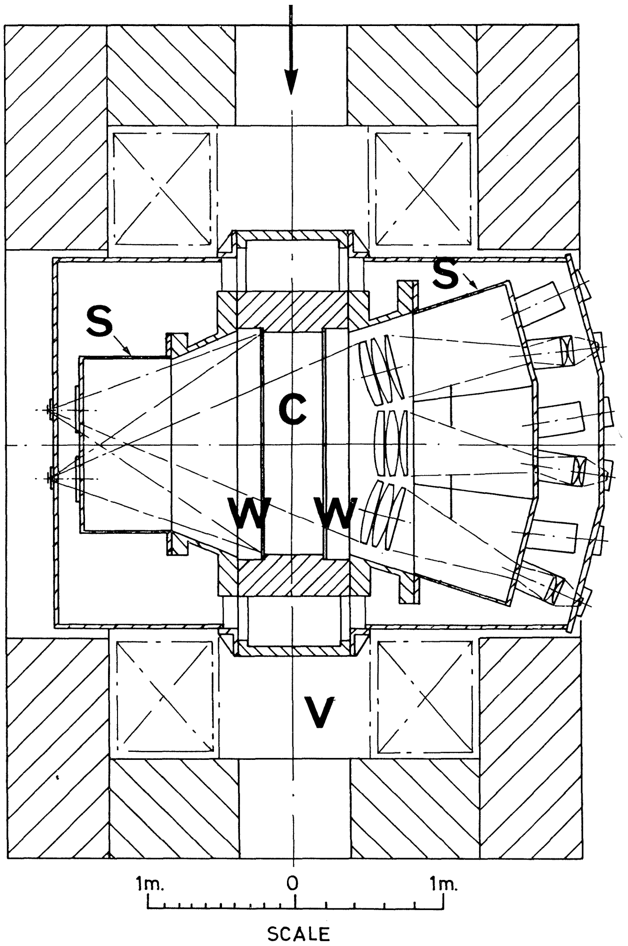
* Physical Review Letters, vol. 13, p. 348 (7 September 1964).

* Such behaviour (an experimental fact for which the theory has only provided an explanation) is certainly difficult to imagine in terms of 'particles', but much easier to understand when the wave nature of matter is considered. In fact a very similar situation exists with polarized light. Circularly polarized light is equivalent to a combination of two beams of plane polarized light, with the planes at right angles to each other, whilst plane polarized light is equally well described as two circularly polarized beams with opposite senses of rotation. A plane polarized beam passing through a selective absorber can thus become a circularly polarized beam, and on passing through another selective absorber becomes again plane polarized (though the intensity is decreased). In the Princeton / Brookhaven experiment the decaying particles were all in a region where the K°_1 fraction of the original beam had completely disappeared and where the absence of other matter in any quantity prevented its re-formation.

60-inch bubble chamber at CERN

From time to time in *CERN COURIER, and particularly in the previous two issues, news has been given of the construction and putting into operation of the 'British National Hydrogen Bubble Chamber', which begins its second major run at CERN in September 1964. In the following pages of text and pictures a more complete account of this apparatus – the largest of its kind in Europe – will be given, together with a general idea of the principles of operation of such a detector of fundamental particles and their interactions.**

Among the techniques used in conjunction with experiments at large particle accelerators, those which enable photographs to be taken of the actual tracks left by the nuclear particles are, in many cases, of particular value. Several techniques of this kind are now available, all depending on the fact that when a charged particle traverses matter the atoms along its path become electrically charged, or ionized. Historically, the first is the cloud chamber, devised some fifty years ago, in which liquid droplets are condensed on gaseous ions and then photographed. This technique has been used extensively in cosmic-ray physics but it has now been largely replaced for use with large particle accelerators by an important visual technique, discovered in 1952 by D.A. Glaser. He utilized the fact that a trail of vapour bubbles can be formed when a charged particle passes through a superheated liquid ; in effect the liquid boils along the line of ions. Glaser rapidly proved that this new technique had very important advantages over the cloud chamber, and it was soon realized that liquid hydrogen is a highly suitable liquid to use in these 'bubble chambers' because its nuclei consist solely of protons.



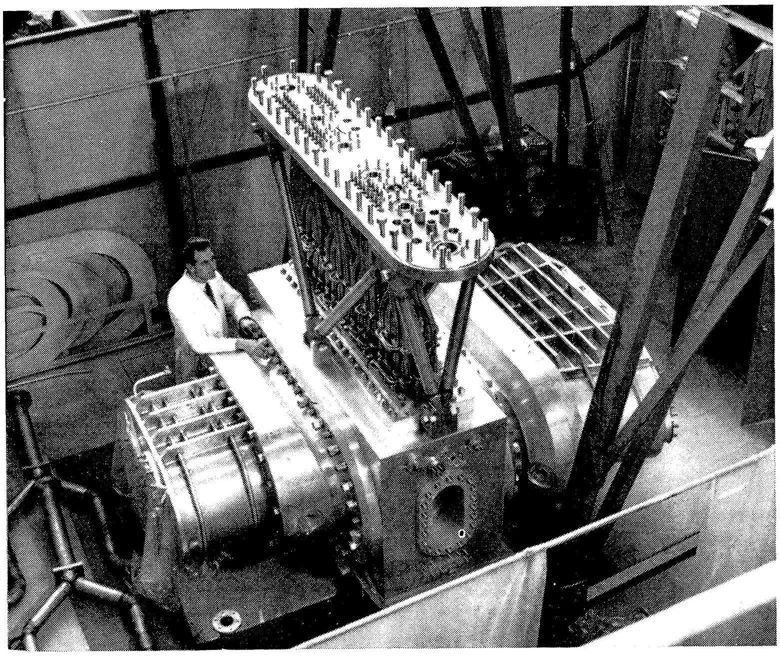
1. Simplified plan of the chamber and its surrounding magnet. At CERN the beam of particles enters as shown by the arrow ; the illumination system is on the right and the cameras are on the left.

British National Hydrogen Bubble Chamber

In 1957 a working party drawn from Birmingham, Liverpool and Oxford Universities, Imperial College of London University and the National Institute for Research in Nuclear Science (N.I.R.N.S.) was formed to discuss plans for a 60-inch British Hydrogen Bubble Chamber for use with the CERN 28-GeV proton synchrotron and the N.I.R.N.S. 7-GeV proton synchrotron 'Nimrod'. A design study was initiated, a grant of £ 419 000 (5.03 million Swiss francs) in support of the programme was announced by D.S.I.R. in 1959 and work on the chamber began immediately.

The construction of the chamber has been a collaborative effort between Birmingham and Liverpool Universities and Imperial College, together with N.I.R.N.S. Most of the components were manufactured by industrial concerns under contract, but the design and model work were carried out almost exclusively by the university and N.I.R.N.S. groups concerned.

The chamber was assembled initially at the N.I.R.N.S. Rutherford High Energy Laboratory at Chilton, Berkshire, and successfully tested there for the first time in January 1963. It was then partially dismantled and transported across England, Belgium and France to Geneva, part of it constituting the widest load ever to travel on some of the


A.E.R.E. HL 8356

2. View of the assembled chamber during its initial assembly at the Rutherford High Energy Laboratory in England. The forty-eight pipes of the expansion system, the chamber suspension, and the top plate of the vacuum tank through which all the pipelines and electrical services are taken, can be clearly seen. The camera side is again on the left.

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* Vol. 3 (1963), p. 37 (March), p. 56 (April), p. 71 (May).
Vol. 4 (1964), p. 27 (March), p. 86 (July), p. 102 (August).

CERN/PI 75.5.63

3. **The complete vacuum-tank assembly, including the chamber body, expansion system, thermal shields, etc., was transported from the Rutherford Laboratory to CERN in May 1963. A low maximum speed was enforced to prevent undue vibration of the more delicate parts, and the physicist in charge kept a bicycle pump ready to ensure that the pressure in the inflatable sealing gaskets was always sufficiently high to prevent vibration of the thick glass windows of the chamber. The lorry with its 30-ton load is seen here in France, coming through the Jura mountains.**

continental roads. The magnet had already been sent to CERN late in 1961. The first experimental 'run' with the fully assembled chamber began in November 1963.

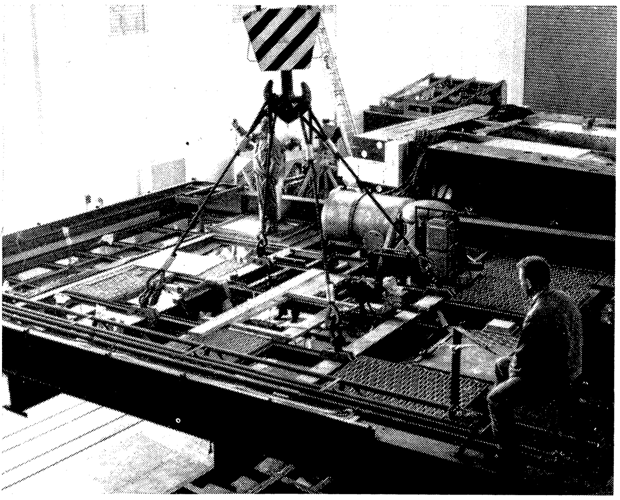
The total cost to D.S.I.R. of the design and construction of the chamber, including its transfer to CERN, was some £ 425 000 (5.1 million Sw. fr.)*. Since the end of 1963, the running of the chamber has been taken over by N.I.R.N.S. and it will eventually return to the Rutherford High Energy Laboratory to be used in experiments at 'Nimrod'.

Chamber construction

A simplified plan view of the bubble chamber and magnet is shown in fig. 1. Five hundred litres of liquid hydrogen are contained in the central chamber C (see also fig. 6), which has internal dimensions (in metric units) of about 152 cm long, 45 cm wide, and 50 cm high and was machined from a single aluminium-alloy forging. The chamber is closed on either side by glass windows W, 16 cm thick, sealed by means of inflatable stainless-steel gaskets able to take up the relatively large dimensional changes caused by cooling the chamber to the temperature of liquid-hydrogen. Each window is protected by a hydrogen shield (S and fig. 7), fabricated from the same aluminium alloy as the chamber. Surrounding the chamber and hydrogen shield is a thermal radiation shield, made of copper-plated stainless-steel with pipes through which liquid nitrogen circulates. The whole of this system is suspended inside an evacuated tank V, fabricated from stainless-steel plate, which is in turn hung from a steel-framed bridge (figs. 4 and 5). As a safety measure, if a large leak occurred in the hydrogen chamber and the pressure inside the vacuum tank rose above atmospheric, the tank would be automatically connected to the steel sphere outside the bubble-chamber building, thus preventing a dangerous rise in the pressure of the hydrogen gas.

Expansion system and refrigerator

Attached to the top of the central chamber is an assembly of 48 pipes, in 4 banks of 12, leading to the expansion valves. The surface of the liquid hydrogen is in these tubes, some way outside the chamber, and at the level of the liquid/vapour surface there are heat exchangers through which liquid hydrogen is circulated to carry off the heat produced during operation as well as that conducted along the pipes from outside the vacuum tank.



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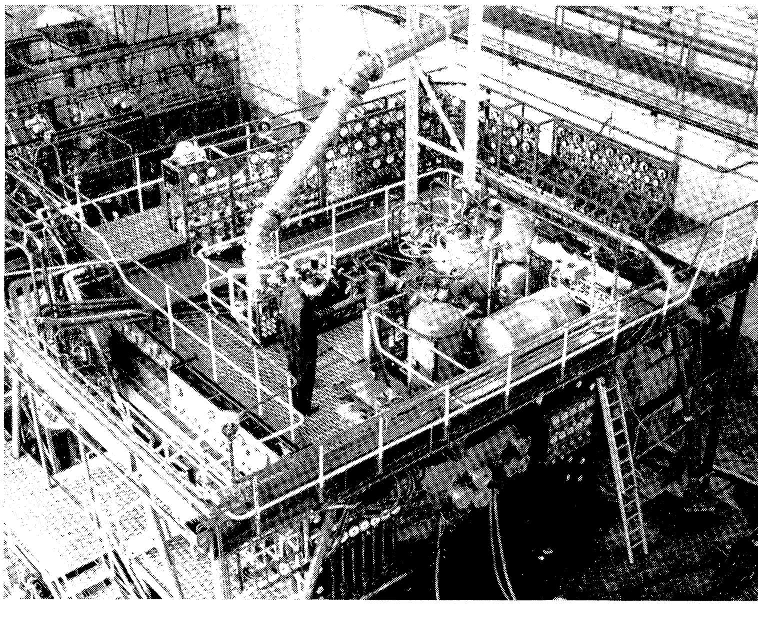
4. **The bridge from which the chamber is suspended, seen here being lifted into the East bubble-chamber building at CERN after its arrival, also came from England in one piece. Behind it can be seen the top of the magnet.**



CERN/PI 183.10.63

5. **This picture shows the bridge after installation of all the equipment. Grouped together in the foreground are components of the expansion system, the horizontal drum being the low-pressure tank to which the chamber is connected for expansion and the vertical drum the high-pressure tank to which it is connected for recompression. Between expansions the pressures in these tanks are readjusted by means of compressors. Valves and gauges around the edge of the platform control and monitor the various pressure and vacuum circuits of the chamber and cooling systems. Underneath, six of the nine light sources can be seen mounted on the outside of the vacuum tank.**

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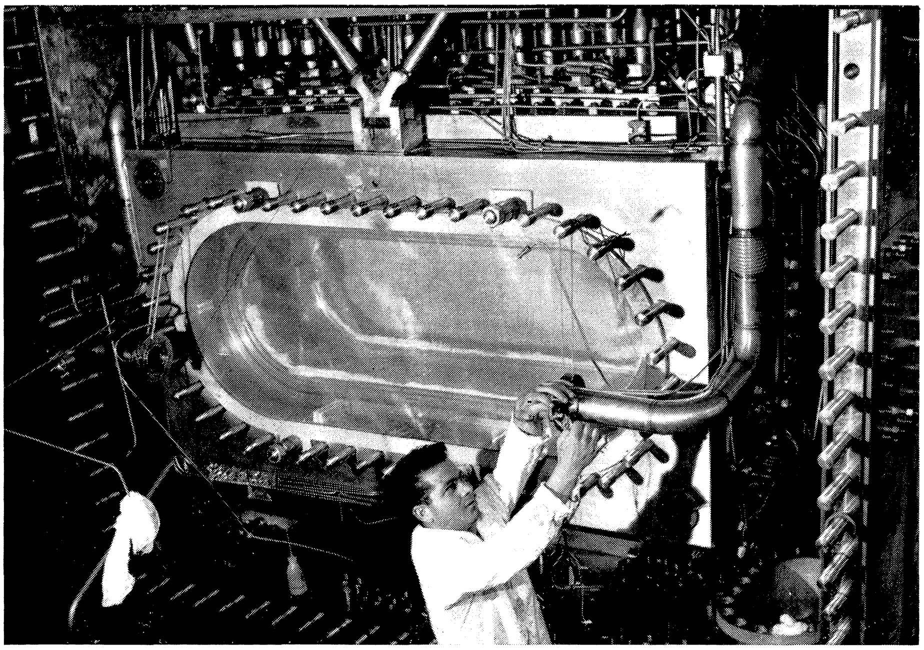
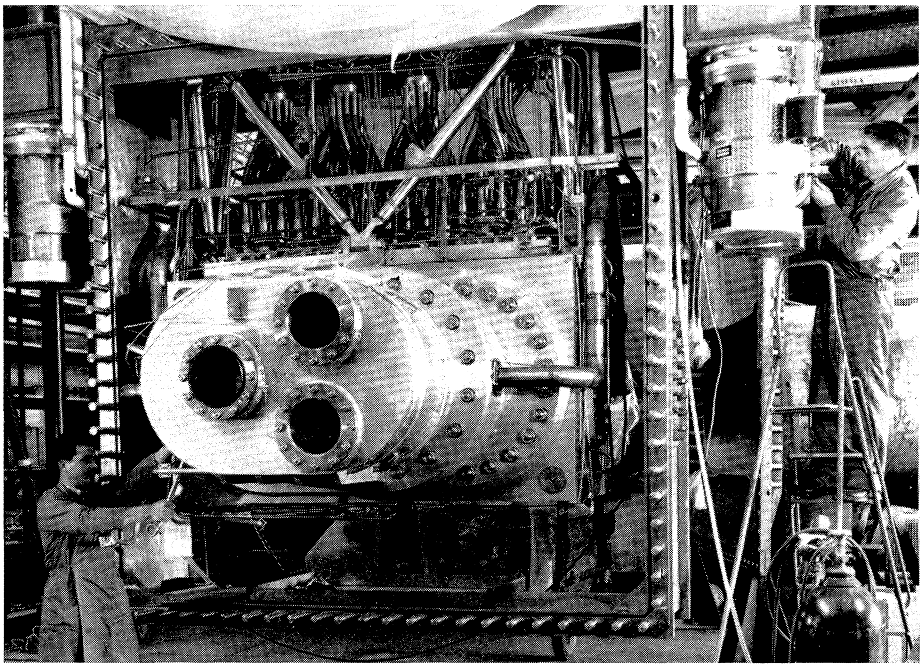
* The figure of £ 1 million (12 million Swiss francs) quoted in the July issue of CERN COURIER (p. 86) was to some extent misleading. It should have been made clear that, besides the cost of the chamber (£ 425 000, or 5.1 million Sw. fr.) and film-analysis equipment (£ 275 000, or 3.3 million Sw. fr.), this figure included £ 300 000 (3.6 million Sw. fr.) for operating expenditure and certain laboratory and equipment costs not specific to the chamber.



CERN/PI 150.7.63

6. The central chamber body, suspended inside the frame of the outer vacuum tank, photographed while the bubble chamber was being dismantled for inspection after its arrival at CERN. The shape of the optical glass windows (the apertures for which are temporarily covered with transparent film) and the volume to contain the liquid hydrogen can be clearly seen. The pipes on either side are part of the safety system that allows the hydrogen to boil off into an external container in case of emergency.



CERN/PI 45.6.63

7. The chamber with the hydrogen shield in place over the window. The disposition of the cameras can be inferred from the arrangement of the ports in the shield. Clearly visible here also are the struts by which the chamber is suspended from the roof of the vacuum tank, as well as the four groups of expansion pipes. On either side of the tank are the vacuum pumps : with the outer covers in position the space surrounding the inner chamber assembly is evacuated so as to reduce considerably the transfer of heat from the surroundings to the liquid hydrogen, in the same way as cold drinks are kept cool in a thermos flask.

When the bubble chamber is set up for operation, the liquid hydrogen in the chamber is at a temperature of -246° C. This is 7° C above its normal boiling point, but it does not boil because the pressure of the gas above is kept at about 6.3 kg/cm^2 (just over 6 times atmospheric pressure). Opening the expansion valve reduces this pressure rapidly to about 2.8 kg/cm^2, raising the level of the liquid in the tubes and putting it into a superheated condition. Bubbles form immediately along the paths of any ionizing particles that then pass through the hydrogen : the liquid volume is photographed and the pressure rapidly increased again before further boiling occurs. This cycle is repeated at a suitable rate to match the pulsing of the accelerator. The length of each of the expansion tubes (seen in figs. 2 and 7) is exactly the same, so that the pressure is released and reapplied uniformly over the surface of the liquid, avoiding turbulence and enabling a high rate of cycling to be achieved.

The chamber has its own refrigeration system, employing three independent circuits. One of these circulates liquid hydrogen through the heat-exchangers in the expansion tubes, as mentioned above; the other two circulate it through channels in the chamber body. The main volume of hydrogen in the chamber does not pass through the refrigerator but remains in liquid form because of the low temperature at which it is kept.

Photography, magnet and control

The liquid volume is uniformly illuminated from outside the vacuum tank by means of nine flash-tube light sources, arranged in groups of three, each group having its own triplet condensor lens. Light scattered from the bubbles forming the tracks renders them visible and enables them to be photographed by means of three cameras arranged in a stereoscopic viewing system. The cameras use unperforated 35-mm film, with the longer dimension of the chamber imaged along the length of the film. Both the light sources and the cameras are operated automatically at the correct part of the expansion cycle.

Surrounding the whole bubble chamber is an electromagnet, weighing 300 tons and giving a uniform field of nearly 15 000 gauss. The presence of this field causes the particles to follow curved paths inside the chamber and thus provides a means of measuring their momentum. The magnet is in two halves, and is mounted on some 400 ball castors running on hardened steel sheets, allowing it to be moved when necessary. Vertical adjustment is made by means of a hydraulic jacking system.

Normally the bubble chamber is operated remotely from a nearby control room, which at CERN is in an annexe to the main bubble-chamber building. This contains all the necessary controls, meters and other indicators for the vacuum pumps, refrigeration circuits, expansion system, flash tubes, cameras, etc, and also an alarm panel indicating any serious malfunctioning of the chamber. All the electronic circuits for the correct operation of the expansion cycle are also installed there.

Hydrogen safety

To guard against the possibility of fire or explosion, the electrical circuits in the vicinity of the chamber (that is, in the bubble-chamber building) have to be either ' intrinsically safe ' or fully enclosed in a nitrogen atmosphere. In the first case, any possible spark would be certain to have insufficient energy to be dangerous, in the second a spark would be effectively insulated from any hydrogen leakage. Where neither of these alternatives is possible, other means of operation have to be used, and it is for this reason that the two overhead cranes in the bubble-chamber building at CERN are operated by compressed air. When the chamber contains hydrogen, strict precautions have to be observed: no smoking or use of naked flames of any kind and no operations that might cause sparks ; beryllium-copper instead of steel tools must be used, for instance. Hydrogen detectors are placed at appropriate points in the building and if the hydrogen concentration in the atmosphere rises above a certain small limit, the extractor fans in the roof are automatically switched to full speed, the doors and windows in the building opened, and an alarm sounded.

Cooling down the chamber

The operation of filling the chamber with liquid hydrogen begins by evacuating all the air from the chamber body and hydrogen shields and replacing it by hydrogen gas at about 1 1/2 times atmospheric pressure, a procedure that is repeated several times to make quite sure that no air or other impurity remains. Since practically everything is solid at liquid-hydrogen temperatures, this is of particular importance to make sure that no deposits form later on the windows. Hydrogen gas, cooled in the refrigerator by means of liquid nitrogen, is then circulated through the cooling channels in the chamber, thus lowering its temperature. To avoid excessive strains in the glass windows the rate of cooling has first to be restricted to 4 or 5° C per hour, although as the chamber gets colder it becomes impossible anyway to cool it any faster. At about -175° C the window gaskets are pressurized, thus sealing the chamber and separating the gas in the inner volume from that in the hydrogen shields. At about this stage also, Joule-Thomson cooling of the hydrogen begins to become effective as it passes through the refrigerator nozzles. When the internal temperature has fallen to about -225° C the third refrigeration loop is set going, providing extra cooling in the expansion-tube system. It is here that the hydrogen first liquefies, falling as a fine rain into the chamber body. Eventually it forms a pool, which steadily grows in volume until the chamber is completely full of liquid. The whole process takes about 3 days.

The operating cycle

To ensure correct functioning of the chamber and to obtain the best quality photographs, accurate timing of each expansion is necessary, the process being fully automatic with a time scale measured in milliseconds (ms, or thousandths of a second). The basic signal comes from the proton synchrotron, at a fixed point in the acceleration cycle, about 30 ms before the particles in the o_2 beam arrive at the chamber. A few milliseconds after this signal the pilot valves begin to open, and these in turn open the main expansion valves, allowing the hydrogen to enter the expansion tank as explained in the caption to fig. 5. The hydrogen takes about 8 ms to expand fully and reach the desired superheated state, and at that point the beam particles arrive. They are detected by a scintillation counter, which provides a secondary timing signal, causing the flash tubes to be pulsed 1 1/2 ms afterwards. This allows just the right amount of growth of the bubbles that form the tracks before the photographs are taken. Immediately after the flash, the expansion valves are closed and the recompression ones opened, returning the hydrogen to its former state in about 10 ms. The film in the cameras is also wound one frame on. This cycle is repeated at a convenient rate, the maximum being just over 30 pulses per minute ●

Chamber (and abbreviation)	**British National 152-cm liquid-hydrogen bubble chamber (BNHBC or HBC 152)**
Design Laboratory	Universities of Birmingham, Liverpool and London (Imperial College of Science and Technology), and National Institute for Research in Nuclear Science (Rutherford High Energy Laboratory).
Operating Laboratory	N.I.R.N.S.
Date completed	November 1962
Approximate cost	£ 425 000 (without installations)
Dimensions of liquid volume	1520 mm long, 500 mm high, 450 mm deep
Strength of magnetic field	14 800 gauss
Filling liquid, and volume	liquid hydrogen ; 500 litres
Operating temperature	27° K (–246° C)
Upper operating pressure (absolute)	6.3 kg/cm^2
Sensitive time	2 milliseconds
No. of cycles possible per minute	30
No. of views photographed at once	3
Size of film	35 mm, unperforated
No. of operators required	teams of 6
Total weight of magnet and chamber assembly	350 tons
First operated at CERN	November 1963
No. of photos taken at CERN so far	275 000
Total length of film involved	90 km
No. of laboratories taking film for analysis	12
Representative experiments	high-energy kaon interaction with protons
Modifications envisaged	multiple-expansion system

This table summarizes some of the main characteristics of the 152-cm bubble chamber. It is similar in layout, and therefore supplementary, to the table published in CERN COURIER **in February 1963, (vol. 2, pp. 22-23) as part of the article entitled ' Spotlight on nucleons ', which summarized data for the four bubble chambers then in operation at CERN.**

BOOKS

Quantum field theory and the many body problem, by T. D. Schultz (New York, Gordon and Breach Science Publishers Inc., 1964 ; paper $ 3.95, cloth $ 6.95).

This short volume provides a very nice introduction to the more formal aspects of the many-body problem. The emphasis is on the use of quantum field theory and the diagrammatic approach. Nothing is assumed other than elementary quantum mechanics and the material is very clearly and logically developed.

The approach is through the one-particle and two-particle Green's functions. Their usefulness is explained and then the formalism is developed from the concept of second quantization up through the Dyson integral equations. The author is mainly concerned with the many-fermion system, and for applications treats the free-electron gas and the electron-phonon system at absolute zero ; a short chapter at the end gives an introduction to many-fermion systems at finite temperature.

One wishes that the author could have lengthened the book somewhat, with a few more detailed applications, for the mathematical apparatus developed is much too powerful for the problems treated. The one problem that is really handled in detail, the free-electron gas, is very well done, particularly the discussion of the dielectric constant and the polarization propagator. The section on the electron-phonon system, however, is too sketchy to be of any real value. However, this book is presented as the first volume of a series on the many-body problem, so one cannot be too critical on this point as presumably the applications are to come. The series has certainly been given an auspicious start, and this volume is to be recommended as an excellent introduction to the recent advances in the theory of many-particle systems, for which it gives ample references.

John Dirk Walecka

Quanta and reality, a symposium (London, Hutchinson and Co. Ltd., 1962 ; 18 s.), is neither a text-book for the expert nor exactly a popular exposition for the layman Falling somewhere between these two, it not only describes current ideas on the fundamental nature of matter — the duality of particles and waves, complementarity, the implications of the principle of indeterminancy — but also

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Last month at CERN (cont.)

or —1, and the overall value for a number of particles is obtained by multiplying the individual values together, so that it also is equal to + 1 (even) or — 1 (odd). CP invariance is then expressed by the fact that the overall value after the interaction must be the same as that before. In the case of kaons the K°_1, decaying into two pions, was assumed to be in an 'even' state whilst the K°_2, decaying into three particles, was in an 'odd' state and could therefore never decay into two pions. As described above, the new experimental results indicate either that CP invariance is not true in this interaction, so that there is nothing to stop such a decay, or that there is some force which can generate the K°_1 component from the K°_2 even in the absence of nearby matter.

Electron storage-ring model

During the first part of August the electron storage-ring model, CESAR, was shut down to allow the installation of new sextupole 'shims' together with two more sextupole correction magnets and other more minor changes. The current in the sextupole windings, and hence the effect of the magnets on the circulating electrons, can be varied from the control room, so that much closer control of the beam behaviour should be possible.

Since the last report in *CERN COURIER* (vol. 4, p. 34, March 1964) the vacuum system has been baked out and the pressure reduced to a value of around 2 x 10^{-9} torr. The stability of the Van de Graaff accelerator, used to provide the electrons for injection at an energy of 2 MeV, has also been improved. Mainly as a result of these developments some twenty or more beam pulses can regularly be 'stacked' in the ring, to give a circulating beam which has a 'half-life' of about 1 second, that is, its intensity (initially some 1 to 2 mA) decreases by a factor of two every second. (Under similar conditions, 25-GeV protons would circulate for many hours, because their higher mass and energy renders them less liable to deflexion by residual gas molecules.)

It will be recalled that electrons injected into the ring circulate on a more or less circular, closed orbit near its inner edge and are then moved on to an orbit of larger radius by the radiofrequency 'stacking' system, successive pulses being stacked on orbits of progressively decreasing radius. Many different 'programmes' for the sequence of operations of the radiofrequency system have been investigated by means of the 7090 computer and the most promising ones then tried out on CESAR itself.

A comprehensive series of measurements on the factor known as the 'Q' of the storage ring has also been carried out in the past few months. These measurements concern the betatron (side-to-side and up-and-down) oscillations of the electrons about the average orbit and are very important from the point of view of stability. To take one example, if Q has a value of 3, an electron disturbed slightly from its orbit (by an imperfection in the magnetic field, say) makes exactly three oscillations in one revolution and will then be subjected to exactly the same disturbance on its second time round. The amplitude of the oscillation will thus increase each time and the electron will soon be lost by hitting the vacuum-chamber wall or some other obstruction. A 'second-order resonance' effect arises with a half-integral Q (2.5, 3.5, etc.) when the electron finds itself in the same position relative to the disturbance after *two* complete revolutions. The value of Q is not the same for all positions in the ring, and in fact with the present adjustments to CESAR it increases steadily from the inner edge of the ring to the outer, having a value of about 2.75, for both horizontal and vertical oscillations, on the central orbit. In the measurements on the stacked beam, evidence was found for resonances up to perhaps the ninth order (only part of the beam being lost in such cases). It is hoped that, by using the correcting fields of the new sextupoles, the variation of Q with radius can be considerably decreased and the mean value so chosen that there is no possibility of exciting any of the lower (and more damaging) resonances. Moreover, since the prime purpose of the storage-ring model is to study the basic mechanisms involved in such processes, the Q may be varied so as to produce a desired range of values for further study of the behaviour of the beam under particular resonance conditions ●

delves further. In bringing forward some of the more philosophical and 'heretical' views about quantum mechanics, the book provides a fascinating glimpse of ideas and controversies which, though at present on the fringe of our work here at CERN, many conceivably bring about as complete a change in thought and actions as the quantum theory itself.

The book presents in written form a series of talks broadcast in the British Broadcasting Corporation's Third Programme in 1961. In his preface, the producer of the series says that its primary aim was to inquire into the layman's question ; 'what are electrons really like ? '. The unforeseen philosophical issues and questions of scientific 'strategy' that resulted from this apparently simple question show how big is the gap that now separates the layman from the theoretical physicist and the philosopher, although the clarity and enthusiasm of these expositions could do much to reduce it.

The contributions are introduced by Stephen Toulmin, director of the Nuffield Foundation Unit for the History of Ideas, who sets the scene by describing briefly how quantum physics came to replace classical physics, how a few physicists, notably Albert Einstein, could never reconcile themselves to the loss of 'causality' that this entailed, and how, in recent years, criticism of the 'orthodox' quantum theory has increased.

In the following two chapters, 'Particles and waves' and 'Waves and probability', the basic ideas of quantum theory are neatly explained by Prof. A.B. Pippard (Cambridge) and Prof. N. Kemmer (Edinburgh) respectively. Then Dr. Mary B. Hesse (Cambridge) provides a clear explanation of the use, and the disadvantages, of models in physical thought, and shows how the various interpretations of quantum physics are all tied to the 'wave' and 'particle' models in some way. The voice of heresy is introduced in the fourth chapter, which records a discussion between Prof. M.H.L. Pryce (Bristol), representing the orthodox view, and Prof. D. Bohm (London), who is one of the leading exponents of the need for a new 'sub-quantum' theory. Here, the main objections to the limitations of the present theory are brought out, and Prof. Bohm explains why he believes that new advances in our understanding will require fundamental changes of approach, such as the abandonment of our present ideas of space and time based essentially on the notion of cartesian co-ordinates.

A 'postscript', by N.R. Hanson, Professor of History and Logic of Science at Indiana University, recapitulates some of the arguments and goes some way further in discussing the kinds of difficulties now encountered by quantum theory in describing high-energy interactions.

Altogether, the book is entertaining on first reading, and contains much to make a second reading worth while. It should stimulate many people to enquire further into the subjects with which it deals.

A.G.H.

Chemical protection of the body against ionizing radiation, edited by Vera S. Balabukha (Oxford, Pergamon Press Ltd., 1963 ; 60 s.).

Research conducted by several authors in the U.S.S.R. (up to 1960) on chemical protection against ionizing-radiation injuries is reported in this volume.

The publication is divided into two parts : the first treats chemical compounds and radio-protective drugs ; the second examines substances which have the property of being able to remove specific isotopes (or groups of isotopes) from the body (particularly those that are present in the body due to fall-out from nuclear explosions).

As is well known, the radio-protective substances act only if they are administered a short time before irradiation takes place (prophylactic action) and only a small quantity of the drug can be administered. Also described in various parts of this book are the chemical and pharmacological characteristics of many radio-protective substances, as well as their modes of action at the endocellular level of biological systems (action on different intermediate metabolisms and on proteins). The authors mention particularly the compounds of the aminothiol series (molecules characterized by the presence of -SH and -NH_2 groups), their derivatives and the prophylactic efficiency of certain of their associations. Of great interest in this field are the studies on the variations of pharmacological activity of various molecules according to the relative positions of the active groups.

In my opinion, the most interesting aspect of this book is the consideration that has been given to the different hypotheses for the mechanism of the action of radio-protectors. Particular note can be made of that hypothesis which considers these substances as energy absorbers, indicating that the action of some protectors is not chemical but physical, with the protector entering into the intramolecular and intermolecular energy-transfer phenomena, especially at the level of the carbon chains in protein.

In the second part of the book, the methods of elimination of certain artificial radionuclides, for example ^{90}Sr, ^{91}Y, ^{210}Po, and ^{95}Zr, from contaminated organs are briefly examined. This problem, which has been created almost entirely by the 'nuclear era' has not yet been resolved and its importance to man is quite obvious.

Some studies are reported on the possibilities of breaking the linkages between very dangerous radioisotopes and blood or tissue proteins (in which the turn-over is very slow, similar to the case of ^{90}Sr in bone). For this purpose, well known complexing agents, such as ethylendiaminetetraacetic acid (EDTA), cyclohexanediaminetetraacetic acid (CDTA) and cyclopentanediaminetetraacetic acid (CPDTA), in the form of sodium and calcium salts are employed. These salts are capable of making strong bonds with the above-mentioned isotopes and thus extracting them from the tissues in which they were deposited. The elimination of the complexing compounds from the tissues represents the ultimate phase of internal decontamination.

By virtue of its highly specialized nature, this volume cannot recommend itself to the general interested reader, but it will, however, find a welcome amongst specialists in radiobiology and radio-chemistry.

Antonio Pasinetti

British painting ; a picture history, by John Woodward (London, Vista Books, Longacre Press Ltd., 1962 ; 42 s.).

Although British painting has effectively only four centuries of history, having virtually begun with the arrival of Hans Holbein (from Switzerland), its exponents in this limited time have been plentiful and prolific. Overshadowed by their more famous Continental contemporaries, and with few claims to originality of style, British painters are not so well known as they deserve to be. This book is a gallant attempt to do justice to the subject in the somewhat limited space of 160 pages, ambitiously including (as the publishers state) 250 illustrations covering the work of 200 artists.

Undaunted, but somewhat cramped, by this problem in logistics, Mr. Woodward has organized his presentation very well indeed. Schools, styles and fashions are skilfully delineated and accurately described. The usual hackneyed procession of familiar Holbeins, Reynolds, Constables, Pre-Raphaelites and Whistlers, resembling nothing so much as a bound volume of Edwardian calendars, has been carefully avoided. A distinctly refreshing approach is created by the deliberate choice of many lesser-known works of the masters. The text is succinct, and the captions are unusually effective.

On the other hand, the actual layout of the pictures suffers from overcrowding and is — perhaps in consequence — rather unimaginative. The black-and-white illustrations are of high quality, but the lack of colour is a serious drawback. Colour is, after all, fundamental to painting ; one suspects that the reaction of most artists to having their work on display in black and white would be violent. Whenever colour does appear, and there are only fifteen plates, it has the impact of an extra dimension. This effect tends to camouflage the relatively poor quality of the colour reproduction and printing.

However, this is not an expensive book. Most of the features adversely criticized stem from the exigencies of keeping down to a price. The binding is handsome, and the quality of paper and printing good. Within its limitations, it is an honest piece of work, and offers remarkably good value for money.

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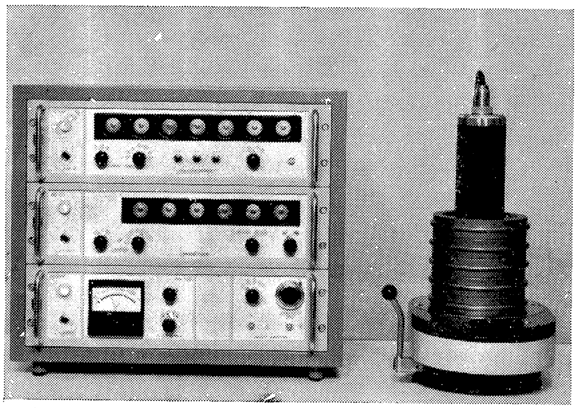

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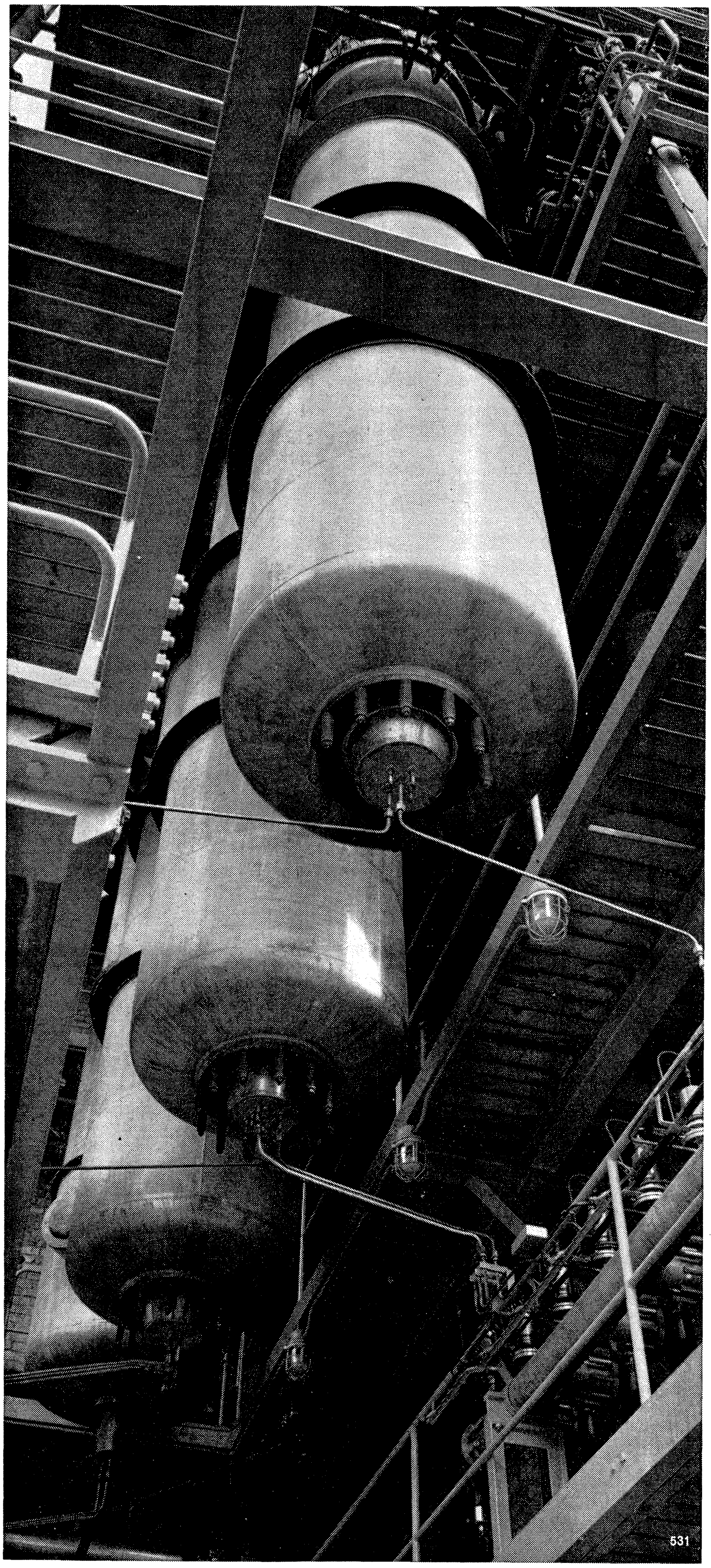

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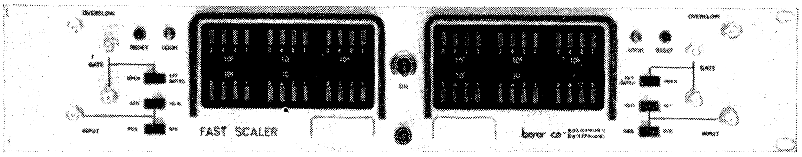

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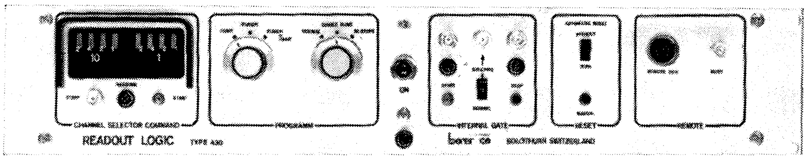

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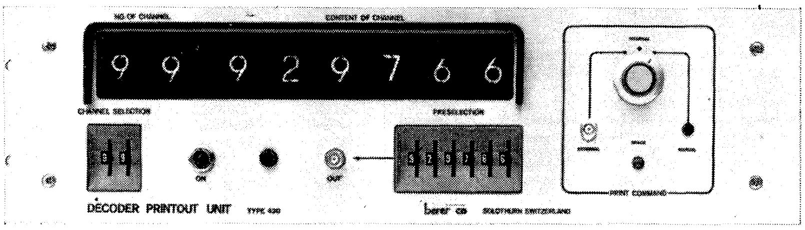

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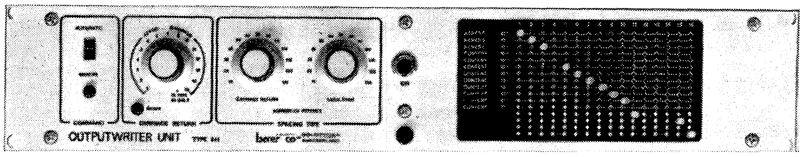

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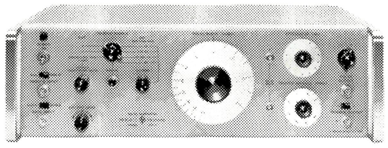

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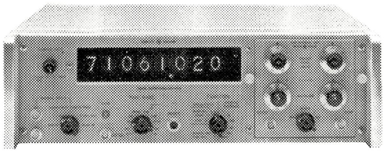

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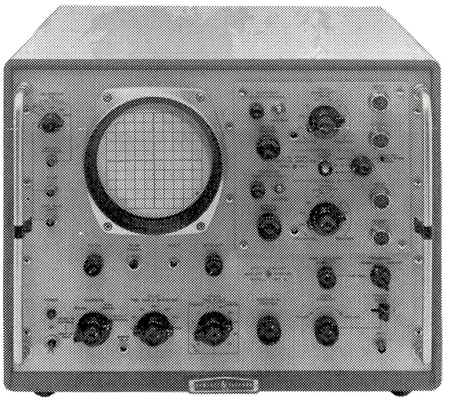

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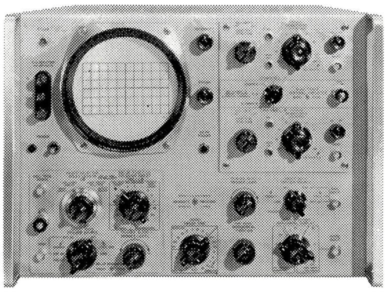

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