

BEBC Progress

doors of the Particle Zoo in an excellent article on 'the strongest force'. Particles are not as accessible as animals but it is possible to get across much of the fascination of particle physics.

Particles are not the exclusive property of high energy physicists. On the contrary, there exists almost a moral obligation to open the doors of the Zoo to the people who are paying for the research. But perhaps a more telling argument is one of self-interest.

There are indications of a widespread and growing disenchantment with science at present. The best documented measure of this is the rapid drift away from science among young people selecting the field for their further education. Science is losing its appeal. Another sensitive sign is the declining amount of space given to science topics by the newspapers. Editors are judging that science is of less and less interest to the public. Political decisions and budgets often reflect situations like this fairly rapidly.

Unless scientists are prepared to come out of the ivory tower onto the soapbox they may find too late that the foundations of the tower are crumbling.

In June 1967 the CERN Council approved the proposal to construct a large hydrogen bubble chamber for use at CERN. It became known as the large European Bubble Chamber (BEBC), the project being carried out jointly by the Federal Republic of Germany, France and CERN.

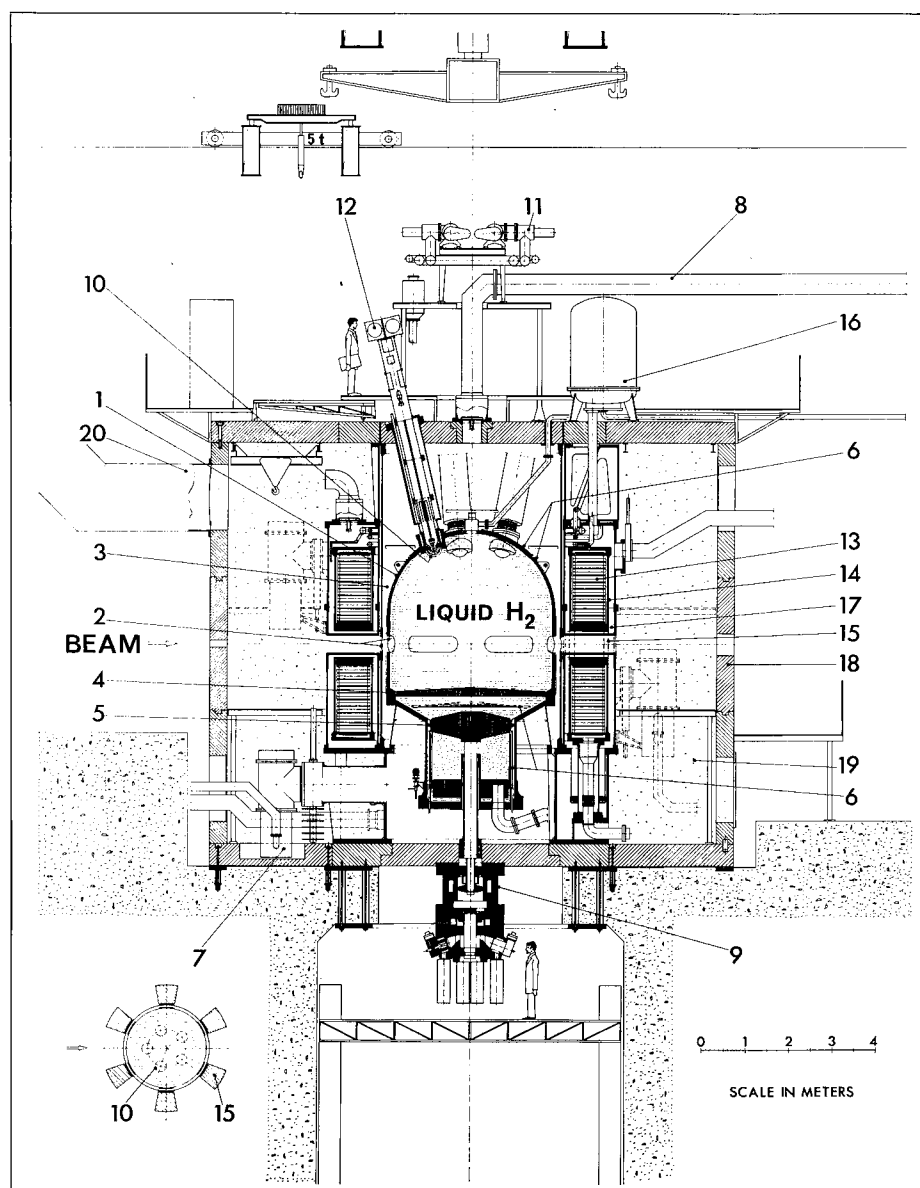
The initial proposal was for a 3.5 m diameter chamber having a volume of 30 m³ (20 m³ of 'useful' volume) with a superconducting magnet to produce a field of 35 kG. Later, certain minor changes were made to the design and it proved

possible to increase the diameter to 3.7 m, thereby giving a total volume of 33.5 m³ (21.5 m³ of useful volume).

For more than a year final design work was done and at the end of 1968 the main parameters were 'frozen'. Invitations to tender for the major components were sent to potential suppliers and the adjudication of contracts took place at the Finance Committee meetings on 4 February and 11 March. This seems therefore an appropriate time to up-date the information carried in the previous CERN

The final design of the 3.7 m d'hydrogen bubble chamber :

- 1) chamber body
- 2) beam windows
- 3) vacuum tank
- 4) separation disc
- 5) piston
- 6) exchangers
- 7) secondary vacuum pumps
- 8) vacuum chamber vent
- 9) expansion motor
- 10) fish eye
- 11) fish eye pumps
- 12) film magazines
- 13) superconducting coils
- 14) cryostats
- 15) coil spacers
- 16) helium buffer volume
- 17) magnet vacuum enclosure
- 18) magnetic shield
- 19) nitrogen
- 20) magnetic shield vent



Samples of superconducting strip

— Sample	1	2a	2b	3	4	5	6
— Stabilizer	Al+Cu	Al+Cu	Cu	Cu	Cu	Cu	Cu
— Cross-section of superconductor (mm ²)	0.059	0.035	0.03	0.032	0.09	0.44	2
— Number of strands	79	260	260	224	116	54	18
— Weight of superconductor (g/m)	28	51	42	43	67	156	235
— Current density in superconductor at nominal current (A/mm ²)	1500	780	730	790	550	240	160
— Cross-section of stabilizer (mm ²)	130	160	157	177	172	159	143
— Resistance of stabilizer in zero field and no stress (10 ⁻⁸ Ω cm)	0.6	1	1	1.16	0.6	0.9	1.33
— Weight of conductor (g/m)	673	840	1600	1620	1600	1580	1515
— Total length of conductor (km)	52.5	52.5	65.5	65.5	65.5	65.5	65.5
— Length of strip without welds (m)	1560	1560	1560	780	180	130	200
— Critical current in parallel field of 51 kG and perpendicular field of 38 kG (kA)	8	8	6.45	6.45	6.45	6.45	6.45

1.	CGE	Centre de Recherches de la Compagnie Générale d'Electricité (F.)
2a, 2b.	CFTH	Compagnie Française Thomson-Houston (France)
3.	SSW	Siemens-Schuckert-Werke (Federal Republic of Germany)
4.	BBC	Brown-Boveri (Switzerland)
5.	IMI	Imperial Metal Industries (United Kingdom)
6.	SUP	Norton International Supercon Division (USA)

COURIER article (the project was described in detail in vol. 7, page 143) and to mention the work carried out using Braracourcix (the magnet test assembly) and the 1 m bubble chamber model.

To recap very briefly the main features of the design: The chamber itself is a vertical cylinder 3.7 m in diameter and about 2 m high with a rounded dome on top where four cameras look through fish-eye lenses. At the bottom of the chamber is the piston and expansion system which produce the volume changes needed for the formation of bubbles in the tracks of charged particles.

The chamber will be filled with 33.5 m³ of liquid hydrogen and surrounded by a vacuum tank. Outside this is the superconducting coil to give a magnetic field of 35 kG at the centre of the chamber. It is immersed in a cryostat containing liquid helium to achieve the very low temperature at which the coil is superconducting. Surrounding this whole assembly is a magnetic screen which shields the high stray magnetic field coming from the coil.

Design Changes

One of the important changes concerns the vacuum tank which surrounds the bubble chamber. It has been extended at the top so that it forms a cylinder reaching to the magnetic screen on the floor and ceiling. This has resulted in more convenient access to the dome of the chamber and in fewer apertures into the tank.

Another change is the decision not to ventilate the space between the magnetic screen and the vacuum tank, but to fill it with nitrogen which further helps to reduce

the explosion hazard. An operator, specially equipped, can enter the space for exceptional work.

A third change concerns the emergency evacuation system for the 33 m³ of liquid hydrogen in the chamber. Part of the liquid will be heated and fed into inflatable balloons.

A hybrid solution has been selected for the refrigeration systems rather than having two separate classical refrigerators — one for the hydrogen of the chamber, the other for the helium of the magnet. Instead, the helium system has been increased in capacity and the hydrogen cooling will be achieved in a heat exchanger through which liquid helium is circulated. This novel solution will probably cost less than the classical solution and has the particular advantage that the hydrogen plant is reduced in size and complexity which further reduces the risk of explosion.

Contracts

Four major contracts have been awarded by the Finance Committee.

1. Superconducting strip

65 km of superconductor is required to wind the coil. Superconducting filaments of niobium-titanium alloy are embedded in a copper strip (61 X 3 mm²) to carry a current of about 7000 A.

The contract is being divided between Siemens (Federal Republic of Germany) and Thomson-Houston (France); the characteristics of the strip supplied by each of the manufacturers being identical.

The total value of the contract is 7.7 million Swiss Francs (3.65 MSF to each firm) and delivery will be spread over the period September 1969 to June 1970.

Left: A table of parameters of the seven types of superconducting strip considered for the magnet of the 3.7 m chamber.
Right: A photograph of the samples showing the disposition of the superconducting filaments in the stabilizer.

2. Stainless steel vessels

This contract concerns the supply of the various tanks of the chamber involving 350 tons of steel. It has been divided into two parts

- the body of the bubble-chamber and its vacuum tank
- the cryostats for the superconducting coils and their vacuum tank.

The tanks measure between 3.7 m and 6.5 m diameter and are up to a height of 5 m. The tolerances on machining and surface finish are particularly stringent, to ensure that the tanks are leak-proof with liquid hydrogen and helium. Welding of thick stainless-steel plates presents some difficulty to manufacturers. At low temperature, the weld seam must have a high mechanical strength and good ductility in order to withstand the stresses which arise from the pulsing of the chamber. Furthermore, the maximum ferrite content of the welds has to be restricted to less than 2% to avoid perturbing the magnetic field.

A contract worth 2.7 MSF for the chamber and vacuum tank has been awarded to Thyssen (Federal Republic of Germany) and another worth 3.3 MSF for the cryostats and vacuum tank, to Alsthom-Neyrpic (France). Delivery will be phased between April and November 1970.

The welding processes proposed by these firms are not identical: Thyssen's is automated whereas Alsthom-Neyrpic's is manual. In both processes the welds are subjected to an on-line X-ray or ultrasonic inspection. Alsthom-Neyrpic is at present developing a process for welding very thick components by electron bombardment. This is much faster (1 m per minute, compared with 1 m per 25 hours) and nearer than the manual process but calls for considerable accuracy when machining components before the weld. This process will be used if perfected in time.

3. Refrigeration plant

The plant is required for:

- purification and liquefaction of the helium and the hydrogen for the magnet and the chamber
- cool-down of the magnet and chamber from room temperature to operating temperature
- steady-state refrigeration

— warm-up of the chamber and magnet.

The contract has been awarded to Sulzer (Switzerland) at a price of 5.02 MSF. The plant is to be ready for operation by 31 October 1970.

4. Magnetic shield

The magnetic shield consists of nearly 2000 tons of cast steel to contain the stray field of the superconducting coil.

The contract was awarded to CAFL (France) for 3.74 MSF. Delivery will be phased between January 1970 and February 1971.

Superconductor tests

The superconducting magnet for the chamber is the largest of its type yet to be built, both in magnetic field intensity and in size. The coil has no iron core and will produce a field of 35 kG in the chamber. (A superconducting magnet of similar size with an iron core, producing a field of 20 kG, is now being brought into operation at Argonne.)

A conventional magnet could have been used for the chamber but power considerations have been the determining factor in the selection of a superconducting magnet. A conventional magnet would have required 57 MW of power (twice CERN's present electricity consumption!) including 1.2 MW for cooling; the superconducting magnet will need less than 1 MW, almost entirely for cooling since losses in the superconductor, and its connections and leads, will be only 200 W.

The comparison of 56 MW against 200 W speaks for itself. Although a superconducting coil is more expensive to manufacture, this is soon offset by the reduced consumption; 5 000 hours operation of a conventional magnet would cost 17 MSF, whereas the superconducting magnet will cost 0.6 MSF.

In May 1968, the first specification for the strip was issued.

In the light of the replies, received in July 1968, it was decided to reduce the cross-section from 88 X 3 mm to 61 X 3 mm to lessen the coil-winding problems. A second invitation to tender was sent in October 1968. CERN received seven samples of superconducting strip two of which were aluminium-stabilized and the remainder copper-stabilized. Most of these sam-

ples were tested at CERN in the 60 kG BRARACOURCIX magnet test assembly (see CERN COURIER vol. 8, page 23). The table on page 64 gives the basic details of the seven samples considered.

Important criteria for selection of the strip were:

- 1) a minimum number of welds per 'pancake' i.e. per 1600 m of strip wound into a flat coil;
- 2) the Nb/Ti alloy must be isotropic as far as the magnetic field was concerned (wires with a circular cross-section were best in this respect);
- 3) the bond between conductor and copper must be good;
- 4) the mechanical strength must be high. (Owing to the magnetic field, the forces on each turn of the pancake winding are very great. The tensile load on the strip at the most highly stressed points is about 10 kg/mm². The vertical force of attraction between the two halves of the coil will be 9 000 tons.)
- 5) cost

The winding configuration has been based particularly on studies done at Brookhaven on which CERN did some further research, and on research done by two European firms, l'Air Liquide (France) and British Oxygen (UK). These studies were concerned, in particular, with the influence of the winding configuration on the dissipation of heat.

The development of satisfactory superconducting strip has required some major research in European industry and CERN has benefited from excellent cooperation with the firms who responded to the challenge of the specification.

The 1 m model

Experiments with the 1 m model of the large bubble chamber, which has many of the features of the final design (except for the magnet) have been under way since June 1968 (see CERN COURIER, vol. 8, page 129).

A great deal of information has been obtained, most of the proposed methods have been confirmed and, in a few cases, better methods have been found. A rapid survey of the various investigations follows: *Use of Scotchlite*: all doubts concerning

the clarity of particle tracks when Scotchlite is used with a considerable depth of hydrogen have been removed.

Bubble formation: photography against a bright background means that pictures cannot be taken until the bubbles have reached a size of at least 600 μ as against about 300 μ in conventional chambers. The longer growth time increases the likelihood of drift and prejudices the accuracy of measurement. However, by operating with a lower hydrogen temperature (25° K rather than the normal 26° K) the rate of bubble formation is increased.

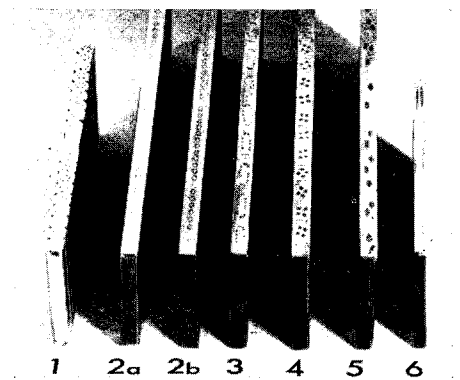
Most of the photographs in the model were taken at 25° K and the period before bubbles measuring 600 μ were obtained was 2 to 3 ms.

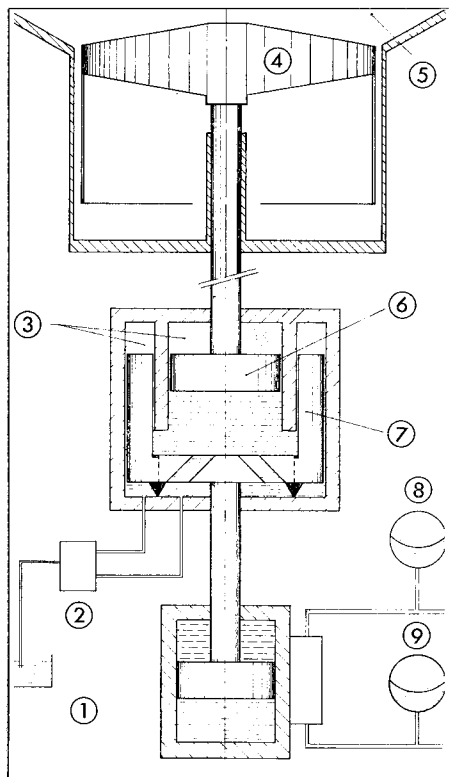
Refrigeration: operation at these low temperatures was made possible because of the excellent operation of the heat exchangers, of the configuration of the chamber, and of the proper sealing of the piston which reduced the formation of parasitic bubbles. The experiments on the model show that it will be possible to operate the large chamber with a reasonable refrigerating capacity, even with a relatively slow expansion (40 ms or more) and a high repetition rate (2 Hz or more). *Turbulence*: thermal properties were studied using measurements of the deflection of a laser beam with thermal gradients in the model, and photographs of the laser beam and of a straight line on the bottom of the chamber.

It was noted that thermal turbulence was very slight during the expansion, and appeared only after 40 ms (well after the photograph would be taken).

Fish-eyes: after a long series of static tests, the hemispherical windows (fish-eyes) were fitted to the chamber for the first time. The joints, secured with an epoxy/aluminium adhesive, remained perfectly sealed and this simple method will be adopted for the large chamber.

There was slight difficulty from a minor leak in the external piping which allowed traces of nitrogen to enter. These condensed on the inner surface of the fish-eye giving rise to some parasitic diffusion of the light. This type of deposition on the fish-eyes is one of the occupational hazards of those working with bubble chambers. It is usually necessary to





Schematic diagram of the expansion system :

1. Energy make-up system
2. Lock up
3. Gas springs
4. Cold piston
5. Chamber
6. Driving piston
7. Counter-weight
8. Accumulator (high pressure)
9. Accumulator (low pressure)

evacuate the chamber and heat it to get rid of the deposit.

Advantage was taken of this incident to try a method of fast cleaning. The fish-eyes are connected to a vacuum system separate from that of the chamber. It is thus possible to fill the space between the fish-eyes with gaseous helium without breaking the main vacuum and without evacuating the chamber. All that is necessary is to lower the level of the hydrogen to just below the fish-eye so that a current of warm helium can evaporate off the condensed nitrogen. The operation took fifteen minutes at the most.

Other systems: experiments with the model have also confirmed the usefulness of mounting the piston at the bottom, and have served to perfect the main components of the expansion, monitoring and remote-control systems.

Finally, experiments on the model have helped to familiarize the team with some of the novel features of the large chamber; the experience gained will be invaluable when the 3.7 m is brought into operation.

Expansion system

Experiments on a reduced-scale prototype of the expansion system will begin in May. They will serve in particular to test the features of the system which differ from those in use on the currently operating chambers.

The dynamic forces generated by the movement of the expansion system of a bubble chamber at each pulse can cause considerable vibration because the masses involved (piston and liquid) can be con-

siderable and because the cycling times are very short (of the order of 40 ms). In the 3.7 m chamber, the moving masses amount to close on two tons, added to which the stroke of the piston is 145 mm to produce the required 1% change in volume of the liquid hydrogen, with a pulse duration of about 40 ms. This will produce a dynamic force of 345 t.

Special measures have to be taken to reduce the effect of forces of this magnitude. A system, rather similar to that in a recoilless cannon, will be used. It involves using a counter-weight equal in mass to the piston, which is hydraulically connected to the piston via a volume of oil so that it follows any movement of the piston travelling parallel to it in the opposite direction. There is then no dynamic force due to the piston-counter-weight system transmitted to the surroundings. The remaining dynamic force will be about 140 t, due to the movement of the mass of liquid inside the chamber itself. This is an acceptable figure.

The hydraulic equipment, many parts of which are being supplied by outside industry, will be assembled at CERN. The main components are scheduled for delivery in April 1970 and testing will begin towards the end of that year.

Construction

Construction of the buildings for the BEBC is well advanced. The connecting hall between the large West experimental hall and the bubble chamber building itself is almost complete and will be used as from the beginning of May for the installation of the equipment to wind the coils of the superconducting magnet. The office and laboratory building is scheduled for completion in July so that the group involved in the project can move across to accommodation near the bubble chamber building ready to work on components as they arrive. Construction of the bubble chamber building and the buildings to house the refrigeration equipment is in progress.

The chamber is scheduled to come into operation in 1971.

CERN News

Council meeting cancelled

The Council meeting scheduled for 12, 13 March was cancelled. It has proved necessary to re-organize the programme for the outstanding decisions on the 300 GeV project. Since the decisions have to be rephased there was no need for the special Council meeting in March. The next Council meeting will take place as usual in June (19, 20).

2 m double pulsing

On 13 March the 2 m hydrogen bubble chamber was operated twice during a single cycle of the proton synchrotron for the first time. This new possibility in the operation of the 2 m chamber will enable some experiments to collect their data more quickly.

9 GeV pions were used in the tests. They were produced by 15 GeV protons from the synchrotron, taking one proton bunch for each bubble chamber pulse and after feeding the 2 m bubble chamber, the synchrotron energy was raised further to supply particles to other experiments (see diagram). Following the modifications which have been carried out on the chamber and its ancillary units, it could pulse four times per accelerator cycle but, with the present operating conditions, this would mean that the bubble chamber would be the sole user of the machine.

Preparation of the chamber for double pulsing began in June 1967 and the necessary modifications in the chamber itself took place during the 1968 annual shutdown of the synchrotron. Other modifi-

