NPA/Int. 61-1
3rd Feb uary 1961

REPORT ABOUT THE BREAKAGE OF THE MAIN GLASS WINDOW IN THE 500 LITER HEAVY LIQUID BUBBLE CHAMBER.

The glass window of the heavy liquid bubble chamber broke during the course of operational studies at about 23.10 h on Sunday 18th Dec. 1960.

The chamber was filled with Freon 12 (CF_2Cl_2) and had been operated during 4 days at temperatures ranging from 65°C to 76°C to investigate the conditions of sensitivity as a function of the temperature and of the pressure cycle.

The criterion of sensitivity was the appearance in the expanded chamber, of typical boiling induced by electrons from a γ source, placed near the beam window. In some 10 o/o of the pictures taken under these conditions tracks of cosmic rays were visible, in good agreement with known data of cosmic ray flux. It could be verified that the chamber became sensitive in a reproducible way at temperatures between 70°C and 76°C when the pressure in the freon was dropped to certain definite values. For example observations taken at 72°C for a wide range of pressures in the expansion tank allowed to check the prediction that the chamber would become sensitive for a drop of 12 atm from a recompression pressure of 25.5 atm.

The expansion took place with the speed foreseen in the design: the total time of pressure drop varied between 10 and 18 msec for pressure drops between 7 and 14 atm, obtained for different settings of the expansion tank pressure.

The freon pressure started to increase immediately at the end of the expansion, partly out of elastic oscillations of the freon and partly due to boiling. In the absence of boiling the frequency of the oscillations was about 150 per second, in good agreement with the calculated value of the resonant frequency of the liquid freon in the chamber.

The initial rate of pressure rise was of the same order as the expansion speed. The pressure tendend to reach the liquid vapour equilibrium value with oscillations around an exponential line.

External recompression, which was delayed in order to observe the above phenomena, was a little slower than expansion and was accompanied by an overshoot of some 3 atm and by a few damped oscillations having 30 msec period.

By changing the flash timing in steps it was possible to observe the growth of bubbles in the chamber. Boiling seemed to start on a horizontal strip roughly in the centre of the membrane, after a pressure drop of some 8 atm. This boiling was independent of the presence of the source and developed rapidly into a large could having a characteristic pattern. Its exact location depended in a reproducible way on the expansion ratio (in volume) and could be related to the local pressure situation at the moment of the impact of the corresponding region of the membrane against the perforated plate.

Diffused boiling originated by radiation from the source appeared for a larger pressure drop, independently from the spurious one.

At the time of the breakage a series of measurements was in progress to determine the effect of the expansion ratio on the minimum pressure obtained during an expansion cycle.

When the ratio was increased from 3.0 o/o to 4 o/o, as an extra precaution against unnecessary stretching of the membrane, which is foreseen for an expansion ratio of at least 5 o/o, it was decided to use only single expansions.

On the particular expansion at the commencement of the accident it is interesting to note that a complete record exists of the operating characteristics even of the actual expansion cycle up to the instant of the breaking of the connection to the pressure pick-up. The expansion during the last cycle was to a depth of 14 atm. When the connection disappeared, some 10 milliseconds after the minimum, the pressure had risen again to 20 atm, showing evidence of unusual boiling.

Other parameters were :

Recompression pressure	25,5 atm
Expansion pressure	5 atm
Pressure in the safety tank	26 atm
Chamber temperature	72 °C
Total expansion time	16 msec

The flash lights were operated at the minimum of the pressure cycle.

Simultaneously with this expansion an uncontrollable leak to the atmosphere was evident. This at first was believed very grave as the chamber has been designed so that in the event of any failure no leak to atmosphere can occur, and only a mechanical failure of the body or beam window could produce such a situation in the properly assembled chamber. It was only later that the exact cause of the accident was known.

Since the working fluid was freon 12 and known to be non inflammable it was considered adequate as safety routine to open the large doors as a ventilation measure. Other procedures foreseen for an emergency worked as planned.

Since it was obvious that the leak was to the atmosphere and uncontrollable it was forecast that the window would almost inevitably break. The slight hope came from a lack of knowledge of the precise location of the leak in the chamber. Under circumstances of very rare good fortune a very large leak from the lowest point in the chamber might discharge the working fluid in the liquid phase so rapidly as to prevent a disastrous thermal shock to the window.

However, after some 2 min 40 sec the window broke. The recorded traces enable the various pressure versus time cycles to be followed and the time scale to be determined with precision. The breaking was accompanied by a muffled thud, but of course otherwise no external evidence.

When the chamber was dismantled it was possible to follow out the leak path and to determine unequivocably that the primary cause of the trouble was a simple failure of a flash protection tube. These pyrex tubes, 5 mm thick and 40 mm in diameter, are pressure tested at 150 atm and examined for strain by optical methods before mounting. However, on account of the nature of glass a sudden unpredictable failure cannot be excluded.

The chamber had been designed to avoid any unfortunate consequences from such an event by a system of completely gas tight seals surrounding all glass parts. Unfortunately, one of the components of this system had, through a misunderstanding, not been put in place, and its absence could not be noticed during normal operation. When the particular glass in question broke the leak was uncontrollable.

The following situation existed at the moment of the window breaking.

Temperature in the liquid freon (chamber bottom)	28°C
Temperature in the vapour (chamber top)	48°C
Temperature in the safety tank	77°C
Pressure in the chamber	7.5 atm
Pressure in the recompression tank	19.5 atm
Pressure in the expansion tank	10 atm

It is clear that the main coaxial valves had remained correctly closed and that the chamber was isolated from the gas system.

The pressures in the recompression and expansion tanks had tended to equalize through the by-pass of the regulator, since the system had been isolated from the compressed air supply by the emergency protections.

The pressure in the safety tank was not directly recorded, but it may be deduced to have regulated to below 13 atm from the fact that after the window broke, the total pressure in the chamber rose to only 13.5 atm.

Traces from liquid freon in the safety tank show that at this time there was still more than half the freon in the chamber. The fundamental design of the chamber involved the principle that if a disaster arose every precaution should be taken to cause the window to explode towards the chamber. Hence the pressure in the safety tank was intended always to be at least equal to the static pressure of the working fluid. This situation is maintained by an electropneumatic servo actuator which reproduces the static working fluid pressure in the safety tank gas. Under these tests this actuator was throttled to follow somewhat more slowly the working fluid pressure but always in the safe sense in the event of a leak.

The appearance of the window was spectacular, with some hundred kilos of glass fragments in the chamber body, including some pieces of tens of kilos. Large pieces had come out solid in the breaking. Fortunately because of the damping effect of the liquid in the chamber, the actual damage, apart from window loss, was relatively trivial. The total loss was as follows:

The window

2 thermometer pick-ups

6 of the 8 protecting glasses

Some dents on the inside chamber wall

Some dents on the perforated plate

Cuts in the rubber membrane

Bending of the fins of the 4 flash units

4 flash tubes (the other 4 flash tubes and fins were not installed)

It was amazing to find that the lower two protecting glasses were intact and serviceable, despite the fact they were buried under all the broken glass. This is strong evidence of the damping. Any of hundreds of even the smaller pieces of glass in the debris, if dropped from the height of the centre of the window in free air, would have broken these tubes. The reference marks were also intact.

The most difficult aspect of the repair is of course the installation and testing of the new window. The adjustment of the packing will take some two weeks alone. The other items have been repaired or replaced from stocks.

In the next assembly the bearing surfaces for the protective pyrex tubes will be coated with mylar foils to reduce possible stresses in the glass due to vibrations.

A method of slightly pressurizing the space between the first and the second line of seals as an overall check of correct assembly is being studied, and a rigid checking system is being devised.

It is expected to resume the technical study of the chamber operation shortly.

L. Resegotti

fv

<u>Distribution</u> : (open)