6.5 ENGINEERING ASPECTS OF THE ANL 12-FT HYDROGEN BUBBLE CHAMBER*

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The 12-ft hydrogen bubble chamber is one of the new large chambers under construction. The size of this chamber poses problems that require more thorough consideration than their counterparts in smaller chambers. The purpose of this presentation is to review some of these problems and to discuss the solutions or the proposed approach.

The chamber was conceived to be a physics instrument with the maximum economy of construction and operation. Consequently, an aspect ratio was chosen that provides good photographic utilization of the liquid inside a uniform magnetic field. These objectives immediately defined the direction for the design of various systems. The most unique problems due to the size of the chamber are in the following areas: operating considerations, photographic system, and the expansion system. The superconducting magnet is also a very important area, but it will not be discussed here.

Operating Considerations

The geometry of large chambers imposes two requirements: slow expansion rates for uniform sensitivity and thermal homogeneity for low optical distortion. An additional requirement, at least with bright field illumination, is fairly low bubble density and a large bubble diameter. This latter requirement necessitates operation at the low end of the temperature region and low expanded pressures. Since parasitic boiling sets the limit to the lowest expanded pressure as well as the rate of expansion, it becomes extremely important to determine the sources of it and to eliminate them.

An argument may be advanced that the parasitic boiling is inversely proportional to the characteristic dimension of the chamber; however, the maximum rate of expansion is also inversely proportional to the characteristic dimension. Thus, although the surface-to-volume ratio is lower, parasitic boiling has more time to develop. The net result may be that for equal surface

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quality, the effect of chamber dimensions on reducing specific parasitic boiling is small. Although these arguments are only qualitative, it is clear that great care must be exercised to avoid cracks and gaps which are well proven empircally to produce boiling. It is even possible that once a clean chamber is achieved, its usefulness can be greatly increased because it may be feasible to use some of the classical heavy liquids such as Freon 13-B1 at low vapor pressures and low expanded pressure in the same chamber.

Tests have been made in our 2-ft model, shown in Fig. 1, in search of qualitative and quantitative answers. We found that it was not possible to expand below 18 psia independent of vapor pressure. We also found that at the same time we had about 0.5 J/liter of P-V work. We do not know the exact reasons for this, but believe that it was parasitic boiling and/or gas in the bellows. Steps have been undertaken to strip the chamber bare and to install a gas vent line in the bellows to determine which boiling is limiting the expansion. It is interesting that the P-V work increases quite suddenly with decreasing expanded pressure. It should be noted, however, that measurements of deviation from straight line in photographs of targets taken through 600-mm of hydrogen under the above conditions show no more than 30 μ rms deviation.

We have also done some additional thinking about modeling. Basically, there are the following unknowns that must be answered: thermal turbulence, kinetic losses, radiation, conduction, and the testing of some selected chamber components. It is evident from D. Thomas' work that a liquid hydrogen chamber of 1-ft dimension would be in a fully-developed turbulent regime and, therefore, a larger dimension gains only a longer single pass optical path. The kinetic losses scale as length to the fifth power and little can be measured until the dimensions are of the order of 10 ft. The radiation and conduction are, of course, calculable. Thus, the larger chamber size is useful only for checking some components; in our case we intend to check out the full-size optical cartridges. The penalties of a larger model than the minimum required are obvious.

We have found a small 6-in. Freon chamber extremely useful for quick qualitative check out of surface quality, cracks, valves, heat exchanger fins, and capillary tubes for boiling.

The 2-ft liquid hydrogen and the 6-in. Freon chambers have helped us to decide that the 12-ft chamber will have a heat exchanger at the top, that everything possible must be done to eliminate pluming due to crevices and cracks, and that a shroud may be useful in increasing the mixing length for heat prior to reentry into the fiducial volume.

Photographic System

It was decided in the early stages of the design to photograph the fiducial volume with wide-angle lenses rather than using either large windows or increasing the height of the chamber to reduce the lens and stereo angles. Initially, 110° lenses placed on approximately an 11-ft diameter circle were considered.

Scanning computer-simulated pictures with this camera arrangement was difficult. It was suggested to simulate photography with 140° lenses placed on a 7-ft diameter circle. These views were found to be much more scannable by bubble chamber physicists. Calculations also showed that good measuring accuracy in all three coordinates could be obtained with adequate volume coverage. Consequently, a feasibility study to design a 140° lens was conducted by Tropel, Inc. with excellent results.

The design is telecentric and, therefore, is relatively insensitive to film undulation. The lens is diffraction limited at f/8 over the entire field. The large symmetrical radial distortion in this lens was not found to be objectionable in the computer-simulated pictures. Tropel is currently finishing the optical and mechanical design, and expect to begin the construction of a prototype quite soon.

The illumination of the chamber volume has always been firmly anchored to 3M Scotchlite, although the bubble size imposed by the bright field illumination provides constant encouragement for ideas about dark field. Late in 1966 we began some tests with FE-582 bare-bead Scotchlite, which are discussed by M. Bougon in another session. With a 10° camera to light source angle, we have photographed electron tracks in hydrogen in dark field using FE-582. We have not done sufficient work to incorporate this feature into the 12-ft design; however, we are continuing (when time permits) with tests and calculations to see if dark field Scotchlite can be utilized with our geometry. Dark field photography allows more variation of the operating conditions of the chamber.

All lenses are placed behind three concentric hemispherical windows, shown in Fig. 2. These windows are strong mechanically for external pressure, eliminate the problem of chromatic aberrations due to dispersion of the chamber liquid, avoid distortion due to hydrogen-glass interface, and eliminate the reflections of the flashtubes. The convex side of the warm window is coated with a low emissivity gold film. The heat input into the chamber with this arrangement is about 0.45 mW/cm^2, which results in a stable thermal boundary layer with a small radial temperature gradient. The radiation shield is a floating window and no large thermal stresses are encountered during cooldown. Our approach to the problem of the ever-present danger of cold window "fogging" will be either by a permanently sealed, evacuated glass-metal window assembly or by a similar arrangement plus ion or sorption pumping.

It has been determined experimentally that with 1042A Scotchlite, a gold-coated window, and a Wratten-22 filter, a maximum of 200 joules of capacitor energy per camera is needed to expose Microfile AHU film at f/16. Without gold the energy requirement is reduced to 100 joules per camera. The current design employs two concentric flashtubes for each lens. Tests with circular EG&G flashtubes of 15-cm total length and 100 joules capacitor discharge every second have shown that with current pulse shaping and 200 μs duration, the tubes will operate over one million cycles. The heat from the flashtubes, especially the infra-red, will be absorbed by the coolant and will not enter the chamber.

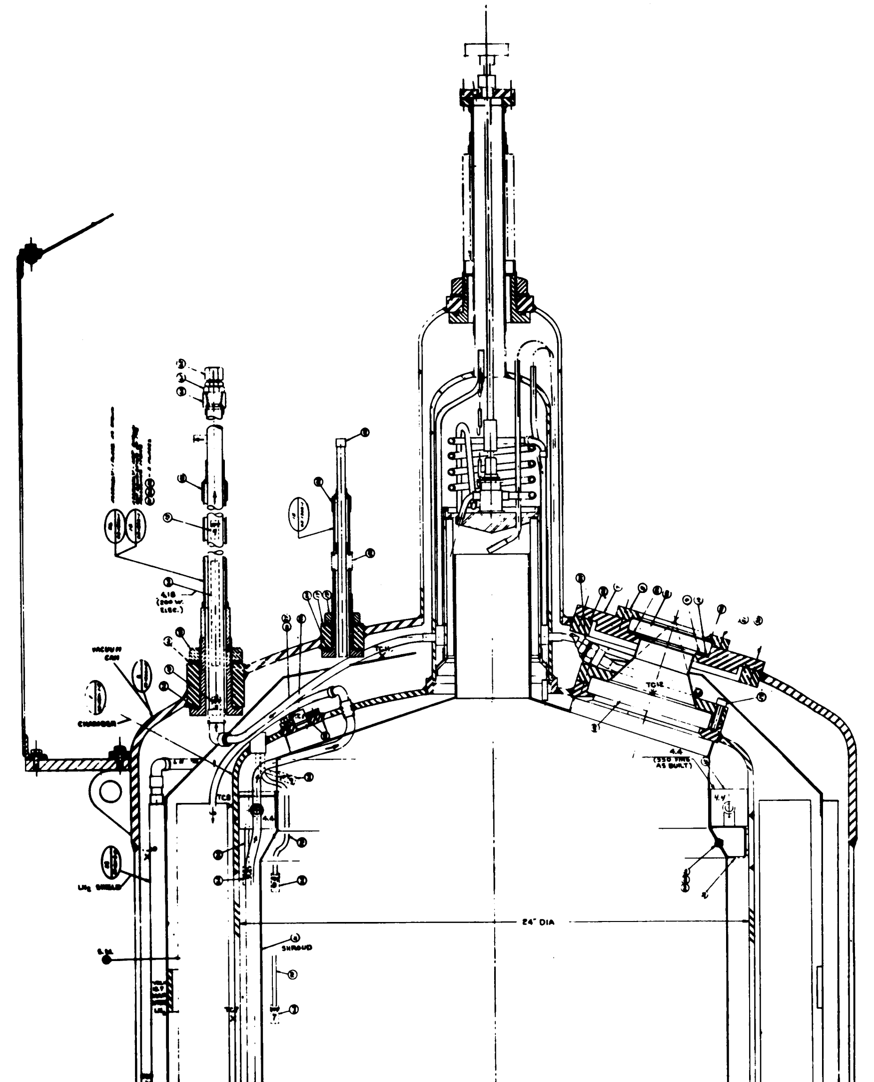
The energy requirements for the flashtubes may increase due to the possibility of installing a neutral density filter to equalize the exposure over the field. We are currently testing flashtubes with higher energy inputs in water-cooled containers.

The film is 70-mm perforated with a 60-mm diameter image, as shown in Fig. 3. The film advance is mechanical. The nominal film capacity is 1000-ft of 5-mil thick film. The random distortion due to change in R.H. is prevented by humidifying the camera wells to 50% R.H. The humidity also assists in preventing problems due to static electricity.

Expansion System

The expansion in this chamber occurs at the bottom. The main reason for this arrangement is to keep the glass windows at the top for safety and to separate the expansion system from the optics. The proximity of the expander to the optics may result in bad thermal turbulence as well as greater possibility of mechanical vibration. Furthermore, with the expander at the bottom, it is more convenient to provide localized cooling if it is required. The power required to drive a large expander by "brute" force is very large. It is, therefore, advantageous to make the expander a resonant system. In the ANL system, oil provides coupling between the bubble chamber piston and the accumulators. Energy makeup is pneumatic. A range of operating frequency can be obtained by filling the accumulators with either liquid Freon or nitrogen gas. The details of the expansion system hydraulics are discussed by J. Simpson later in this session. I only wish to mention that with our uniform magnetic field, it is possible to use a metallic omega bellows. The cooling and condensation of the bubble in the bellows interior presents a challenging engineering problem, and no firm solution is yet reached; however, we do have several proposals under consideration.

LIST OF FIGURES



24" LIQUID HYDROGEN BUBBLE CHAMBER

Fig. 1

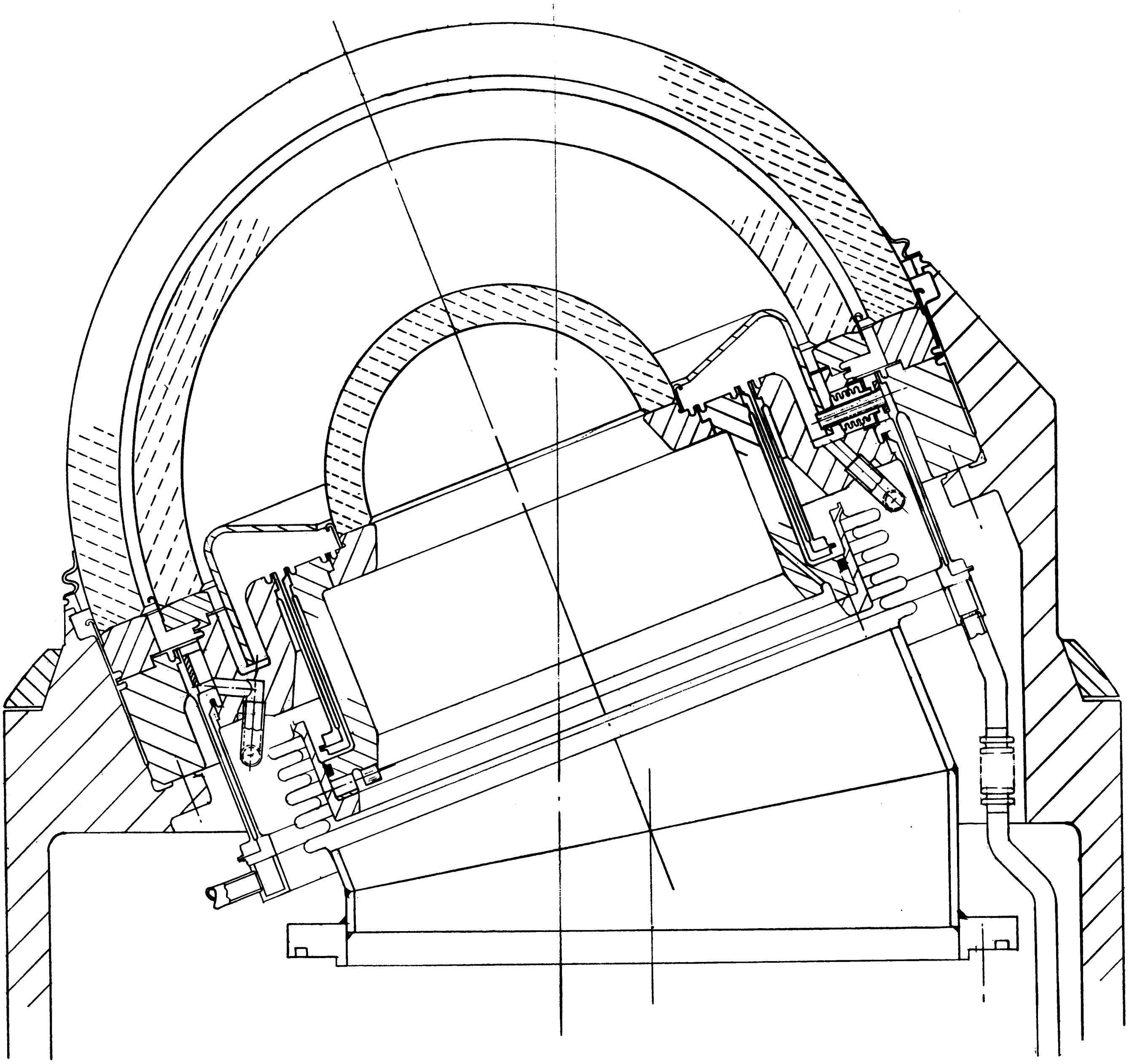
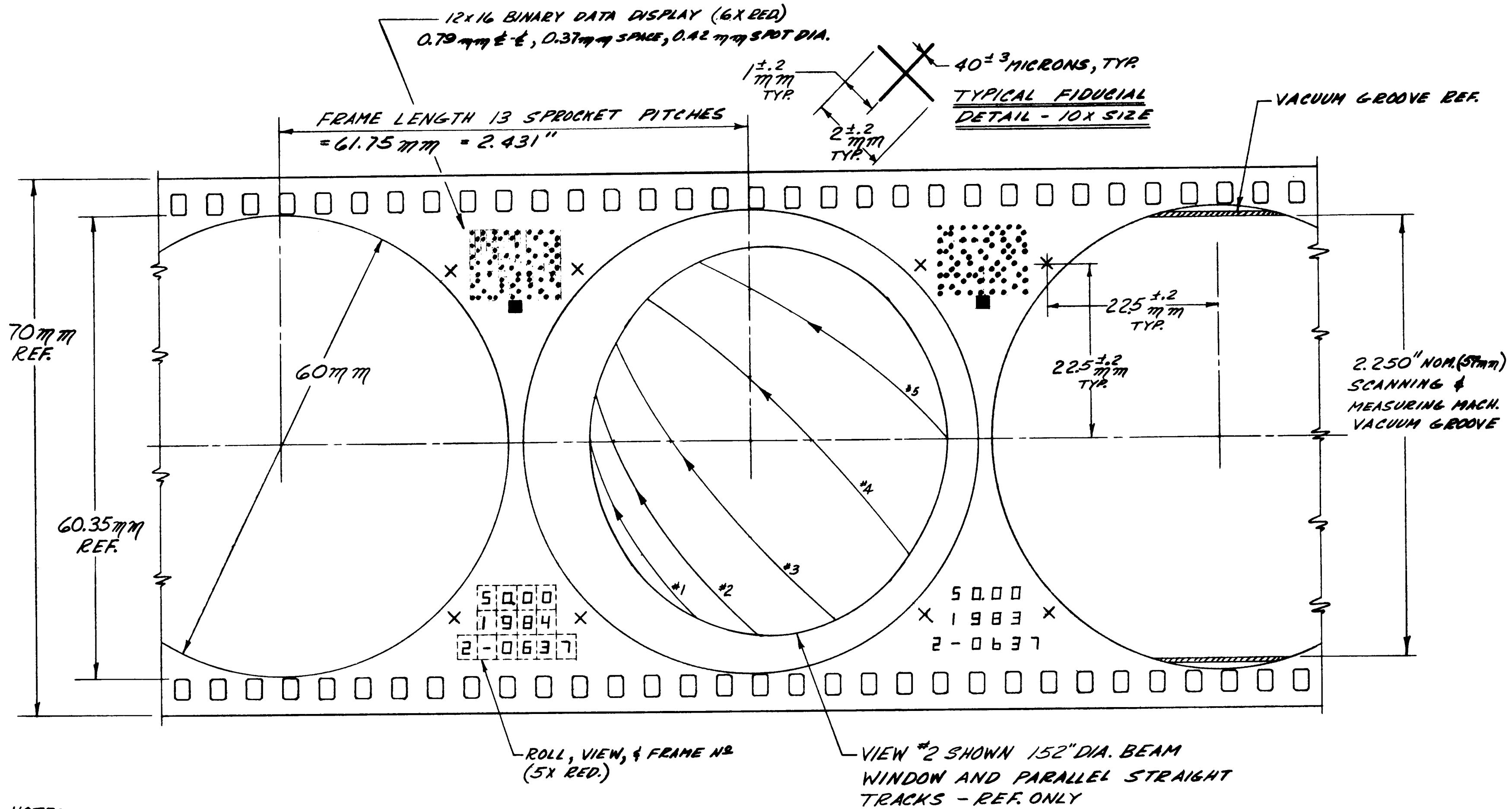


Fig. 2



NOTE:

1) FILM CONFORMS TO A.S.A. STD. #PH1.20-1956 WITH TYPE II PERFORATIONS.

2) RELATIVE LONGITUDINAL LOCATION OF SPKT. HOLES AND IMAGE NOT FIXED. LOCATION TO REMAIN FIXED WITHIN ANY ROLL.

Fig. 3