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Note on Observations of Cavitation in Different Fluids

Many observations [1, 2, 3][3] have shown that the performance of a centrifugal pump with different fluids or with the same fluid at different temperatures is not the same at the same cavitation number when the latter is based upon the vapor pressure of the bulk fluid. Various similarity rules have been put forward in these works to account for the observed effect; namely, that lower net positive suction heads are achievable in most cases compared to those observed in cold tap water. This difference is ascribed to the thermal effect associated with evaporating a certain fraction of the bulk fluid and the attendant decrease of vapor pressure. Scaling rules of the vapor-pressure decrease are made by assuming the process static and that all of the fluid in the inlet of the pump is at the same pressure. The measurements of Salemann [4] show that such a simple concept is inadequate, and he offers further speculations about the nature of the cavitation process as do Acosta and Hollander [5]. The purpose of this note is to describe an experiment intended to show the types of cavitation that occur and, where possible, to measure directly the reduction of vapor pressure or net positive suction head observed in pump experiments.

The test arrangement consists of a closed hydraulic loop, a means of pressurization, recirculation, and a cylindrical test section. The test section is composed of a glass working section 1.1 in. in diameter and 4 in. long, and an upstream stilling section 12 in. in diameter. The stilling section contains a vapor-pressure bomb containing the working fluid, a support system on which objects are mounted and made to cavitate in the transparent working section, and a differential manometer with associated valving. External heating and cooling heat exchangers are also available. The purpose of the manometer is to measure the difference in pressure between the cavity formed in the working section and the vapor pressure of the flowing fluid. This difference, other things being equal, will be a direct measure of the change required in NPSH (net positive suction head) for various fluids and inlet conditions. However, as will be seen, it is not always possible to measure the cavity pressure.

Preliminary measurements and observations have been made with water up to 250 F and Freon 113, a fluorinated hydrocarbon with a normal boiling point of 117 F. Cavitation was observed behind a $^3/_{16}$-in. disk held normal to the stream in the working section. A small tube transmitted the pressure within the cavity behind the disk to the manometer through the support assembly. A disk was used in these experiments only for convenience. In the future, shapes that do not give a separated wake will also be used. Some shortcomings and limitations of the equipment were revealed in these first experiments. However, the following observations can be made: At inception, a cloud of small cavitation bubbles filled the wake behind the disk. As the inlet pressure was lowered, this region grew until (in water) the cavity length was about 10 disk diameters, at which time a clear and distinct bubble with a fluctuating re-entrant jet was formed similar to that observed in water tunnels, Fig. 1(*a*). This jet frequently impinged on the back side of the disk and prevented measurement of the cavity pressure. With further reduction of the cavity pressure, the cavity disappeared downstream, and the working section became "choked." Under these conditions, the pressure in the cavity with water as the working fluid was found to be about $^1/_2$ in. Hg less than the vapor pressure at temperatures of 200–250 F. The dissolved air content was about 2 ppm for these tests. Similar observations in water at room temperature have shown the cavity pressure to be greater than the vapor pressure by about 25 per cent. This is due to air diffusion, whereas the vapor-pressure depression observed supports the contention [5] that vapor entrainment and subsequent evaporation from the surface (and hence cooling) lower the vapor pressure at these higher temperatures.

Several photographs of cavities of moderate length in Freon and water are shown in Fig. 1. It is apparent that the form of the cavitation is quite different in the two liquids, a fact suggested in [4]. While the water cavities are relatively clear and well defined, the Freon cavities are always indistinct and frothy, consisting of many small bubbles. Whereas the entrainment from the cavity is slight in the case of water, it is dominant in Freon. The frothy character of the Freon cavity precluded measurement of cavity pressure. Interestingly enough, the vapor-pressure depression of the Freon was sufficient, evidently, to prevent the tunnel from becoming choked, and a clear bubble could not be observed for any combination of temperature or pressure available.

From the foregoing remarks, it can be seen that similarity arguments not based upon physical observations are likely to be inappropriate. In this connection, we point out that the Freon and water-cavitation photographs in Fig. 1 are paired to be at the same value of B[4] [2, 4], ranging from $B = 2$ to 0.65. It is clear that this parameter does not insure a similar form of cavitation. Likewise, it would appear that similarity arguments based on vapor entrainment and heat transfer[5] to the cavity surface will not be general, either. Although this mechanism appears to be reasonable for water, sufficient experimental work has not yet been done to examine this suggestion in detail. Also, it must be remarked that the concentration of cavitation nuclei in various fluids and under various conditions may play a dominant role in the cavitation scale effects being considered here. The thermodynamic processes alluded to herein may, therefore, be only incidental.

The instrumentation of these experiments did not permit direct comparison of the cavitation numbers to be made for cavities of the same size but of various temperatures, nor could the velocity be varied over a sufficiently wide range. Further work along these lines is continuing, and it is hoped that the outcome of these experiments can be reported in the near future.

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[3] Numbers in brackets designate References at end of paper.

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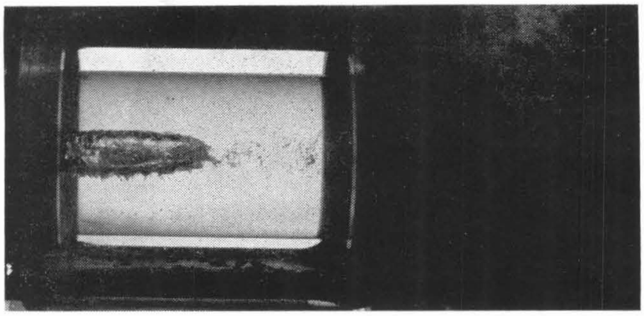
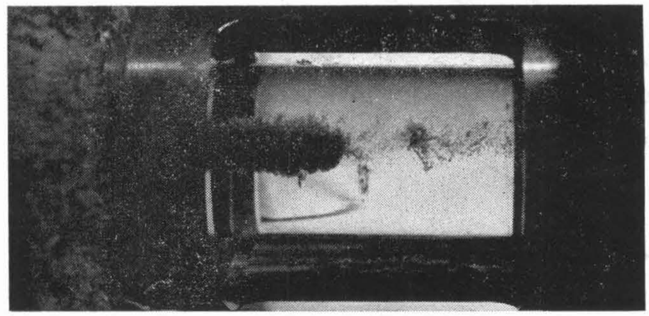
[4] The vapor-liquid volume ratio for a head depression of 1 ft.

[5] The presence of heat transfer requires as additional parameters, for similarity, the Reynolds number and Prandtl number. The exact functional dependence depends on the type of flow and the particular boundary conditions.

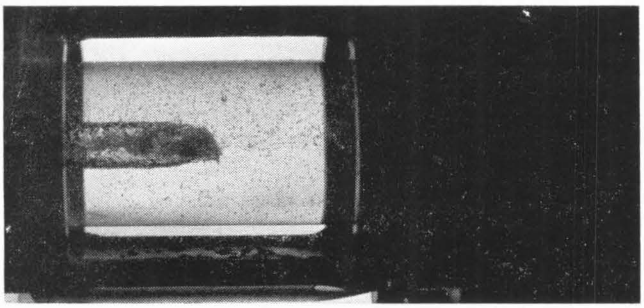
Discussion on this paper will be accepted at ASME Headquarters until January 10, 1961



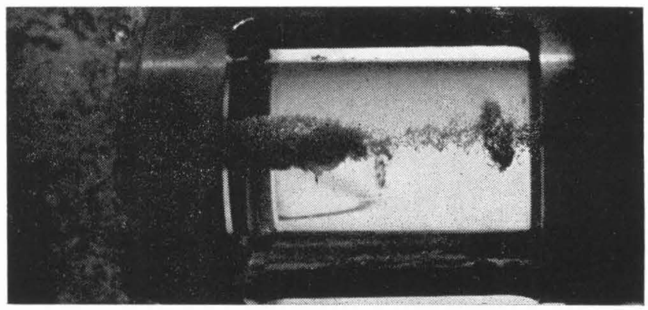
(a) **Water, *B* = 2 (nominal temperature, 208 F)**



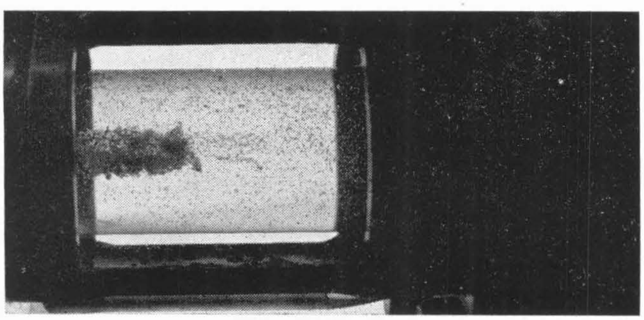
(b) **Freon 113, *B* = 2 (nominal temperature, 115 F)**



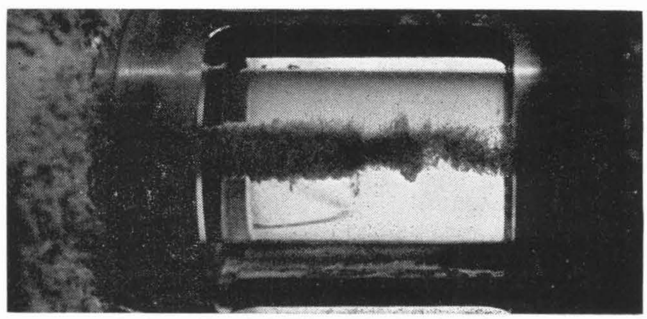
(c) **Water, *B* = 1.0 (239 F)**



(d) **Freon 113 *B* = 1.0 (135 F)**



(e) **Water, *B* = 0.65 (245 F)**



(f) **Freon 113, *B* = 0.65 (150 F)**

Fig. 1 Photographs of cavities formed on a small disk. Flow is from left to right, and disk is just out of view. Nominal flow velocity is 19 fps. Photographs are compared on the same value of *B* (vapor-liquid volume ratio for a head depression of 1 ft).

Acknowledgments

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