# An Extended Use of the Hydrogen Bubble Flow Visualization Method

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THE establishment of the hydrogen bubble flow visualization method as an experimental tool for both quantitative and qualitative measurements for study of flows in a water medium has now been well made. The success of this instrument over less or better known techniques can be summarized briefly by the following points: 1) it does not permanently discolor the fluid; 2) the small size of generating wire minimizes the possible disturbance to the flow proper; 3) the use of combined streak lines gives a comprehensive picture of the velocity field of unsteady flows;[1] and 4) tracer particles are easily placed in the flow at any desired location.

Sources of error have been extensively analyzed,[1] and the accuracy has been demonstrated to be at least as good as any other method available for use in water. Even more recent work at the David Taylor Model Basin has shown that it is now possible to use the bubble with a flow velocity as high as 20 ft/sec.[2] The low velocity had previously been a limitation. The purpose of this note is to report yet another extension and possibility for investigation: namely, measurements in liquid-water mixtures. Specifically, excellent success of the hydrogen bubbly method was achieved in a glycerine-water mixture up to 40% (by weight) of glycerine.

Constant time lines were generated by energizing a wire with a Hewlett-Packard 214A pulse generator, which had to be operated at maximum amplitude, when a pulse width of 5.0 msec was required to produce lines that could be photographed. At speeds up to 1 fps, such a pulse width gave clearly defined lines, but at higher speeds the lines became progressively more ragged, which would badly reduce the accuracy of quantitative data. Excellent streak lines were produced by a 3-in. length of kinked wire by an applied d.c. source of 30–50 v.

Glycerine-water mixtures became permanently cloudy with continued use; lighting therefore requires careful attention.

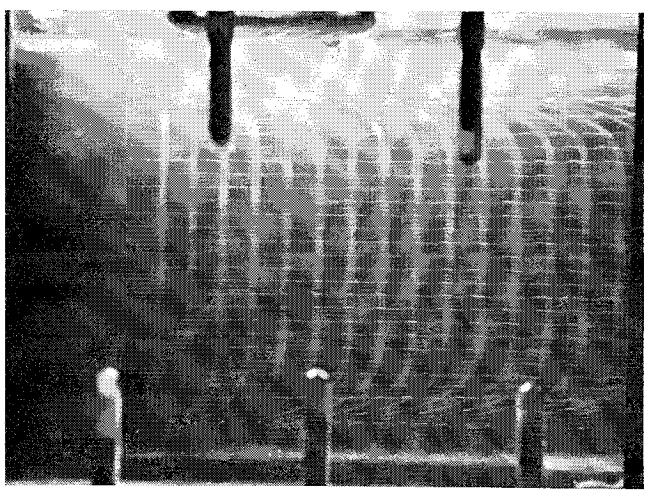

**Fig. 1 Developing plane Poiseuille flow in glycerin-water mixture (35% by weight).**

A sharply collimated source proved most effective, whereas the use of matt-black paint whenever possible helped to reduce light scatter. More efficient filtering of the water supply or purer water might eliminate this difficulty.

A typical photograph taken in a 35% mixture is offered as a sample of the mixture usage (Fig. 1). This picture was made in a channel 3 in. deep, 12 in. wide, and 6 ft long, as a plane Poiseuille flow was developing from rest. The pulsing wire used was one of the kinked variety, and for reference the pulse lines (actually bands) are $\frac{1}{20}$ sec apart.

### References

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[2] Mattingly, G. E., Jr., "Hydrogen bubble visualization technique," David Taylor Model Basin Rept., Washington, D.C. (to be published).

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# Transient Stresses in Solids Induced by Radiant Surface Heating

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IF the surface of a solid is exposed to a very high rate of radiant heating, transient stresses may be induced either by thermoelastic coupling at low surface temperatures or by rapid vaporization at high surface temperatures. The magnitude of both of these phenomena is strongly dependent upon the rate at which energy is supplied to or absorbed at the surface. This note will discuss some preliminary considerations and describe experiments on rod-type specimens heated in an arc-imaging facility.

If the free surface of a solid is suddenly heated, it is possible to generate elastic stress waves propagating from the surface into the solid. This problem was first specifically analyzed by Danilovskaya[1] in 1950, although the governing equations have been available for some time. Since 1950, a large number of theoretical papers have appeared,[2] and within the last few years qualitative experimental evidence has been obtained.[3–5] The stresses considered are developed solely from the inertial restraint of the thermally expanding material, so that it is necessary to heat the surface extremely fast in order that appreciable particle accelerations are induced. In fact, the rise time of the surface temperatures must be short compared with the characteristic mechanical response time of the solid.

The experimental evidence for this phenomenon has been obtained with pulsed (on the order of 1 $\mu$sec or less) energy sources. These include exploding wires,[3] pulsed lasers,[4, 5] and pulsed microwave energy and electron beams.[4] The results all show pressure signals detected at positions remote from the radiated surface and arriving at times appropriate for propagating elastic waves. Quantitative agreement is not always possible because of the difficulty in prescribing the amplitude and distribution of the absorbed energy.

If the total energy input as well as the flux or power density is large, the surface rapidly reaches the vaporization temperature, and a pressure is established proportional to the rate of

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