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IMPROVEMENT OF THE DISTRIBUTION OF LIGHT SCATTERED BY BUBBLES IN THE CERN H.L.B.C.

1. Introduction

In the CERN heavy liquid bubble chamber illumination of track bubbles is provided by 8 flash tubes, the axes of which are parallel to the axis of the chamber. The tubes are arranged symmetrically around the perimeter of the chamber. To provent light passing directly from the flashes into the camera lenses the flashes are surrounded by thin metallic baffles which are painted matt black; these baffles also serve in restricting the light to within a certain angular range around the mean angle perpendicular to the flashes.

It had been noticed for some time that the light scattered from bubbles varied considerably throughout the chamber and that, in particular, the illumination near the plate was very low. An attempt had been made to increase the scattered light intensity at bubbles near the plate by having a system of baffles which had uniform spacing (d) from the window end to within about 150 mm of the plate end a spacing of 2 d from this point to the back of the chamber.

This report contains an analysis of the intensity distribution of light scattered by bubbles for various configurations of baffle spacing and geometry. Various suggestions for achieving a more uniform distribution are given. One of these suggestions has been adopted and appears to have improved the output of light at the back of the chamber.

2. Calculation of the Distribution of scattered Light Intensity

2.1 Since the light scattered by a bubble at a given point in the chamber is a complicated function of many factors a computer program was written to calculate the light scattered by a bubble situated at any place in the chamber.

The intensity of light scattered through a given angle by a bubble in a medium of refractive index μ is made up of constributions of multiple reflections inside the bubble. The scattering from a bubble in propane ($\mu = 1.25$) is shown in figure 1. This curve was calculated by a method similar to that of Davis (1955).

To reduce computing time to a reasonable level the following assumptions were made:

a) The flash is considered as a line source of light. In evaluating the contribution from a small region of the flash the section is considered as a point source with intensity proportional to the length of the section.

b) At reflection at the chamber walls one considers the reflection coefficient as constant. In practice the situation is more complicated because there is in general a phase shift during reflection at a metallic surface.

c) Absorption of light by the chamber liquid is neglected.

2.2 Organisation of the program

The program for calculating the intensity of illumination of light scattered by bubbles (FLASH) contains the following subprograms :

Subprogram Name	Use
REFRA	Given the co-ordinates of a bubble and the co-ordinate of one of the lenses evaluates the refraction path to the lens.
REFLEX	Calculates the reflection path from a region of the flash via the chamber walls to the bubble. The number of reflections is specified in the arguments of the program.

Subprogram Name (ctd.)	Use
INTENS	Calculates the incident intensity of illumination at the bubble after a given number of reflections at the wall. Due to the curvature of the walls there is a focussing effect and thus one cannot use simple inverse square law considerations.
SCATT	Calculates the amount of light scattered by the bubble at a given angle of deviation.
ANGPHI	Calculates the angle of deviation between the incident and scattered ray at the bubble.

Two versions of the program FLASH were written. One considered the existing baffle geometry (see figure 2); the other version considered annular baffles arranged symmetrically around the flash.

3. Scattered Intensity of Illumination using the existing Baffle Geometry

In figure 3 the scattered light intensity is plotted as a function of the distance of the bubble from the back of the chamber; in this case there is no reflection at the walls. The bubbles are considered to be on the axis of the chamber. In figure 4 wall reflections are taken into consideration. The camera position is also on axis; this greatly reduces computing time without unduly altering the results. Various baffle spacings are considered in curves a, b and c. Curve d corresponds to the baffle spacing system used in the chamber for the past few years. As can be seen, both with the chamber walls reflecting and non-reflecting, the solution which has been used until now to increase the intensity at the back of the chamber is only slightly effective; the gain in light output from the back of the chamber is offset by the increased intensity of illumination at approximately 250 mm from the back. Curves e represent the effect of two modifications to the system, (a) coating the last 100 mm of the flash with gold in such a way that the gold film covers approximately half the perimeter of the flash and is placed away from the axis of the chamber and (b) polishing the sides of the baffles which are facing the membrane (again over the 100 mm of the flash nearest the membrane).

In practice the baffles are grouped (for ease of mounting) into 3 sets. The system is such that between the individual sets there are spaces where about 20 mm of flash is exposed. The light from these spaces would modify the curves shown in figures 3 and 4 such that the intensity of illumination is a maximum at the face of the window. In any modification it will be necessary to suppress this additional contribution.

Figure 5 shows the distribution of the scattered intensity of illumination in a plane 500 mm from the back of the chamber and perpendicular to the chamber axis. Due to the reflections at the walls a roseate pattern can be seen. Similar patterns have in fact been observed in the chamber when the liquid is dirty and are due to the focussing effects of the walls.

5. The scattered Intensity of Illumination using annular Baffles

The intensity of illumination obtained by using annular baffles of width 10 mm arranged symmetrically around the flash was calculated to see whether this system offered any definite advantages over the present system. Figures 6 and 7 illustrate the illumination due to bubbles placed as in figures 3 and 4. Although the distribution is more uniform it can be seen that the magnitude of the intensity over the majority of the length is substantially lower than that found using the present system. Figure 8 shows the distribution in a plane perpendicular to the axis.

5. Collimating Systems

It is possible, whilst maintaining the same angular output distribution of light from the flash tubes, to increase the amount of light transmitted by using special collimating systems.

Figure 9 (a) represents the collimating system employed at present. From the point of view of paraxial optics the system shown in figure 9 (b) has the same angular output distribution, however, in this case light is collected from a greater length of the flash so that, again in the paraxial optics sense, the light output is effectively doubled. The annular lens in figure 9 (b) has a focal length of 1/2. Figure 9 (c) shows the thick lens equivalent of figure 9 (b).

Two other collimating systems are shown in figures 10 and 11. In both cases one relies on reflection of light at the non-transmitting portion of input side of the collimator to compensate for the fact that the effective aperture of the system is reduced. Optimum dimensions of both systems have been obtained and although the light output is more than doubled as compared to the classical system, difficulties of manufacture seem to preclude their use.

6. Conclusions

The present work shows that it is possible to achieve a more homogeneous distribution of light scattered by bubbles. By modifying the region of the flash nearest the membrane it is possible to increase substantially the illumination at the back of the chamber. The system of annular baffles arranged symmetrically around the flash offers the advantage of a more homogeneous light distribution but even with the incorporation of collimators the intensity level is not as great as in the present system of baffle geometry.

The system described in section 3 and illustrated in figures 3 (e) and 4 (e) has already been installed in the chamber. Examination of photographs obtained with the chamber running and preliminary tests of the system in which scattered light by bubbles in water was observed indicate that this configuration does indeed give an increase in light output at the back of the chamber although the illumination is still less in this region. A system of collimation for the end of the flash tube nearest the membrane is now being designed and it is hoped that this will further increase the illumination at the back of the chamber.

7. Acknowledgements

I should like to thank A. Lefrançois and D.C. Cundy for useful discussions and suggestions.

M. Price

Reference

G.E. Davis - Journal of the Optical Society of America, 45, 572, 1955.

Distribution : (open)

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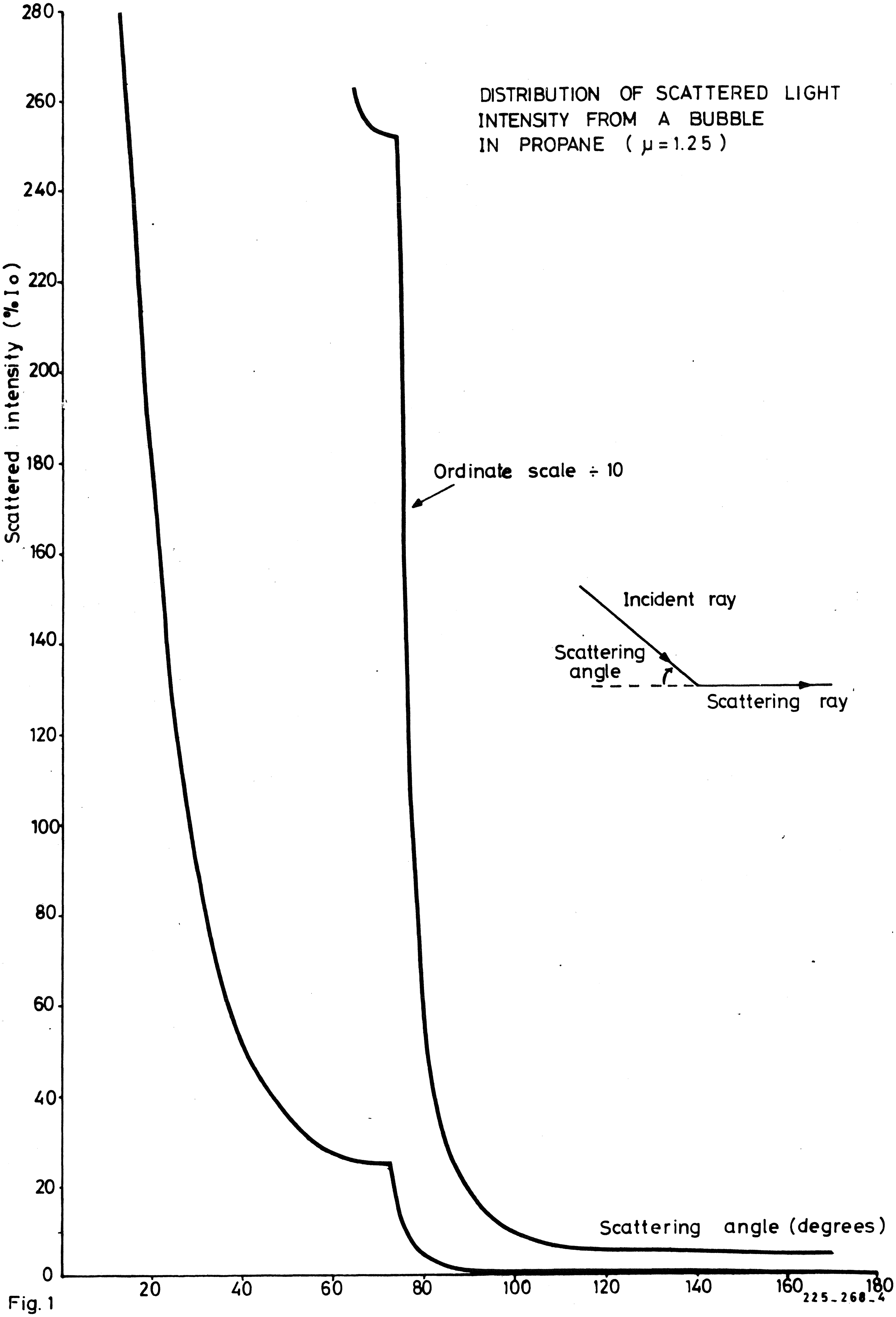

Fig. 1

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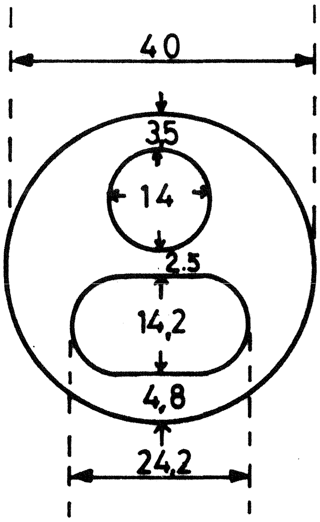
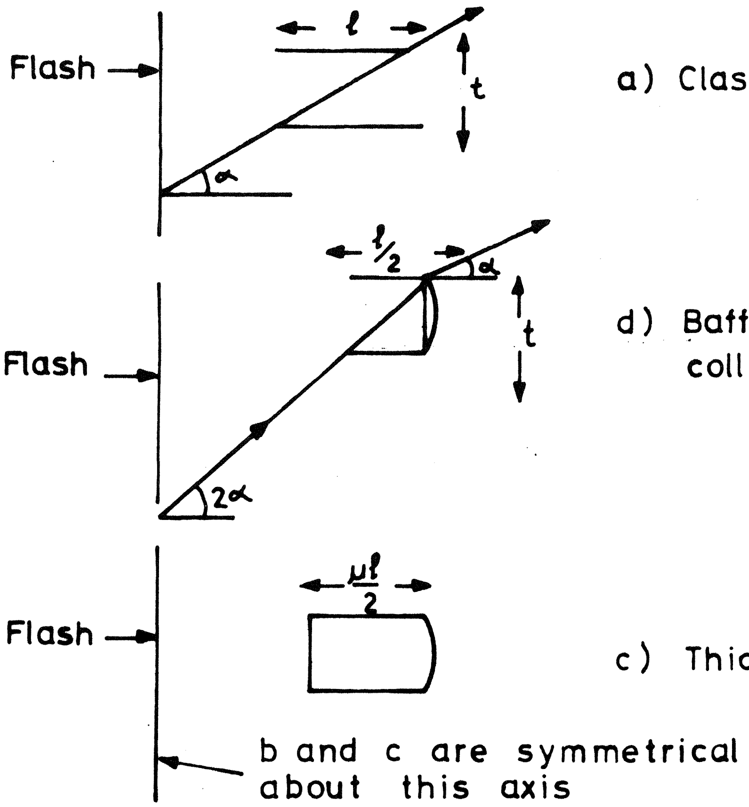


Baffle geometry and dimensions (in mm)

Fig. 2



a) Classical baffle system

d) Baffle system with simple collinating lens

c) Thick lens equivalent of 6)

Fig. 9

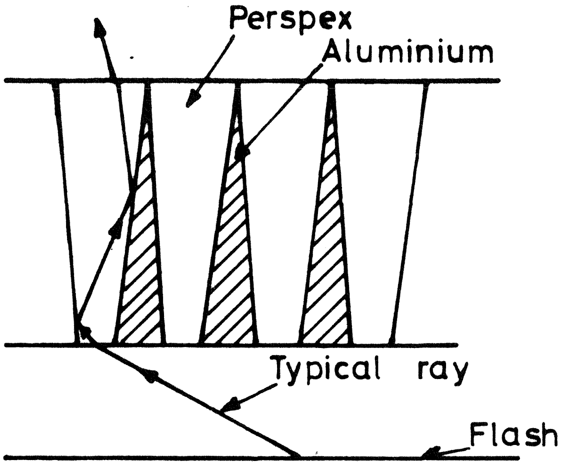


Fig. 10

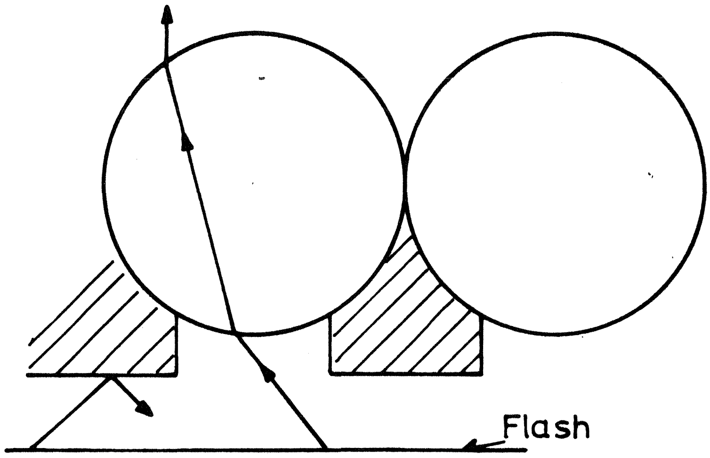


Fig. 11

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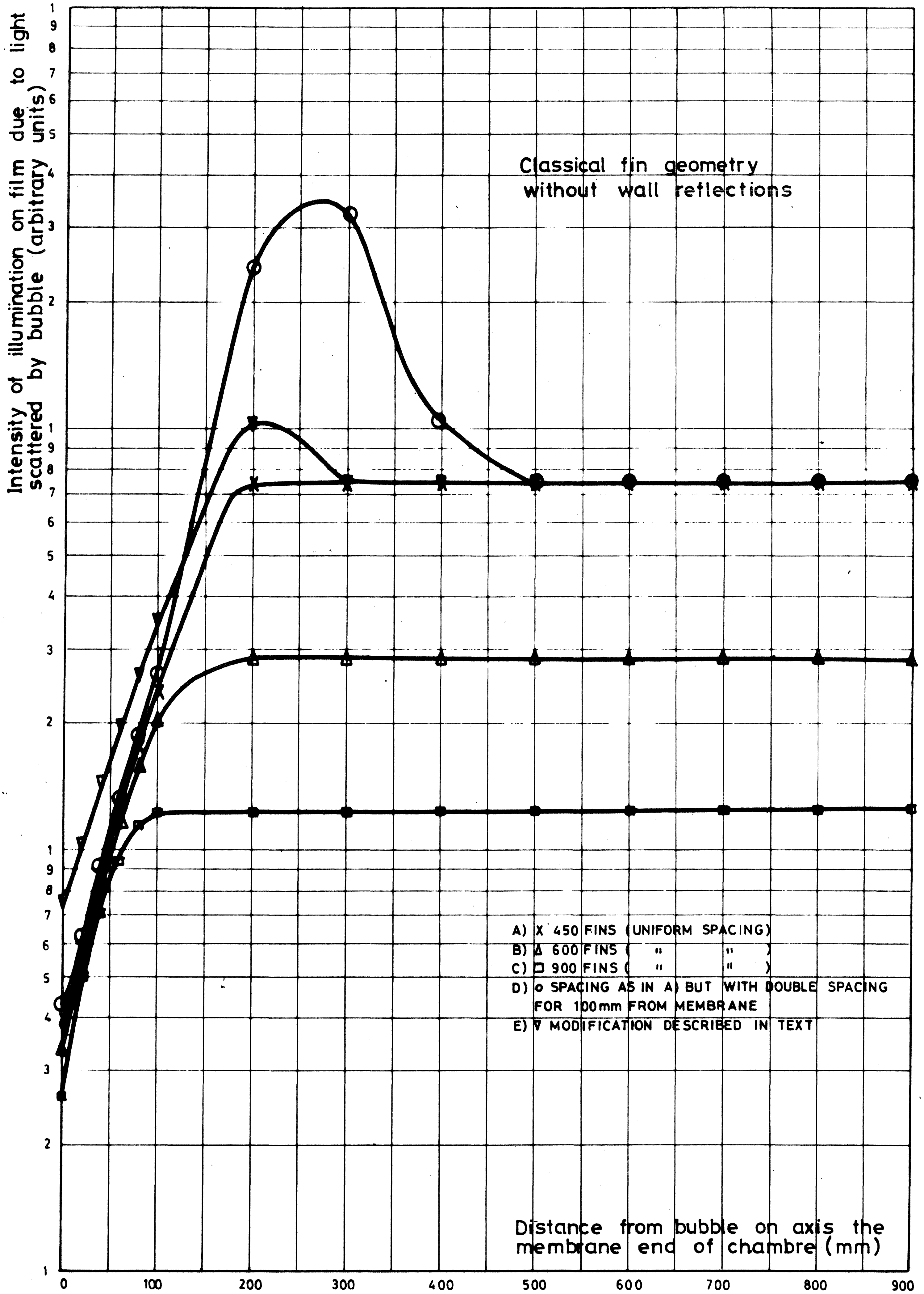

Fig. 3

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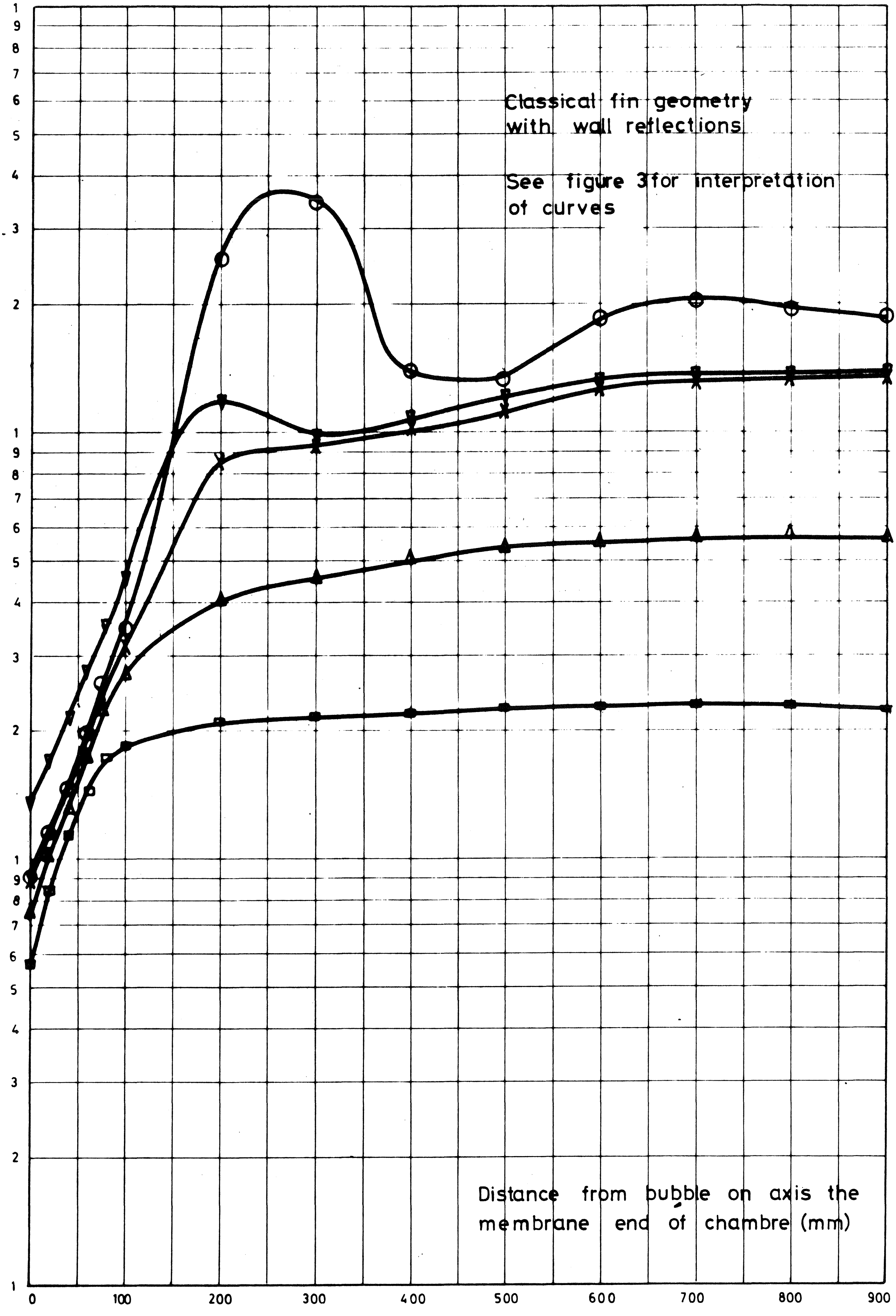

Fig. 4

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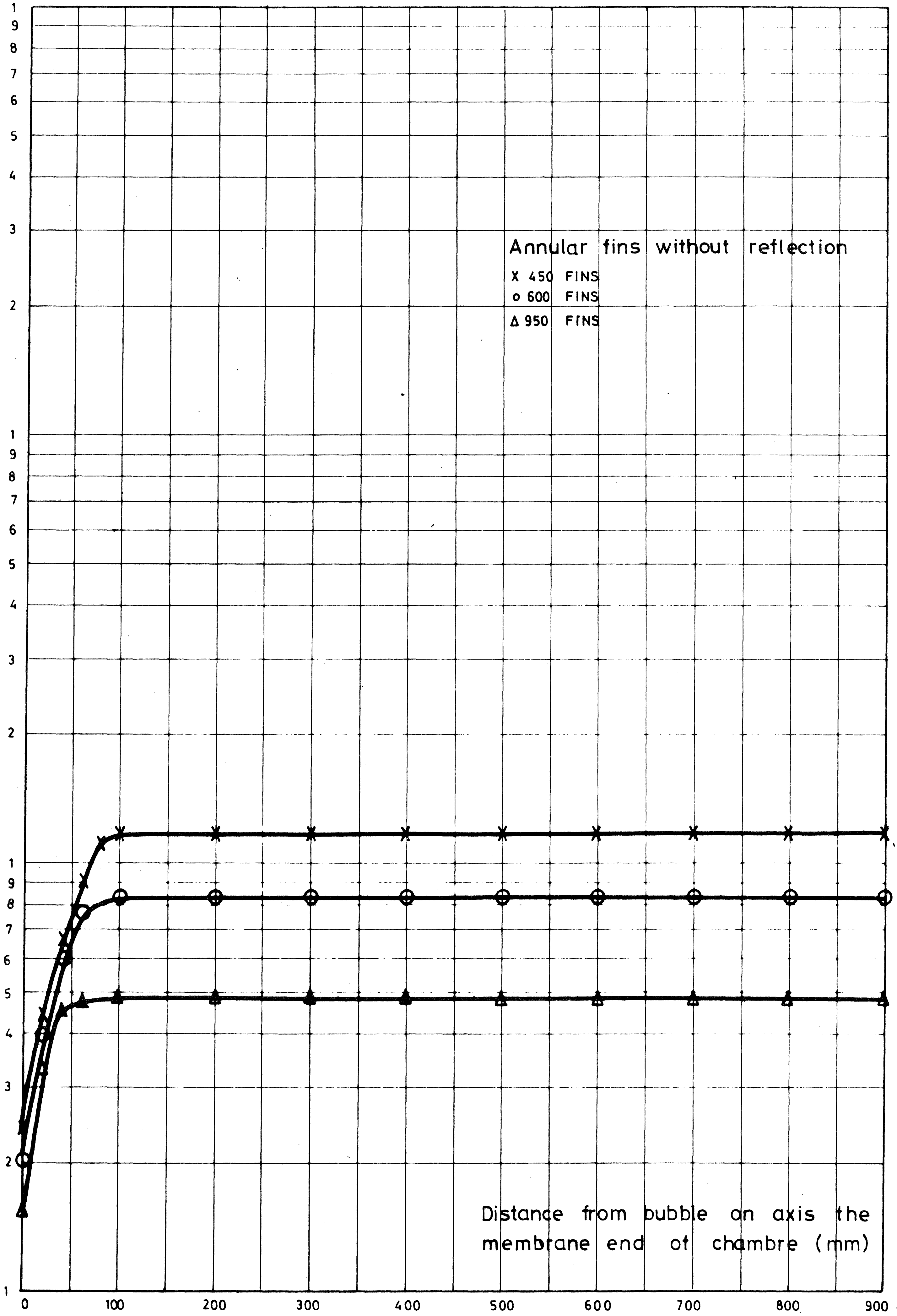

Fig. 6

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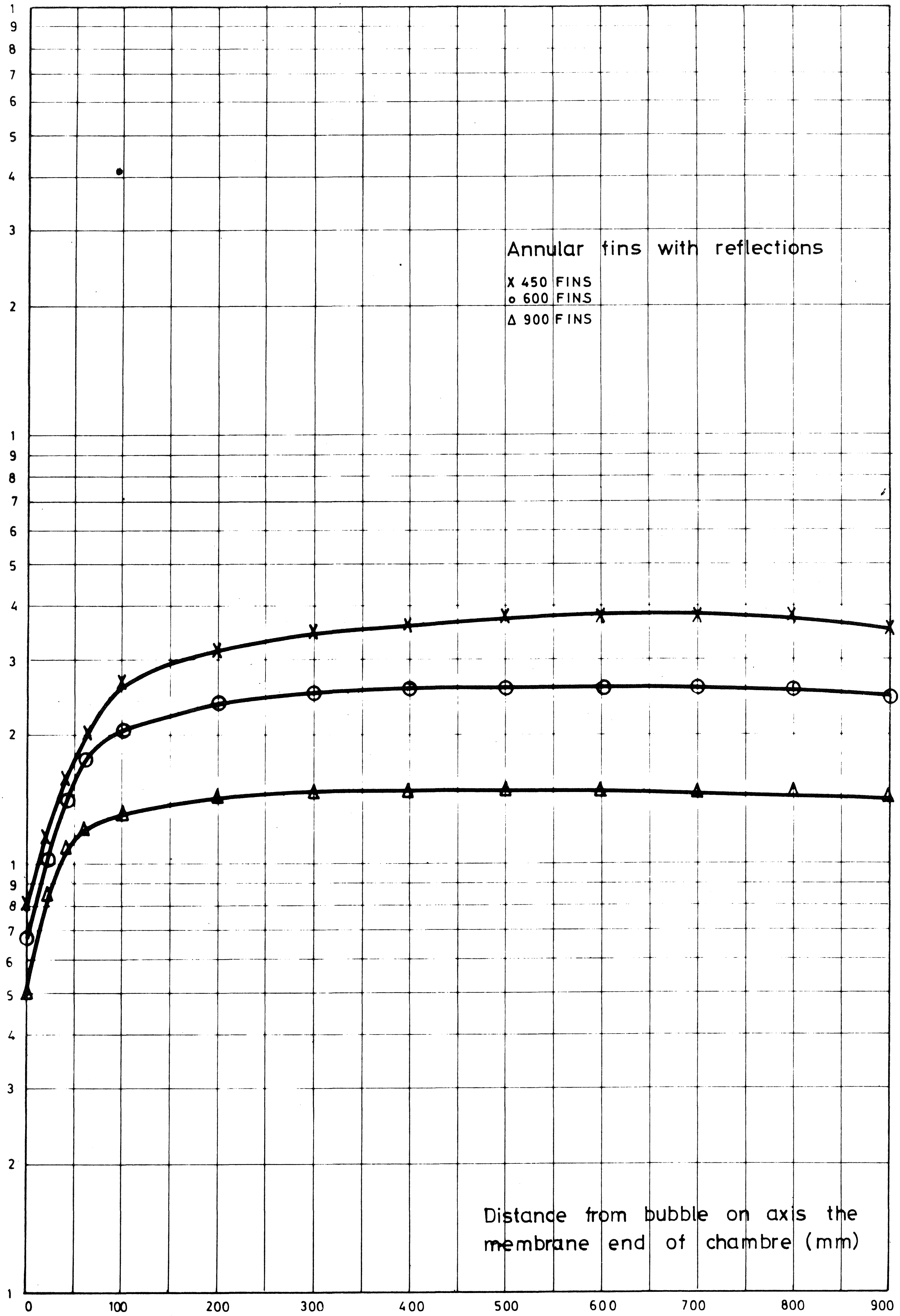

Fig. 7

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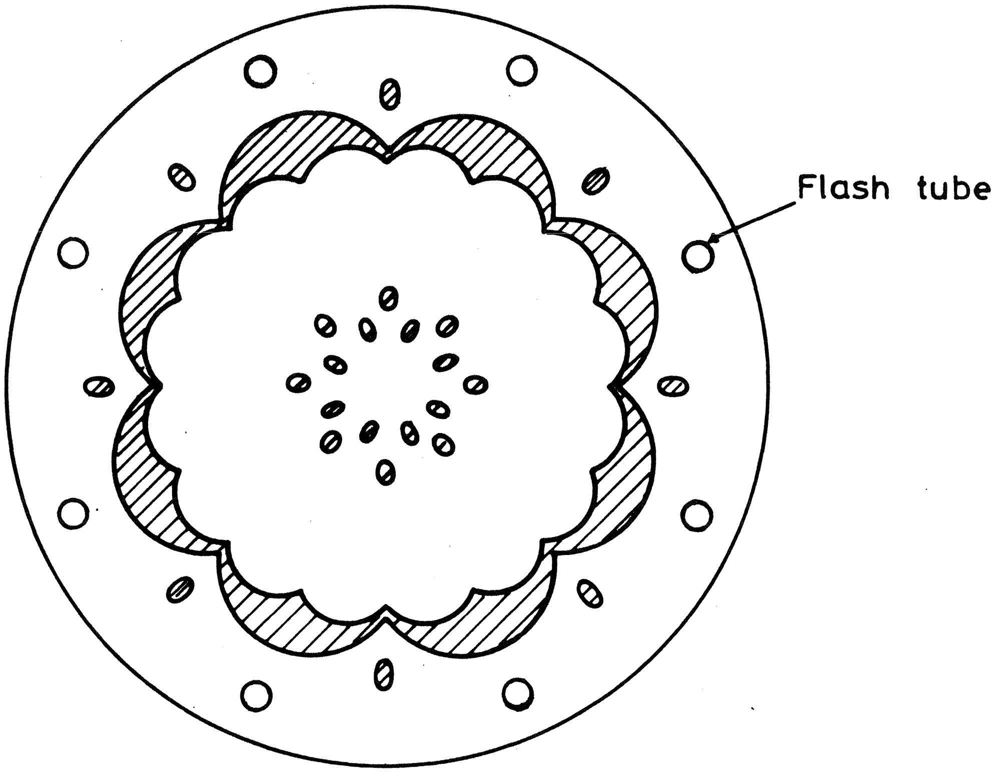

Fig. 5: Classical fin geometry

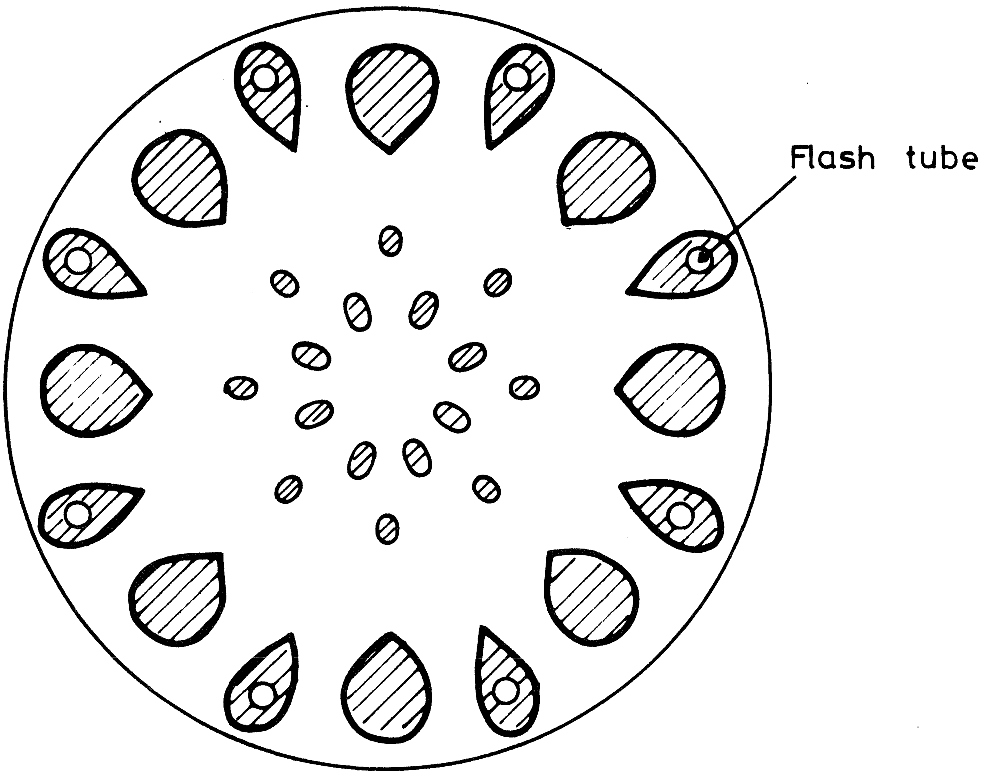

Fig. 8: Annular fins.

Figures 5and 8 illustrate the intensity distribution in a plane normal to the axis of the chamber: shaded areas indicate regions in which the intensity is more than 3 times the mean intensity.

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