Rutherford Laboratory
Technical leaflet

C2.1

THE 1.5 METRE CRYOGENIC BUBBLE CHAMBER

A bubble chamber is an instrument for the visual observation of the paths taken by electrically charged particles. It is used principally to study the nuclear interactions which occur when incoming particles collide with the individual atomic nuclei of the Chamber liquid. Often these interactions result in the formation of numerous secondary particles which themselves suffer further collisions or decay spontaneously into other particles after an extremely short time. Liquid hydrogen is very suitable as a chamber working fluid because the hydrogen atom has the simplest nucleus of all, a single proton. The incoming particles are all of one kind, having already been separated before arrival at the bubble chamber. Depending on the particular experiment K mesons or π mesons either positively or negatively charged, protons, or other particles can be used. Thus it is possible to study the interaction of one type of particle of known energy with target protons in a hydrogen chamber. The chambers can also operate filled with deuterium (heavy hydrogen) whose atomic nuclei each consist of one proton and one neutron. Using this filling nuclear interactions involving target neutrons can also be studied.

In a recent extension of the technique, a target containing liquid hydrogen or deuterium is mounted in the chamber which is filled with a neon-hydrogen mixture. Beam particles interact in the target and gamma rays produced in the interaction can be detected by observing the electron/positron pairs formed in the dense mixture. This internal target technique is described in detail in Technical Leaflet C1.

The liquid in the chamber is normally maintained under a pressure sufficient to prevent boiling. The pressure applied to the chamber is suddenly decreased resulting in a superheated condition during which the energy deposited by the passage of ionising particles through the chamber initiates boiling. The path along which the particle passed is traced in the liquid of the chamber as a streamer of fine bubbles. About one thousandth part of a second after the passage of the particle, the bubbles are big enough to photograph using flash illuminations. After the photograph has been taken, mass boiling of the superheated liquid is prevented by a rapid re-application of pressure to the chamber, returning it to its initial state.

The chamber body which contains 500 litres of liquid has internal dimensions 150 cm along the beam direction 45 cm wide and 50 cm high. The chamber, machined from a single aluminium alloy forging, is closed on either side by glass windows 16 cm thick sealed by inflatable stainless steel gaskets able to allow for the differential contraction between the glass and body on cooling to liquid hydrogen temperature -246°C. The windows are protected by hydrogen shields fabricated from the same aluminium alloy as the chamber body. The top of the chamber is closed by an assembly of 48 pipes leading to the gas expansion system. This whole unit is hung inside a stainless steel vacuum tank which in turn is hung from a steel support frame on which are also mounted all the local control panels and operating equipment.

The chamber is maintained at its operating temperature of about -246°C by a refrigerator which circulates liquid hydrogen through cooling loops. The refrigerator has a capacity of 3 kilowatts at -250°C and uses liquid nitrogen to precool high pressure hydrogen gas before it undergoes a Joule-Thomson expansion which results in partial liquefaction. Three independent cooling loops are used, two controlling the temperature of the chamber body and a third supplying heat exchangers at the liquid surface at the lower end of the 48 pipes of the expansion system.

In typical hydrogen operation, the expansion system maintains the chamber pressure at about 6 Atmospheres and lowers it to near 2.5 Atmospheres momentarily during each expansion. The expansion cycle is repeated every two seconds.

An electromagnet surrounds the chamber, the soft iron yoke weighing 240 tons and the two coils 30 tons each. A uniform field of 12½ kilogauss is attained when a D.C. power of 4 megawatts is dissipated. Cooling of the coils is provided by passing 400 gallons of water per minute through the hollow conductors. The magnet is in two halves so it can be moved to give access to the chamber and is mounted on some 400 ball castors running on an armour plate steel floor.

The chamber is operated from a nearby control room containing all the necessary controls, and indicators for operating the refrigeration circuits, expansion system, flash tubes, cameras etc. Alarm panels indicate malfunctioning of the chamber. The compressors and vacuum pumps for the refrigerator and expansion system are in a separate building, adjacent to which the liquid nitrogen storage vessels and gaseous hydrogen storage cylinders are sited.

Nimrod Division.

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