BUBBLE CHAMBER REPORT DESIGN AND OPERATION OF A FAST CYCLING LIQUID HYDROGEN BUBBLE CHAMBER (*)

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(Presented by H. Blumenfeld)

INTRODUCTION

The 3 BeV Princeton-Pennsylvania Proton Accelerator operates at 19 pulses per second. We planned to build a liquid hydrogen bubble chamber which could take full advantage of this repetition rate (1).

Such a chamber offers several distinct types of problems:

— We have to provide a mechanism for producing suitable tracks, 19 times per second, and for eliminating the bubbles during the subsequent interval.

— We require auxiliary equipment, in particular a camera and a flash lamp, to operate at this repetition rate, in case we want to accumulate random pictures in an efficient manner.

— We planned from the beginning to use the chamber with selective detectors, so that the light can be triggered by a favorable signature.

a) Chamber

The mechanical problems associated with a fast cycling chamber, and the problems of counter control, induced us to choose a chamber of rather modest proportions, namely a cylindrical chamber with a 30 liter volume, 15 inches in diameter and 10 inches deep. To make the chamber suitable for fast cycling, we had the following requirements: produce few bubbles and get rid of them as fast as possible. To satisfy the first condition we avoided all filling or sensing apertures below the piston rings. We sacrificed a pressure sensor in the chamber liquid, and we made the piston retractable.

The chamber body was machined from an aluminum forging, 6061-T6. The beam entrance, and exit sides, consist of 3/16" aluminum. The thin exit port is desirable for certain types of counter control. Provisions were made for separate cooling of the window seals.

The windows are held in place with stainless steel clamp rings, (302 Stainless Steel, Ladish Co.) work hardened to 100,000 psi yield strength, which act as springs. We seal the windows and the chamber with a 0.100" copper ring plated with 0.005" of solder on the inside seal and a 99% indium, 1% silver, ring for the outside seal, with a pump out in between.

b) Cooling column and temperature control

The chamber is cooled near the piston rings. This section is made of an O.F.H.C. high purity copper forging. The cooling hydrogen is circulated around the outside of the copper forging. The cooling capacity is estimated at 1000 watts. The temperature is sensed by a H_2 vapor pressure thermometer, a copper tube soldered around the copper forging, which responds with a time constant of the order of 1 second. The temperature is controlled by means of a 1/10 watt carbon resistor epoxied to the copper forging. This resistor in turn, through a feedback circuit, operates a linear valve which regulates the rate of escape of the boil-off gas from the heat exchanger. This system controls the chamber temperature to $\pm 1/10°$ K. An independent check on the chamber temperature is provided by a linear variable differential transformer (Schaevitz engineering), which records the piston equilibrium position. This position is very sensitive to the chamber temperature. The reservoir providing the hydrogen for the heat exchanger has a 10 liter capacity. Carbon resistors sense the hydrogen level. The reservoir is fed intermittently from a 1000 liter H_2 dewar, to which it is connected by means of a 50 foot long transfer line. The transfer line consists of a 1/4" I.D. monel line, joined by means of

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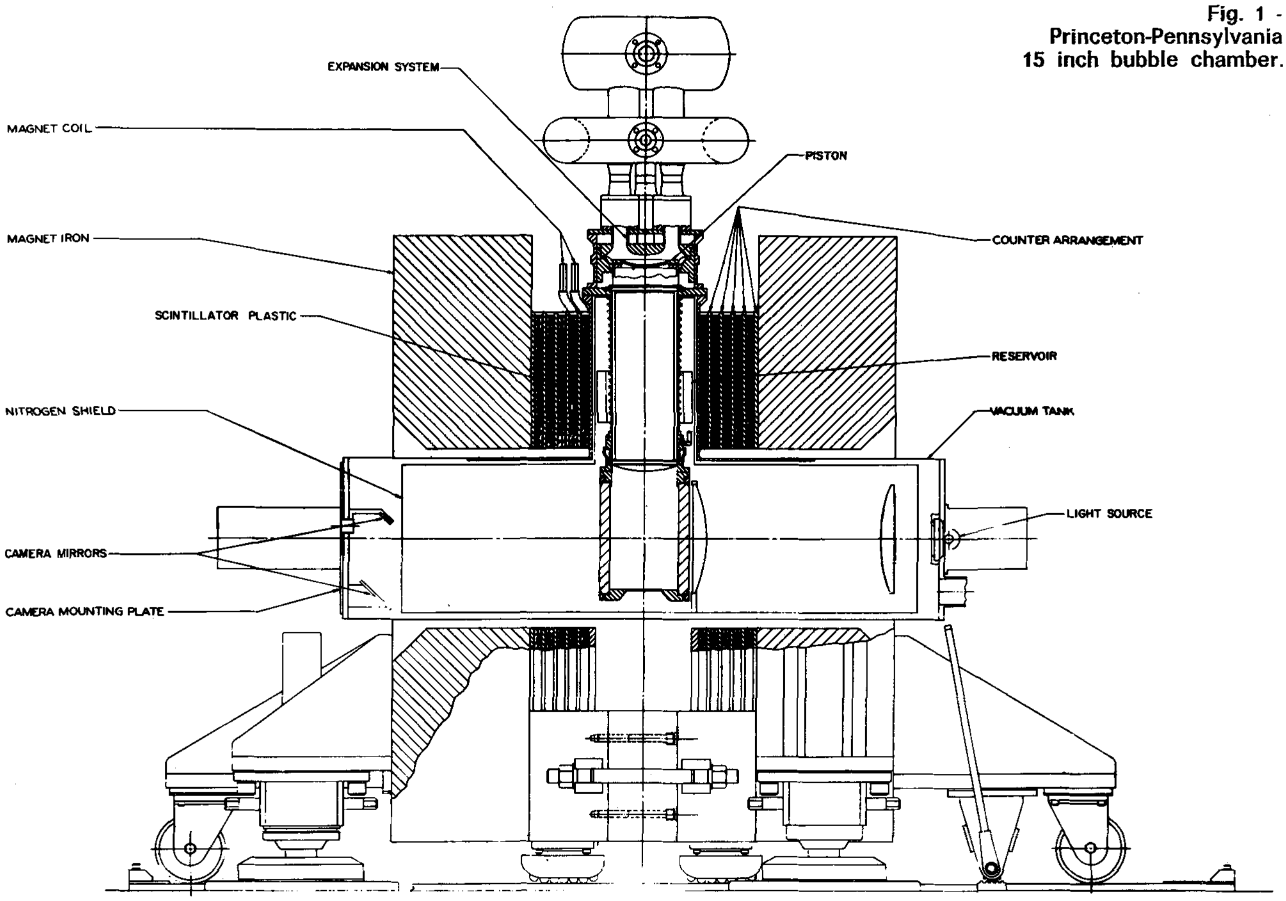

Fig. 1 - Princeton-Pennsylvania 15 inch bubble chamber.

swagelock fittings, and a 2" O.D. copper tube. The end sections are made of flexible bellows.

c) Piston and expansion system

The desirable goal is a short expansion cycle. The piston is a 8 1/2" diameter, 26" long hollow cylinder, weighing 12 lbs. The main cylinder is made of 0.090" thick wall of epoxy resin and fiber glass (Spiralloy, Hercules Powder Co.). This was used to avoid electrical eddy current heating. The bottom of the piston, a polished aluminum dome clamped with a titanium ring to the spiralloy cylinder, has a 1" layer of polyurethane foam on the inside. The two piston rings of high density polyethylene, slide against the O.F.H.C. copper bore which has been electrolyzed. (Electrolizing Co.).

The piston is attached at the top, by two sheets of Buna N reinforced with nylon (Fairprene, Dupont). This pressurized diaphragm is attached to a slider which enables the piston to be retracted 2", so as to uncover the filling hole.

The expansion system is powered by a 150 h.p. helium compressor. The pressure to the piston is controlled by 4, 1 1/2" boot valves, (Grove Co.) 2 for the expansion and 2 for compression. They in turn are controlled by a 3/8" 3 way solenoid valve. (Barksdale Co.).

d) Operation

Typical operating conditions will be described. With the chamber at a vapor pressure of 63 psia, the expansion groove valves allow the pressure on top of the piston to drop from 96 psia to 50 psia, and the pressure is then restored to 96 psia after 10 milliseconds, as indicated in Fig. 2. The piston responds as a « semi-resonant » structure with a period of 8 milliseconds. The percentage change in volume $\Delta V/V = 8.0\%$. The chamber will accept tracks over a period of 1 millisecond and the bubbles can be photographed 500 microseconds after particle traversal. The chamber operates without much difficulty up to 10 cycles per second. At 20 cycles we have instabilities, the oscillations due to the previous expansion have not yet died out. Distortion appears negligible, of the order of coulomb scattering, at up to 20 cycles per second, even amidst heavy boiling. Average hydrogen consumption rates are 5 liters per hour static loss, 20 liters per hour at 10 cycles per second, 30 liters per hour at 20 cycles per second.

The track bubbles disappear in times of the order of 20 milliseconds. The main boiling is due to the window seals. We have accumulated, during the last two months, a total of 4×10^6 expansions, mainly at rates of 5 cycles per second. The failures have been confined to the Grove boots, with an average boot life of 5×10^5 cycles. Having two expansion valves and two compression valves with independent timing is a great help in shaping the pressure wave and in damping out unwanted oscillations.

We cycled the chamber also with a 1" thick graphite plate in the hydrogen. So far the excess boiling from the bottom edge of the plate limited the operation to 5 cycles per second.

e) Photography

We take pictures on 70 mm film, non perforated Recordak SO 142, all three views in a triangular arrangement on one film, 10 triplets per foot, with a demagnification of 16×. Our new camera can take 2000 feet of film and operate in a pulsed mode at 20 frames per second, but it is still undergoing testing. We have used till now a G.E./F.T. 230 lamp which can give us up to 5 flashes per second at 10 joules per flash. We will use a CRT to put up to 300 bits of information on film in NIRNS code. (Display Products Co.). This was developed by the group at the University of Pennsylvania working, under Professor W. Selove, on the flying spot digitizer.

f) Magnet

The magnet, 5000 amps at 600 volts gives a field of 18,000 gauss with uniformity of ± 2% over the

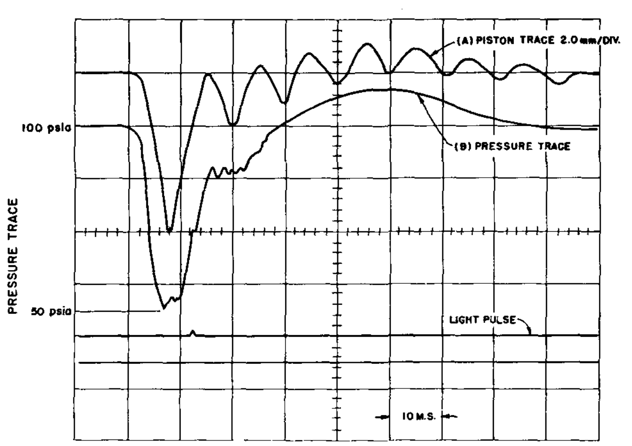

Fig. 2 - a) Trace of piston position as function of time; b) Trace of pressure on top of piston as function of time.

volume of the chamber. Each helmholtz coil consists of 5 pancakes, 1" thick, of triple wound double layers with an inside diameter of 25" and an outside diameter of 70". A 1/2" thick scintillator is clamped between each set of pancakes. The current density in the copper is 25000 amps/cm^2. The magnet is cooled by 440 gal. of water per minute, and the temperature is kept below 120°F to avoid softening of the plastic. The magnetic field does not in any way interfere with the operations of the chamber up to the highest cycling rates.

g) Future developments

During the next few months we plan to fill the chamber with deuterium and to operate it with a plate made of tantalum.

We are working on a hydraulic expansion system, modeled after the system which was used on the small propane chamber (2).

We are getting a better antireflective coating on our condensing lenses (Optical Coating Lab.) and we are obtaining a flash lamp (Impuls physik GmbH) which will enable us to flash 20 times per second at 20 joules per flash.

DETECTION SYSTEM

The chamber, when fully operative, will be able to produce close to 500,000 pictures per day (if we can load the camera fast enough). This is a much larger number than we can comfortably analyze at present. We therefore planned, from the beginning, to try to utilize the chamber with some type of counter control on the flash lamp.

This effort has resulted in an array of 96 scintillators arranged as in Figs. 3 and 4, sandwiched between magnet coils. The scintillators (NE102) and light pipes were supplied by Nuclear Enterprise Limited. Under simulated operating conditions they show an appreciable flow at temperatures above 130°F. The 96 photomultiplier tubes used in the array are RCA 6655A. The primary motivation for this arrangement was to build a detector for K^+ particles. The K^+ particles will be detected by their delayed decays. We have the problems of efficiency, background and bias. The detectors are not intended for the identification of events, but only for increasing the fraction of pictures taken which do contain an event of interest; thereby making the scanning easier. We estimate that we can trigger on 20% of the K' particles produced in the chamber. The background will be due to pions stopped in the scintillator, (about 90% of the stopped pions will stop in the magnet coils) slow neutrons, and noise.

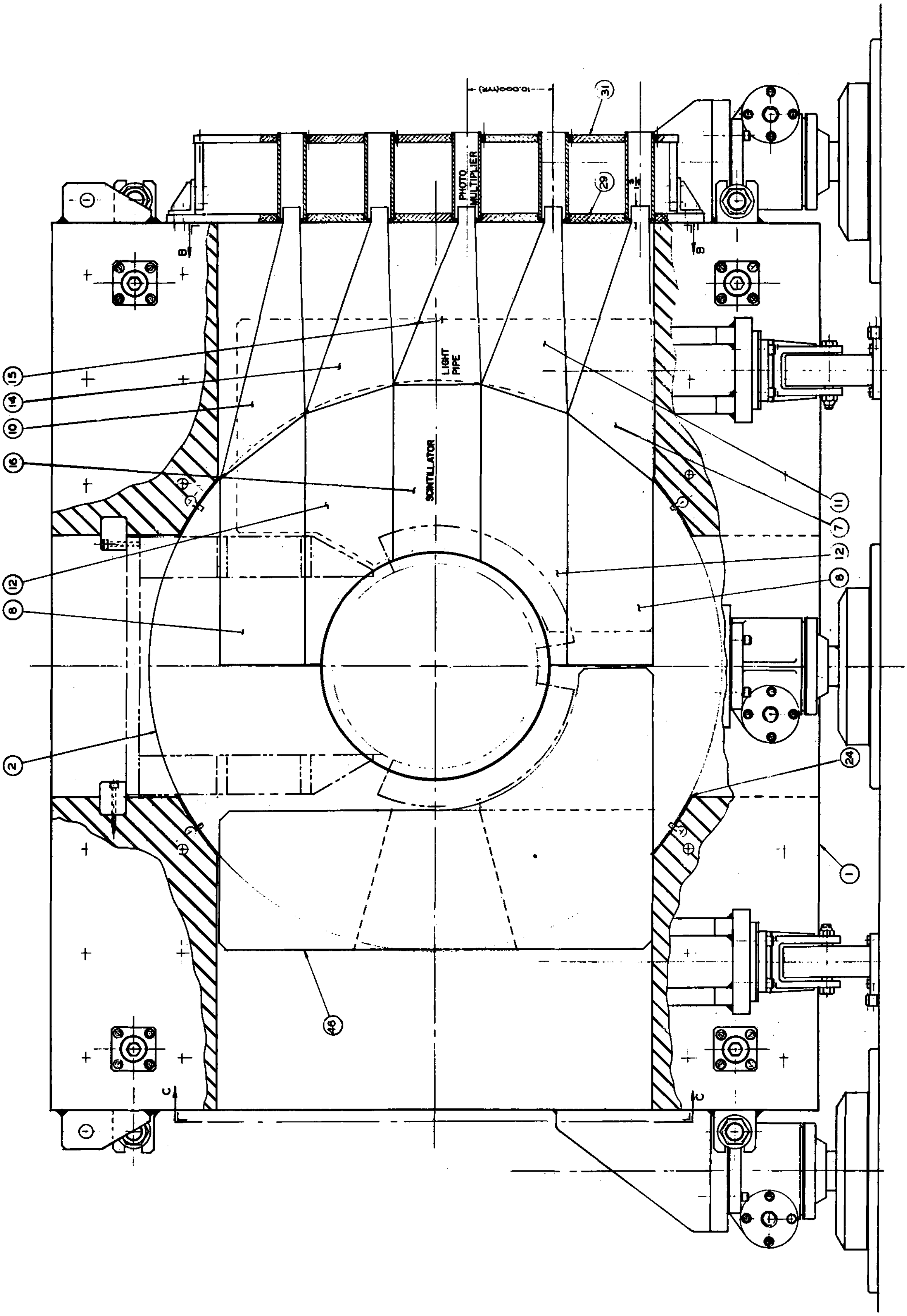

Fig. 3 - K + detector assembly cross-section.

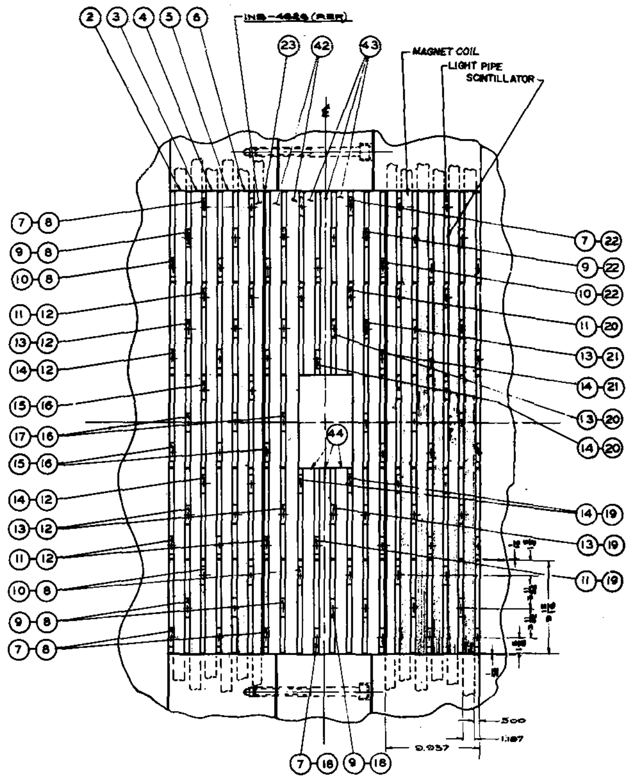

Fig. 4 - Scintillator assembly.

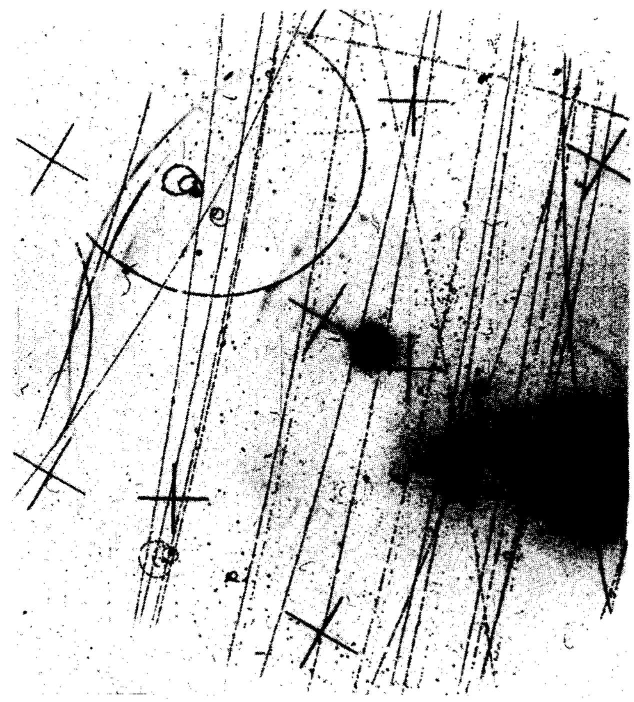

Fig. 5 - 10 cycles per second - 14,000 Gauss.

A gate is formed by two beam counters in front of the chamber and an anticoincidence behind the chamber. The fanned out « clock pulse » from this set of beam counters is then put in delayed coincidence with all of the 96 scintillators. A delay of the order of 10 nanoseconds has proved sufficient to eliminate most « prompt » pulses and still accept a fair fraction of the K^+ particle decays. A favorable pulse then opens a gate to flash the light. For check out purposes, we have built a display panel which indicates which counters have been hit. We will also be able to indicate this information on our film when the C.R.T. is completed.

We plan in the future to use this set of scintillators to trigger on events where many prongs are produced in the chamber. We are working on the problem of providing anticoincidence counters between the chamber and the scintillators, to enable us to trigger on neutral particles coming out of the chamber, the difficulty here being one of geometry, since it requires a combination of cryogenic temperature, high vacuum, high magnetic field and photomultipliers in a rather limited volume of space.

To facilitate the sharing of secondary beams at the accelerator we have built a ferrite « beam kicker » magnet. It is S.C.R. controlled, and permits a field, over a region of 5"×5"×40", to be turned up to 1000 gauss in 100 microseconds and to decay in 10 milliseconds.

We want to acknowledge the major effort of Professor T. Bowen in the early stages of this project.

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