NPA/Int. 68-33
26.11.68

THE ULTRASONIC HELIUM BUBBLE CHAMBER

by

R.C.A. Brown, H.J. Hilke, A.H. Rogers *)

CERN - Geneva
26th November, 1968

---

*) Now at Stanford Linear Accelerator Centre.

There has long been an interest in using an ultrasonic standing wave system to provide the necessary expansion in a bubble chamber. Several advantages would ensue: the most obvious, apart from the replacement of the bulky expansion system by static crystals, being the potential high repetition rate.

In a search for the ultrasonic excitation of bubble growth along the tracks of ionising particles, Hughes $^{1)}$, Hahn and Peacock $^{2)}$ and West and Howlett $^{3)}$, have demonstrated neutron sensitivity in organic "heavy" liquids. However, all previous attempts to produce bubble tracks ultrasonically have been unsuccessful, regardless of the choice of liquid.

Hughes $^{1)}$, Schoch $^{4)}$, and Rogers $^{5)}$, have discussed the possible advantages of helium as a working liquid. Conventional helium bubble chambers can work with expansions as small as 100 torr; these pressure amplitudes are realisable by ultrasonic techniques. Following trials using β-radiation in a helium ultrasonic chamber at M.I.T., Mass., $^{5)}$, we decided early in 1967 to build a small helium chamber at CERN, in which ultrasonic expansion could be tested in particle beams.

Principle of Operation

The working conditions in an ultrasonic bubble chamber are illustrated in Fig. 1). Figure 1a) shows the instantaneous variation of pressure along the axis of the standing wave field between the crystals. Planes a,b,c are the pressure antinodes of the standing wave. Figure 1b) shows the variation of pressure with time at any antinode. The static pressure p_o is always slightly higher than p_v, the saturated vapour pressure at the working temperature, in order to avoid steady boiling of the liquid. A certain minimum pressure p_c is necessary in order to form a critical bubble from the energy deposited by an ionising particle. (See Seitz $^{6)}$). A particle traversing the antinode during the interval of time between t_1 and t_2 can generate a critical bubble in less than 10^{-9} sec. However, under the working conditions of a conventional helium chamber, it is impossible to grow a bubble to a visible diameter (100 μ), during the expansion half-cycle of a typical ultrasonic field. Fortunately, the absorption of sonic energy from the field is irreversible.

Consequently one can show that at sufficiently high amplitudes, bubbles formed early in the interval between t_1 and t_2 will not be completely recompressed in the subsequent half-cycle, and can then grow to visible size over a number of cycles [7]. If we call the end of the "sensitive interval" for bubble growth t_3, the ratio $(t_3 - t_1) / T/2$ gives the fractional sensitive time, where T is the period of the sound wave. Part of the transfer of energy is by a process of resonant absorption, as predicted by Trammel [8], and demonstrated earlier by the authors in collaboration with others [9]. Finally, it should be noted that the dependence of bubble density on particle velocity is essentially unaffected by the distribution of sensitive regions.

Description of the Chamber

The chamber is essentially a horizontal cryostat composed of three cylindrical glass vessels. The inner vessel contains two piezoelectric crystals (PZT 4), the mechanical alignment of which can be adjusted from the exterior. The crystal diameter is 7 cm, and their separation can be set from 5 to 25 cm : for the results reported here we used a separation of 5 cm. The inner vessel is surrounded by a heat shield evacuated to $< 10^{-6}$ torr. An independent cooling circuit draws liquid helium through evaporation chambers in the inner vessel; the resulting helium gas is then recirculated around the heat shield and through tubes in close contact with the mechanical supports: this avoids the necessity for a liquid nitrogen shield. Figure 2) shows the chamber with the glass vessels demounted.

We used a 25 Joule flash of about 40 µsec duration, in conjunction with a cylindrical reflector and lens system, to produce convergent illumination. Natural size photos were taken on Polaroid 3000 ASA film with a 300 mm f/64 camera objective. Optical imperfections, such as flares, grey field, and slight distortions, are caused by viewing through the multiple curved glass surfaces which are an inherent feature of this test chamber.

The apparatus is aligned for operation so that the particle beam passes along the cylindrical axis of the chamber.

Experimental Results

The crystals were pulsed at 110 KHz with 700 V rms by a power amplifier constructed for earlier experiments on ultrasonic excitation in Freons 10). After the crystals and chamber had been carefully tuned to electrical and acoustic resonance, the chamber was found to give bubbles along the tracks of minimum ionising pions and protons in the temperature range 3.4 - 3.65° K. (See Fig. 3).

Bubbles were observed to grow to visible size (100 μ) within 600 μsec i.e. within 50 to 60 cycles of the sound field. The fact that bubbles can appear at half wavelength intervals is explained by the migration of bubbles to the pressure nodes 10). The bubble density along the tracks is typically 8 - 10 bubbles per centimetre. Comparison of the number of tracks observed to the measured beam intensity leads us to conclude that the fractional sensitive time, as discussed above, is at least 50 %.

Preliminary data 11) from the British 80 cm Helium Chamber indicates that in Helium the bubble density is rather independent of temperature for a given under-pressure Δ p. It is well-known, however, that for constant Δ p the rate of bubble growth increases rapidly at lower temperatures. These facts led us to operate at the lowest temperature attainable in our apparatus. To do this it was necessary to pump directly on the sensitive liquid : in this condition it is not possible to vary static pressure and temperature independently. Thus we cannot yet study the reabsorption of bubbles as a function of the static pressure.

It appears that with these powerful sonic fields the bubbles grow to an unstable size in less than 1.5 msec, subsequently breaking to form diffuse bubble clusters (Fig. 3 c). The pressure amplitude was estimated to be more than 200 Torr. But it is possible that at the lowest temperatures the excitation produced negative pressures, which are known to cause extremely rapid bubble growth.

Acknowledgements

We are greatly indebted to Dr. C.A. Ramm and to Prof. W. Jentschke for their continued interest and support. One of us (H.J.H) is very grateful to the late Prof. Schoch, who first aroused his interest in ultrasonic bubble chambers and gave much valuable help.

We wish to thank E. Frick and H. Ancey for their excellent work in the design and construction of the chamber; also G. Griot, E. Baltzersen and H. Warren, for their assistance with the experimental work.

We gratefully acknowledge the support of CERN, the U.S. National Science Foundation, and the Ministerium für Wissenschaftliche Forschung, during this project.

Distribution : (open)
Scientific Staff of NPA Division

References

1) A.L. Hughes, Proc. Int. Conf. on Inst. for High En. Ph., Berkeley (60), p. 99.

2) B. Hahn, R.N. Peacock, N. Cim. 28, 2 (63)
N. Instr. Meth. 20, (63)

3) C. West, R. Howlett, AERE - M 1880 (67)
AERE - R 5487 (67)

4) see P. Amiot, CERN Internal Report (PS-AR/59) and private communication

5) see I.M. Asher, H.M. Bozler - M.I.T. Bachelor's Thesis (unpublished)

6) F. Seitz - Ph. of Fluids 1, 1 (58)

7) A. Rogers - to be published

8) G.R. Trammel - J. Appl. Phys., 33, 5

9) G. Harigel, H.J. Hilke, A. Rogers, G. Horlitz, S. Wolff;
E. Fretwurst, G. Lindström, submitted to J. Appl. Phys.

10) H.J. Hilke, to be published

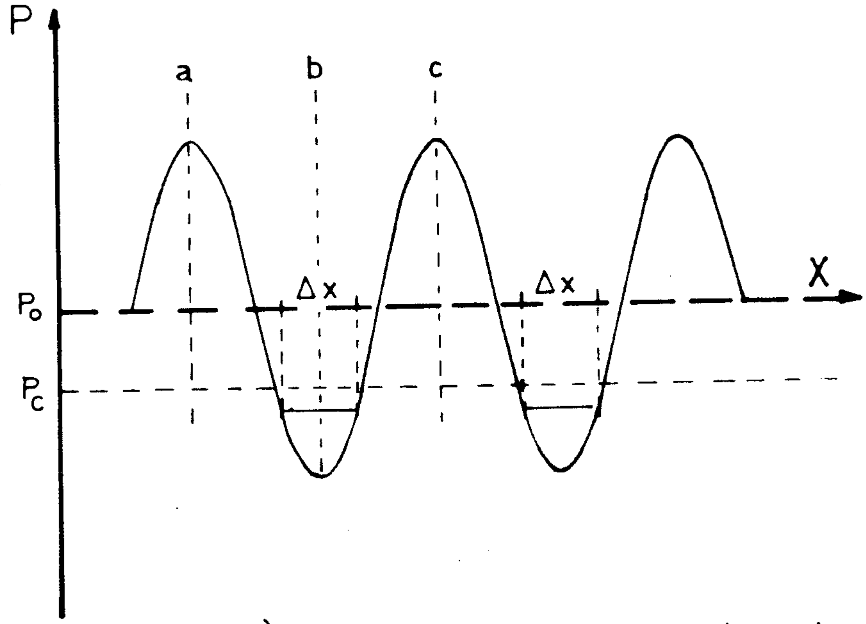
11) Private communication from T.D. Peel

12) G. Harigel, G. Horlitz, S. Wolff, DESY 67/14

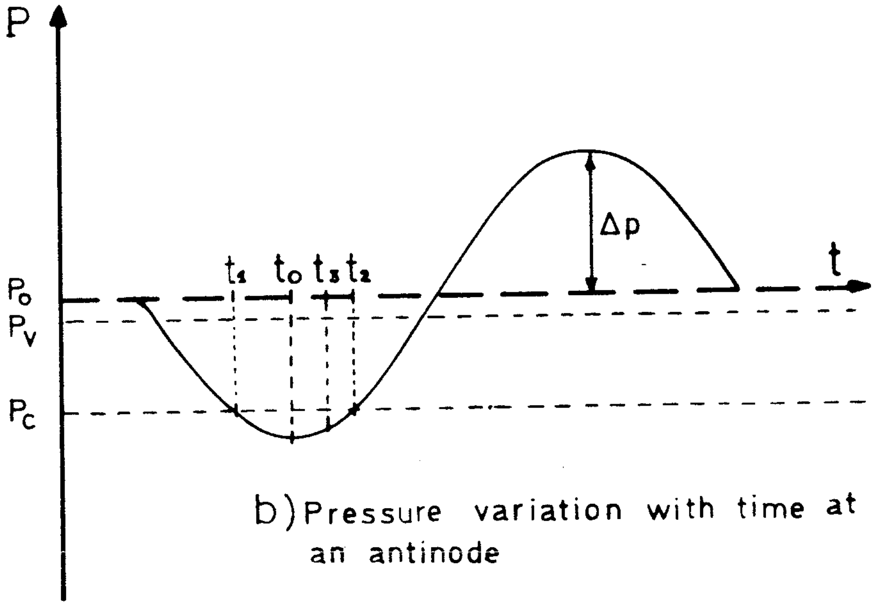
Figure Captions

Fig. 2) The Helium Chamber shown without the three glass flasks. Note the crystals mounted at the right between the cooling vessels. The spiral pipes are for recirculation of the cooling gas.

Fig. 3) Reproduction of polaroid photographs taken at 3.5° K. Photos a) and b) were taken after 1 msec of sonic excitation; c) taken after 2 msec shows bubble multiplication.



a) Pressure variation along the axis of the standing wave field at $t=t_0$



b) Pressure variation with time at an antinode

Fig. 1

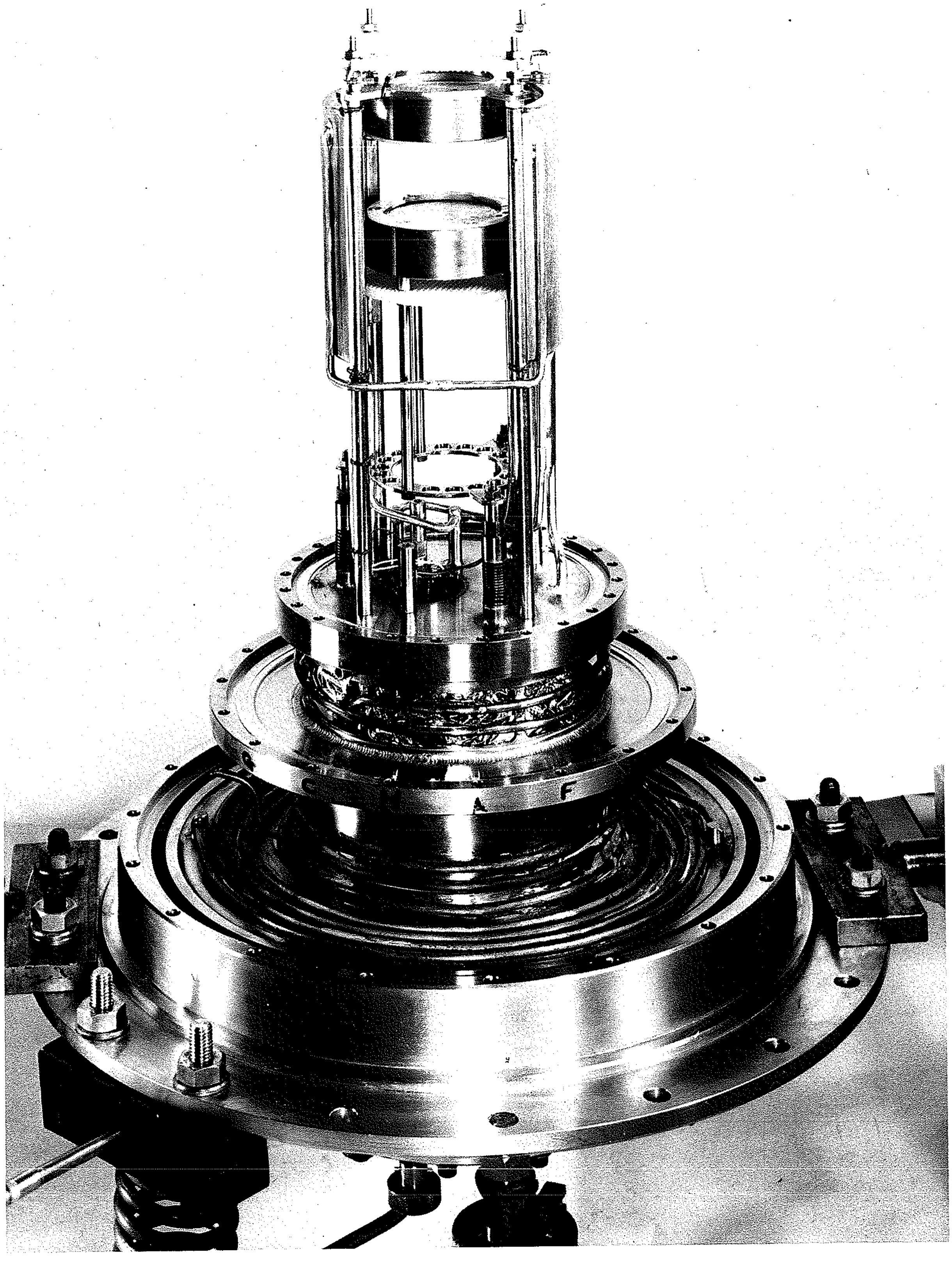


Fig. 2

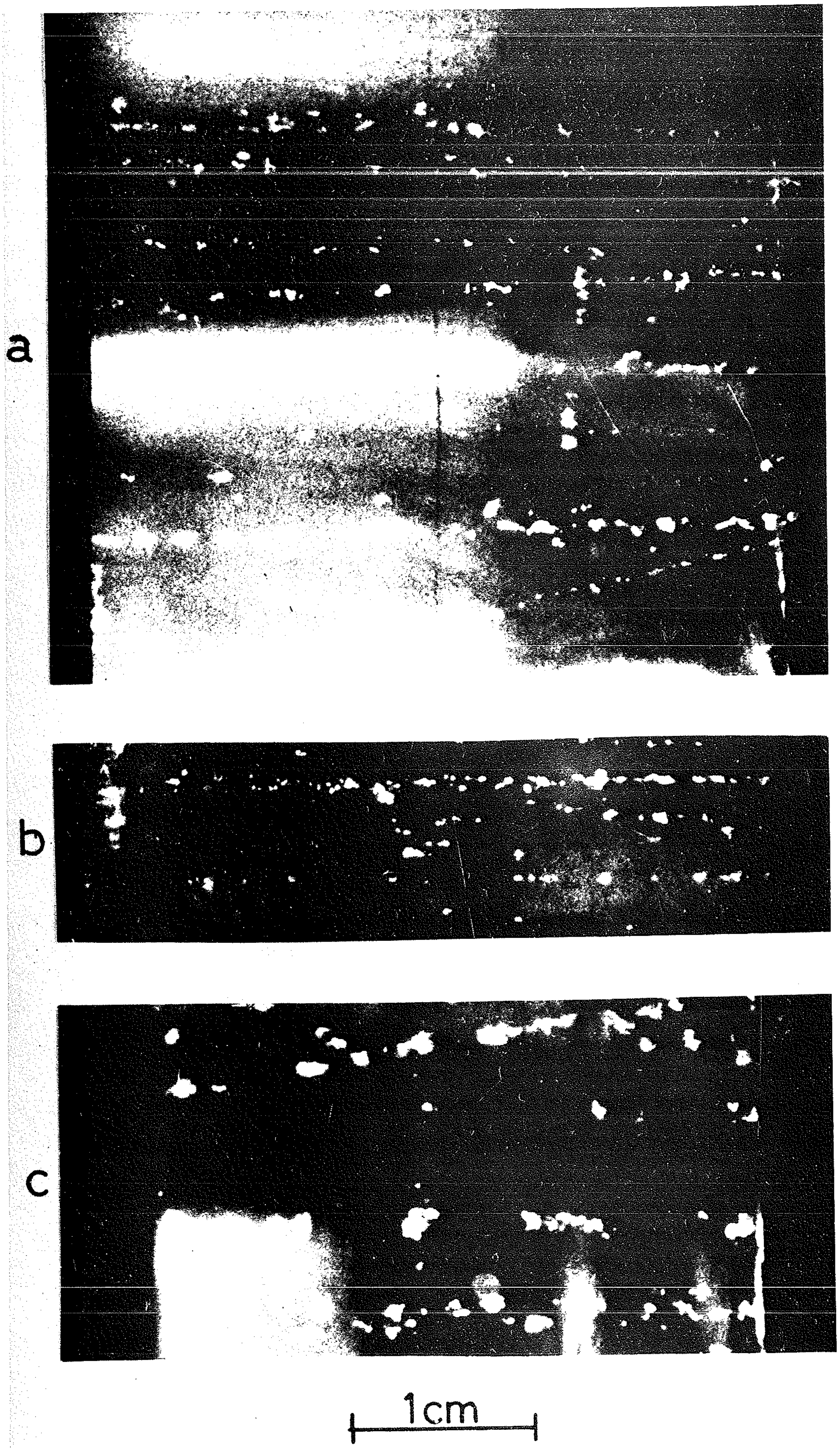


Fig. 3