

TESTS ON SCOTCHLITE† PLACED IN A SIMULATED HYDROGEN CHAMBER*

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I. INTRODUCTION

Use of Scotchlite† in retrodirective illumination systems for bubble chambers, while generally successful, ^{1, 2} has encountered several difficulties. The most serious were peeling of the material from the walls at cryogenic temperatures and non-uniformity of different batches of material supplied by the manufacturer.

Accordingly, a test program was set up at this laboratory to establish mounting procedure, to determine if Scotchlite currently available would have adequate optical performance, and to select the best material from available lots. This paper describes the techniques used and results obtained.

II. MOUNTING OF SCOTCHLITE

It was decided at SLAC to use removable liners mechanically mounted to the chamber walls and the piston. This would allow faster replacement of the pre-fabricated units, should the Scotchlite be damaged, without the need to chisel the remains of the material from chamber walls. The problems of eddy current heating of the piston further required that the piston liner be an insulator. It seemed natural, therefore, to use fiberglass-epoxy laminant as the liner material, because its suitability for cryogenic use has already been demonstrated.³ The problem, therefore, was to develop a satisfactory method to glue Scotchlite to the fiberglass panels.

It has been suggested that a simple immersion of test panels in liquid nitrogen was not a satisfactory test.⁴ A three-step test program was therefore used:

- a. Rapid immersion in liquid nitrogen.
- b. Flexing in liquid nitrogen.
- c. Rapid immersion in liquid helium followed by rapid warmup.

Test panels 7 inches x 20 inches and 0.125 inch thick, with a spherical surface approximately 80 inches radius, were prepared using glass cloth and Union Carbide resin ERL-2256, with ZZL-0814 hardener. Lot 28 Scotchlite was used, and various methods of bonding were tried.

In all cases Scotchlite was vacuum-formed to conform to the panel curvature, and bonding was performed in a vacuum fixture. Results are summarized in Table I.

*Work supported by the U. S. Atomic Energy Commission.

† Registered trademark of 3 M Company.

TABLE I
SUMMARY OF TESTS ON ADHESION
OF SCOTCHLITE TO FIBREGLASS PANELS

Method	Surface Preparation	Adhesive	Test	Results
1.	Light sandblasting	Scotchlite's own. Several samples were tried with curing times up to 1 week at room temperature and with slight heating.	Immersion in LN ₂	Peeled on immersion
2.	0.01" Mylar molded as top layer of panel. Scotchlite side sandblasted.	Union Carbide ERL-2256 resin ZZL-0814 hardener brushed on, cured 100°C for 3 hours.	Immersion in LN ₂	Mylar to panel bond peeled, mylar sheet tearing. Scotchlite to mylar bond seemed good.
3.	Light sandblasting	Shell Epon 826 with activation A a. Cure at room temperature for 24 hours. b. Cure at room temperature for 72 hours.	Immersion in LN ₂	a. Ripped and peeled on immersion. b. On immersion showed multiple small bubbles.
4.	Light sandblasting	Union Carbide ERL-2256 with ZZL-0814 brushed on, cured 110°C for 3 hours and room temperature over night.	a. Immersion in LN ₂ b. Light heating with heat gun after immersion c. 60,000 flexings in LN ₂ d. Gradual cooling to -100°C, cooling to LH ₂ in 15 minutes. Immersion for 18 hours, rapid warm-up	a. No effect b. No effect c. No effect d. No effect

Method 4 (Table I) successfully passed all tests and was therefore judged satisfactory for fabrication of the retrodirective liner. The remaining problem, that of joints between 12-inch-wide strips of Scotchlite, was briefly investigated. Butt and lap joints were prepared and photographed. A lap joint with approximately 1/2-inch overlap, sealed with Scotchlite's own adhesive, was found most satisfactory.

III. OPTICAL PROPERTIES OF SCOTCHLITE

All samples of Scotchlite that became available were tested, but extensive tests were confined to SPR 704 material designated as Lot 26 (the original Scotchlite), Lot 28 (purchased by SLAC for the 40-inch chamber), and Lot 32 A (recently supplied by 3M).

A. Bench Tests

Initial optical tests were bench tests measuring the angular reflectivity, dispersion, and spectral reflectivity of the material. The angular reflectivity was measured both photographically and with a phototransistor coupled to a CRT display. The results in Fig. 1 show that for SO 291 film between incident angles of 0° and 35° , reflectivity is almost constant. It also demonstrates the variation in spectral reflectivity of Scotchlite: Lot 26, which was most efficient with SO 291 panchromatic film, was least efficient with SO 142 film, which is less red-sensitive. Measurements of spectral reflectivity were therefore undertaken and results are shown in Fig. 2. They agree closely with similar data obtained at BNL.⁵ An interesting point is raised, however, as our tests indicated increased reflectivity below a minimum observed of $450 \text{ m}\mu$. All other tests to date neglected to measure reflectivity below $450 \text{ m}\mu$ and assumed cutoff at that point. Since our data is based on a single point at $400 \text{ m}\mu$, and in general films are most sensitive at shorter wavelengths, further investigation of Scotchlite reflectivity below $450 \text{ m}\mu$ seems highly desirable.

Our dispersion measurements were in agreement with those made at other laboratories. However, no good method has yet been proposed for correlating those results to actual performance of the Scotchlite in a bubble chamber, although to date the dispersion curve has been the sole method of comparison among various batches. The main problem with Scotchlite has been to obtain adequate track contrast, and no real criteria for deducing the expected contrast from a dispersion measurement have been evolved.

B. Liquid Hydrogen Tests

In order to provide realistic contrast measurements, it was decided to photograph gas bubbles in liquid hydrogen. A tank was constructed 6 inches in diameter and 20 inches deep (depth of SLAC chamber), which could be filled with liquid hydrogen at a pressure up to 45 psig (Fig. 3).

A section of curved fiberglass liner was installed at the back of the tank to which patches of Lots 26, 28, and 32 A were applied.

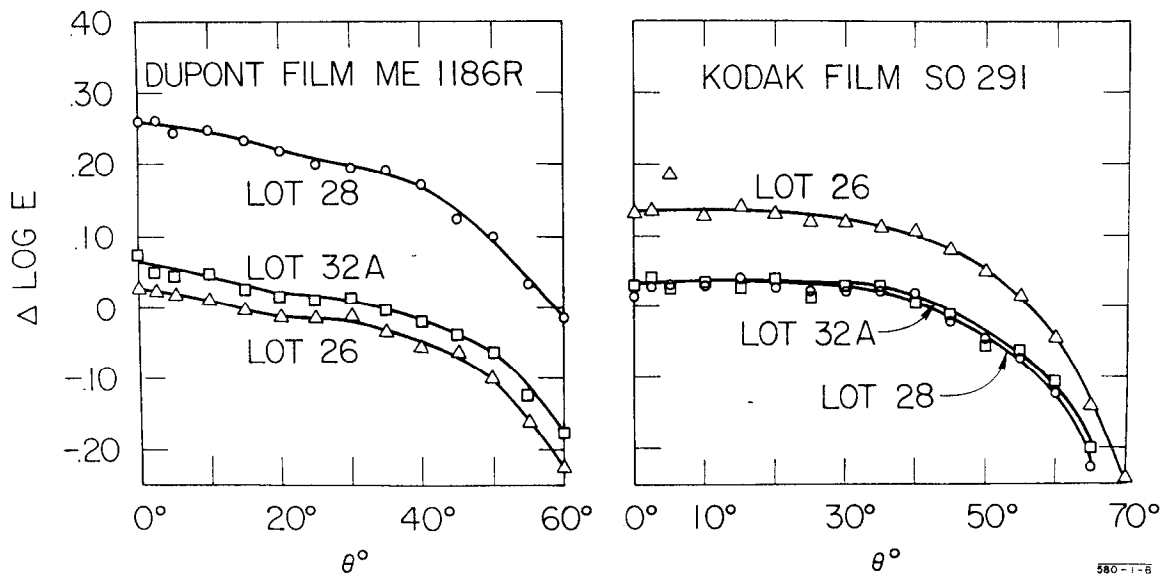


FIG. 1--Variation of the angular reflectivity of various batches of SPR 704 Scotchlite.

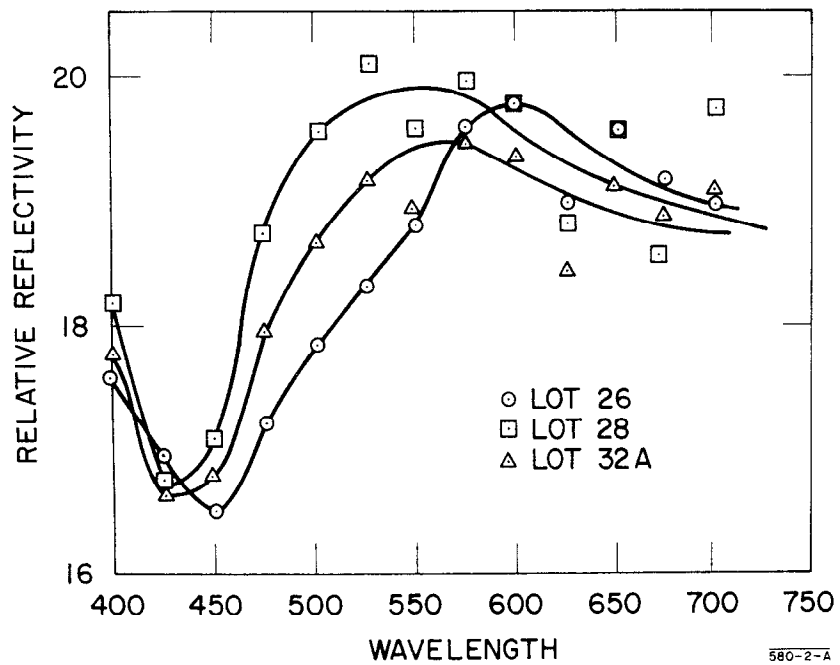


FIG. 2--Spectral reflectivity of Scotchlite.

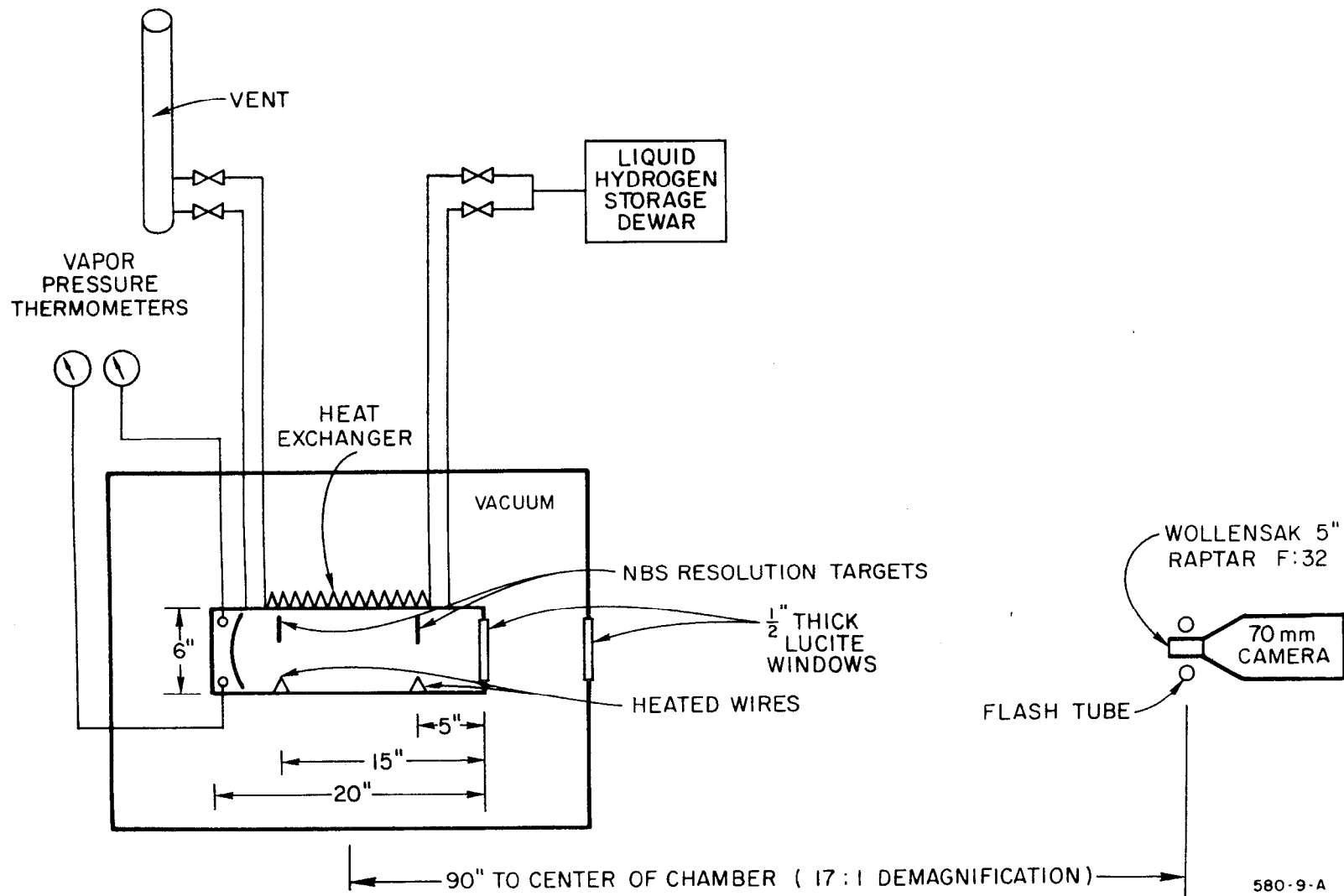


FIG. 3--Schematic configuration of Scotchlite in LH_2 experiment.

Bubbles could be generated at 5-inch and 15-inch depths by two methods:

- 1) Introduction of hydrogen gas through 0.001-inch-diameter capillaries.
- 2) Electrically heated thin wires.

Method (1) produced bubbles too large in diameter and was not used in the actual tests, but the heated wire generating method was satisfactory. The bubbles were photographed with a 70-mm camera and a ring flash tube, thus duplicating the proposed 40-inch HBC optical system. NBS resolution targets were mounted above the bubble-generating wires so that worsening of the photographic resolution with depth could be estimated. A photograph of the bubbles obtained with this apparatus is shown in Fig. 4.

IV. EVALUATION OF DATA FROM SIMULATED LH₂ CHAMBER TESTS

As the first step it was necessary to demonstrate that bubbles photographed in the test tank approximated the actual bubbles produced in a hydrogen bubble chamber. Films from the 30-inch BNL chamber taken with Scotchlite, Lot 26, were selected for the comparison. This was done both visually and by measuring density profile across the bubbles.

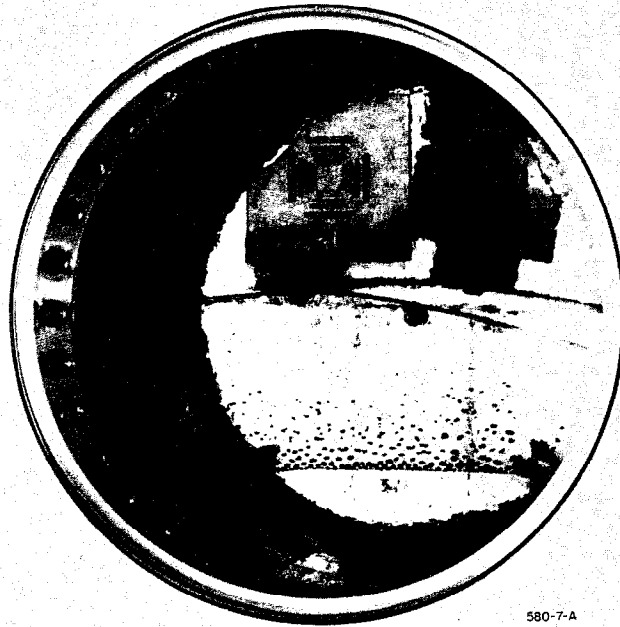
Test photographs of Lot 26 Scotchlite were viewed side by side with 30-inch chamber film, under identical conditions of illumination and magnification (Fig. 5). Bubbles could be selected from test photographs which were identical in appearance and size to actual track bubbles. The same pairs of bubbles were measured, using a modified Joyce-Loebel microdensitometer. Again the density profiles were similar (Fig. 6). It was concluded, therefore, that using the same Scotchlite retrodirector, our test chamber duplicated photographic characteristics of bubbles in an actual operating bubble chamber.

Measurements were then made to determine the effect of:

- a) Exposure, on bubble contrast, for the three different Scotchlite samples.
- b) Flash tube diameter on contrast.
- c) Chamber turbulence on bubble contrast.
- d) Exposure on visibility of chamber turbulence (background mottling).

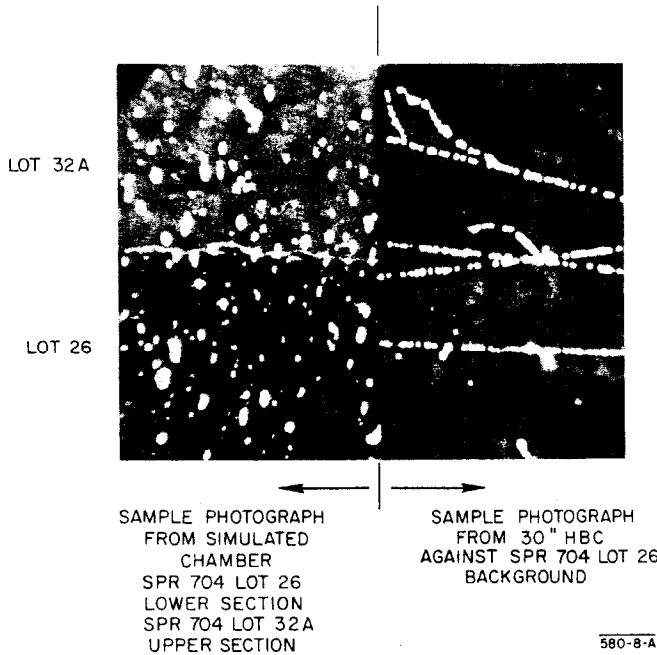
All tests were conducted at previously determined best focus. The two films used in the tests were Eastman Kodak SO 291 and Dupont ME 1186R.

Probably the most interesting result was obtained from measuring contrast as a function of exposure (Fig. 7). It can be seen that contrast, defined as a signal-to-noise ratio in microdensitometer readout, was independent of the batch of Scotchlite used, whereas the overall efficiency differed from one batch to the other. Thus, given enough light, the same contrast could be achieved with the least efficient of all Scotchlites tested, Lot 28, as with the best, Lot 26. With the light source configuration used in the 40-inch SLAC chamber, this amount of flash tube power required is not



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FIG. 4--Bubbles generated in LH₂ test tank by a heated wire at 5-inch depth.



LOT 32A

LOT 26

SAMPLE PHOTOGRAPH
FROM SIMULATED
CHAMBER
SPR 704 LOT 26
LOWER SECTION
SPR 704 LOT 32A
UPPER SECTION

SAMPLE PHOTOGRAPH
FROM 30" HBC
AGAINST SPR 704 LOT 26
BACKGROUND

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FIG. 5--Comparison of test bubbles with BNL 30" HBC tracks.

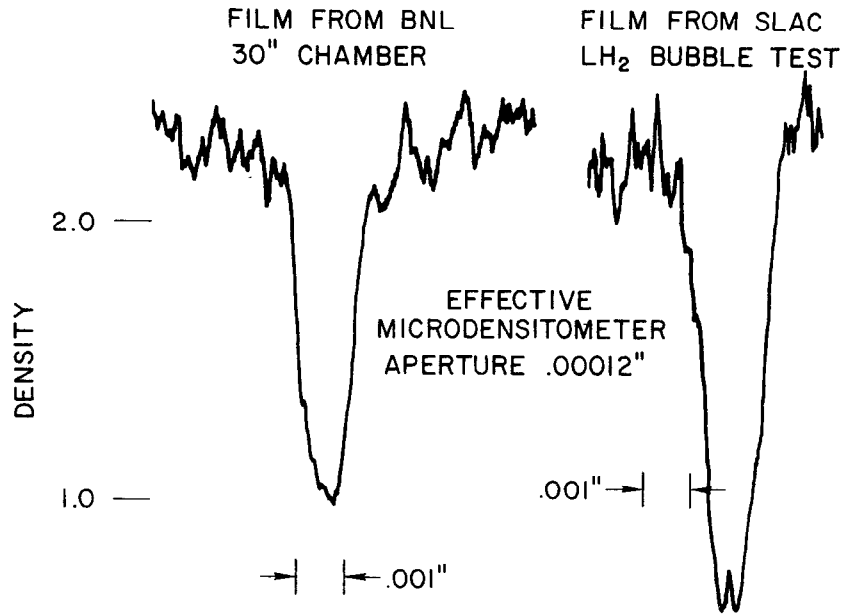


FIG. 6--Comparison of density profiles of photographs of test bubbles and BNL 30" HBC tracks.

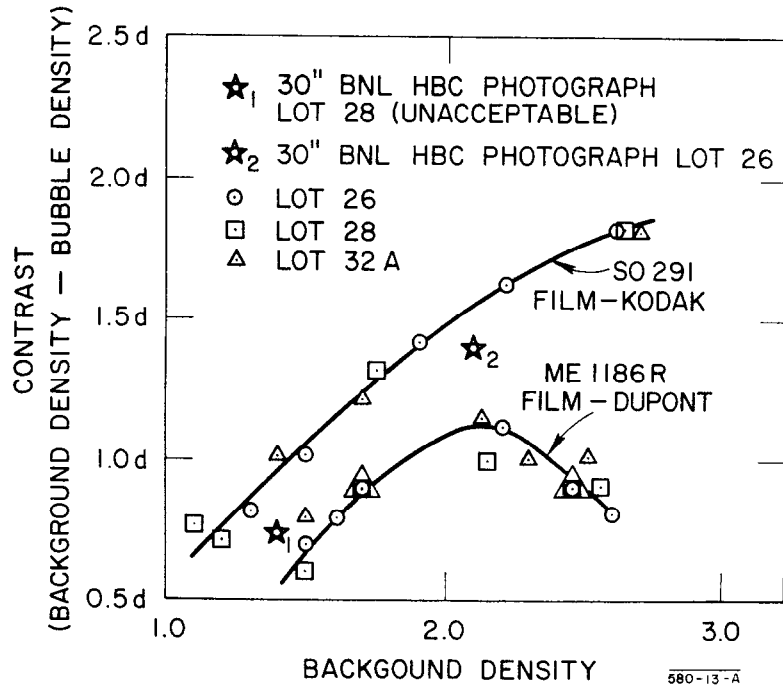


FIG. 7--Bubble contrast vs. background density.

excessive (Figs. 8 and 9).

An interesting effect was noted in comparing SO 291 and ME 1186R films. ME 1186R is not as red-sensitive, and it lacks an antihalation backing. The latter probably accounts for a relatively rapid fall-off of contrast with increased exposure. This effect as well as its lower contrast makes ME 1186R less suitable than SO 291 for use in our chamber.

Variation of flash tube diameter from 1-3/8 inches i. d. to 2 inches i. d. showed surprisingly little effect on achievable contrast (see Fig. 10). This is in contradiction with results predicted from known dispersion tests.

The chamber turbulence has a marked effect in reducing the obtainable contrast. It is probably responsible for the lower contrast observed when actual bubbles in hydrogen were compared to simulated conditions using glass beads in oil.

The test chamber turbulence was easily visible in the photographs as background mottling. However, it became progressively less noticeable as background density was increased, i. e., with increased exposure. Unfortunately this effect was only noted visually. Microdensitometer traces across the background were not consistent enough to indicate systematic increase of background uniformity with exposure.

V. OTHER SIMULATION TECHNIQUES

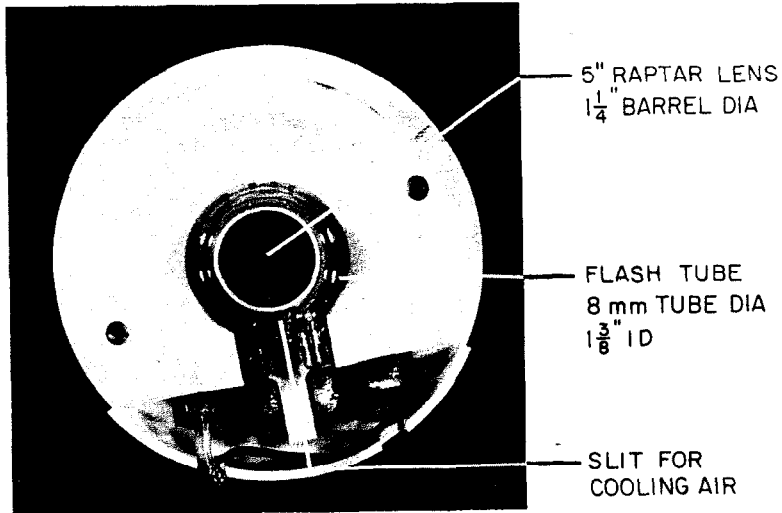
Theoretical considerations of contrast of bubbles in LH_2 indicated that they should behave as opaque spheres⁶. If so, chamber simulation could be simplified by resorting to glass beads in oil or even to opaque spots in air. Comparison of microdensitometer traces of such simulated bubbles is shown in Fig. 11. To further illustrate the validity of the simulation, Fig. 12 shows contrast versus background density of test bubbles in liquid hydrogen and for opaque spots in air. It appears that this simplest of all simulations is, in fact, valid.

Acknowledgments

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References

1. W. M. Powell, C. Oswald, G. Griffin, F. Swartz, "Bright-Field Bubble Chamber Illumination Using a Beaded Reflective Screen," Rev. Sci. Instr. (December 1963).



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FIG. 8--40-inch HBC light source configuration.

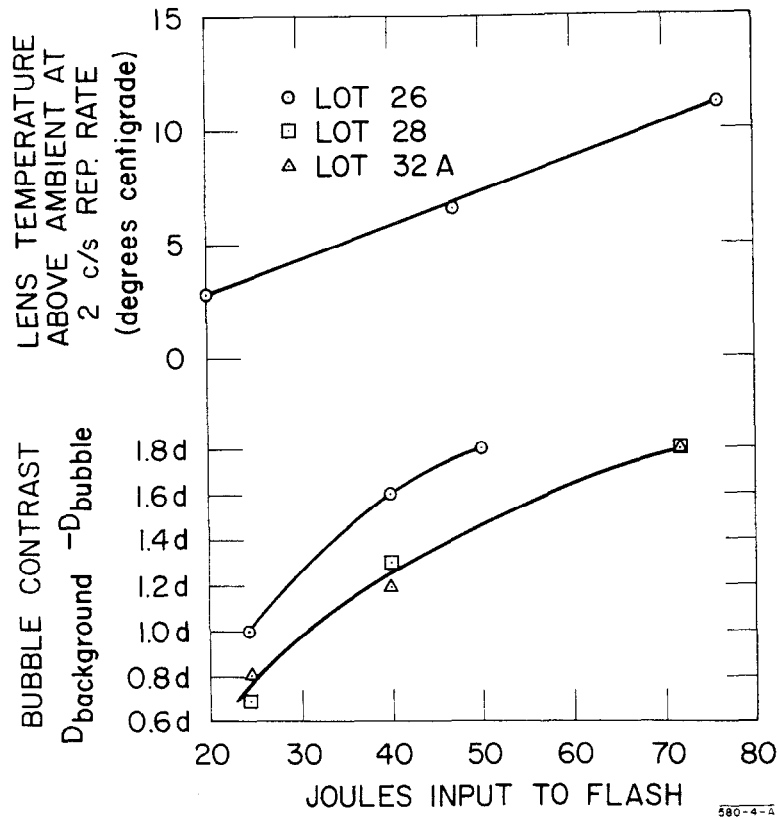


FIG. 9-- Bubble contrast vs. flash tube power input and lens temperature for 40-inch HBC.

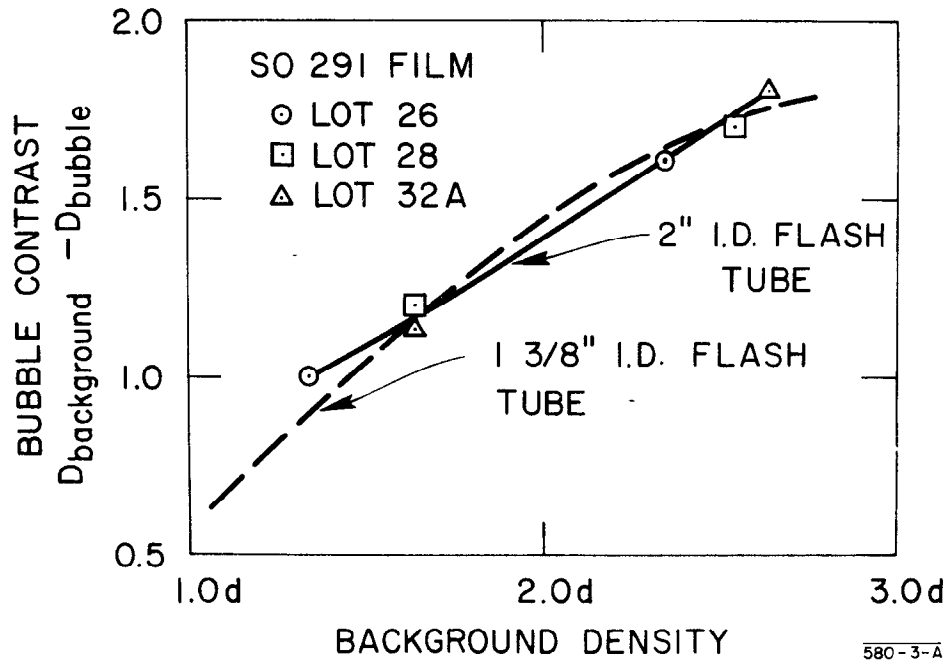


FIG. 10--Bubble contrast vs. background density for varying flashtube diameters.

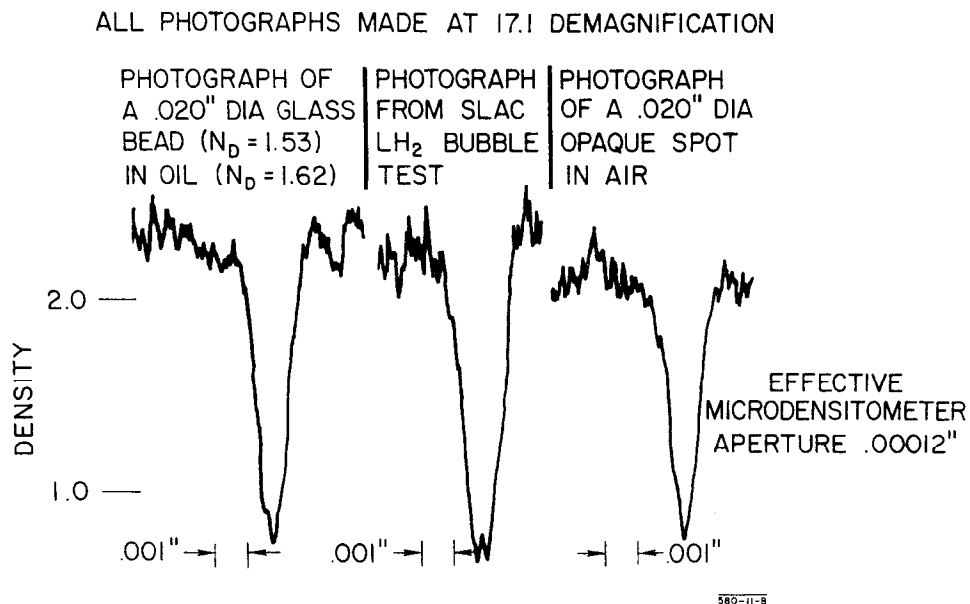


FIG. 11--Comparison of density profiles of photographs of opaque spots in air, glass beads in oil, and test bubbles in LH₂.

2. Private communication and film samples from A. G. Prodell, BNL
3. H. Brechna and W. Haldemann, "Physical Properties of Filament-Wound Glass Epoxy Structures as Applied to Possible Use in the LH₂ Bubble Chamber," Advances in Cryogenic Engineering, vol. II (1966).
4. J. T. Koehler, BNC. Private communication
5. C. Richardson and J. Koehler, unpublished data presented at Inter-Laboratory informal meeting on Scotchlite held at ANC on June 8, 1966.
6. H. Barney, "Looking Through the Bubble," private communication.

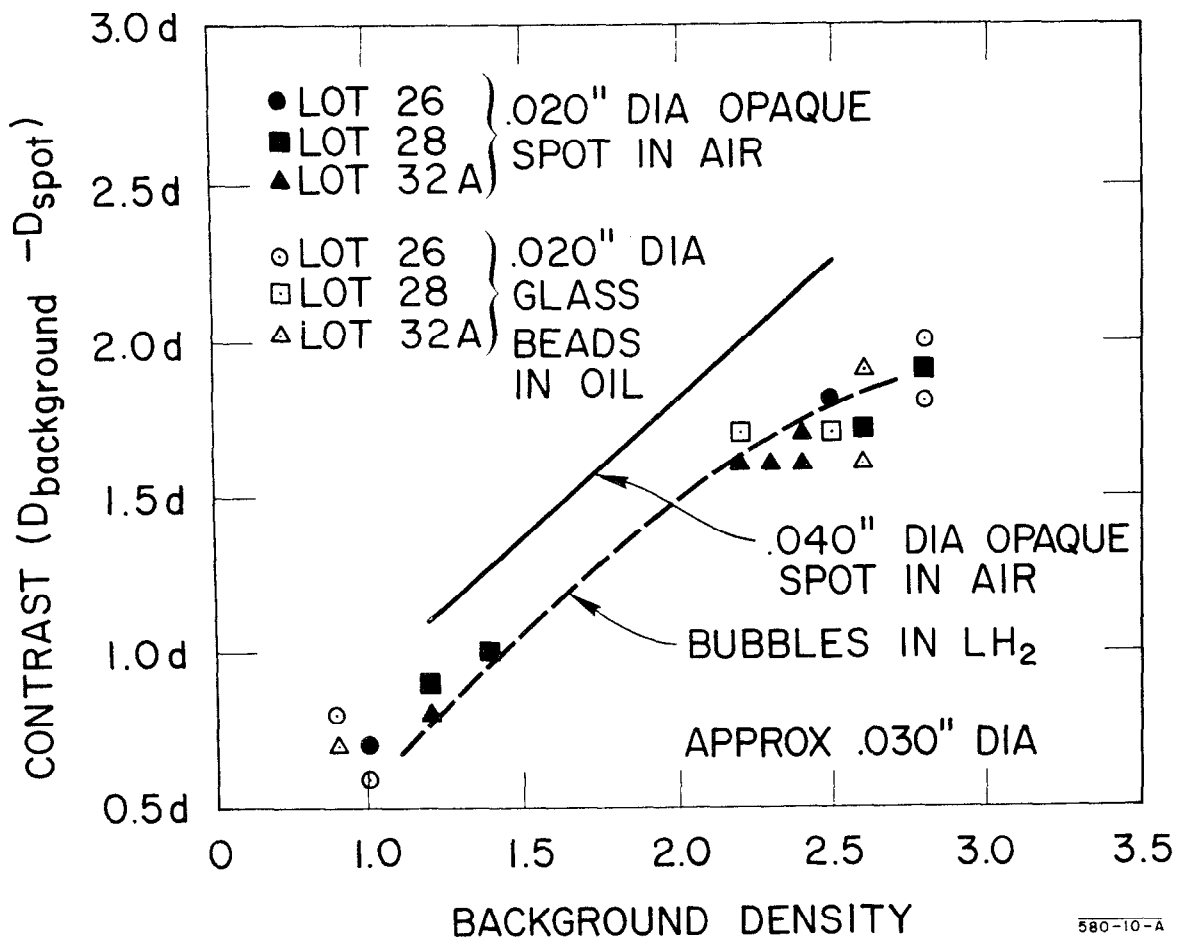


FIG. 12--Contrast vs. background density of opaque spots in air and test bubbles in LH₂.