UNIVERSITY OF MICHIGAN

Department of Mechanical Engineering

Cavitation and Multiphase Flow Laboratory

Report No. UMICH 01357-31-I

Standard Method of

VIBRATORY CAVITATION EROSION TEST - ADDENDUM I

(Second preliminary draft)

Close-Clearance Stationary Specimen Test and Tests with Different Temperature, Pressure, and Liquid Conditions

F. G. Hammitt

(Chairman, Sub-Committee, Cavitation and Impingement Erosion of ASTM Committee G-2)

Support provided by:

NSF Grant GK 1889

December, 1974

Standard Method of VIBRATORY CAVITATION EROSION TEST - Addendum I

INTRODUCTION

The standard method already promulgated (1) covers the usual cavitation erosion vibratory test situation wherein the specimen is vibrated at high frequency (20 kHz standard) in a quiescent pool of the test liquid (cold water). The container walls are relatively remote from the vibrating specimen ($\sim 10^3$ x the vibration amplitude). The acceleration imposed by the vibration on the specimen is $\sim 10^4$-10^5 "g", imposing considerable stresses upon the attachment device between horn and specimen, as well as stresses of important magnitude to the eroded region of the specimen.

There are cases where it is undesirable (or impossible) because of the nature of the test material (elastomerics, e.g.) to use this standard test set-up, since the test material may not be sufficiently strong and/or rigid. Successful tests of such materials, however, are reported (2).

There are also cases where the "open" geometry of the standard test is not optimum. For example, there are many cases where cavitation in slot geometry (bearings, centrifugal pump wearing rings, stationary close-clearance passages as valve seats, etc.) is the end application of the testing. For

these cases, a vibratory cavitation test set-up is possible (and has received some utilization) wherein the test specimen is in the form of a stationary "anvil", near to which the vibrating horn with a dummy specimen is brought (3-7). The resultant cavitation field produces erosion upon the stationary specimen as well as of course the vibrating dummy specimen, which can be replaced as necessary. Obviously this arrangement models much more closely bearing applications, etc. than does the standard open test geometry, since the mean clearance between vibrating dummy specimen and stationary test specimen is of the order 0.020 in. (0.51mm).

There are other cases where it is desired to conduct vibratory cavitation erosion tests at temperatures, pressures, or for liquids other than those specified in the standard, i.e. 72^{o}F (22^{o}C), 1 atmos., water. Wide variations in all these parameters have been utilized already in many tests (8-13, e.g.)

It is the purpose of this addendum to provide information to standardize the variables described above. All definitions and explanations already in this Standard Method are still applicable unless specifically stated to the contrary.

1. APPARATUS

1.1 Close-Clearance, Stationary Specimen Test

1.1.1 Figure 1 (of addendum) is a schematic representation of the Close-Clearance Stationary Specimen Vibratory Cavitation Erosion Apparatus, showing only those portions differing from the normal apparatus shown in Fig. 1 and 2 (of Standard Method). The dimensions of the dummy specimen, and the frequency and amplitude with which it is driven, are the same as given for the test specimen of the Standard Method. Previous tests have shown (3-7 e.g.) that a maximum damage rate is obtained under these conditions if the mean clearance between vibrating dummy and stationary test specimen is $\sim$ 15-20 mils (0.25-0.50 mm). Hence the standard mean clearance will be 18 mils (0.46 mm).

1.1.2 The stationary test specimen will consist of a flat plate of the material to be tested (a composite is possible wherein a thin elastomeric coating is bonded to metallic backing) of at least 1/4 inch (6.35 mm) thickness, and including in its surface at least a 1 inch (25.4 mm) diameter circle.

1.1.3 The "Procedure" for the test is for the most part as given in the Standard Method. Sections 7.1, 7.4, 7.5, 7.6, 7.7, 7.7, 7.8, 7.9, and 7.10 apply exactly. Sections 7.2 and 7.3 should read:

"7.2 The tip of the dummy specimen shall be immersed at least 1 inch (25.4 mm), and no more than 2 inch (50.8 mm).

7.3 The water shall be settled carefully for at least 15 min. before start of first test to avoid uncertain quantities of entrained air."

1.1.4 The "Calibration of Apparatus" against known results is impossible at this point, since insufficient testing with this arrangement has been done.

However, a cautionary note must be added. The temperature of the water in the close clearance gap increases markedly during the test (6) and this can importantly affect the results. Present result (6,14) indicate non-repetitive results unless the gap water is maintained at desired temperature by a slow forced liquid circulation, perhaps through a small central hole in the anvil. The uncertainty of results otherwise obtained, e.g., from the use of different horn assemblies even though frequency and diameter is the same (15) has been recently observed.

2.2 Tests for Liquids other than Water and at Various Temperatures and Pressures

2.2.1 Figure 2 (of addendum) illustrates the significant features of the probable arrangement of apparata for tests of this type. It is of course not always necessary to change the apparata in this fashion if the liquid conditions to be used included exposure to 1 atm. of air. Numerous tests have been made (9,10,11,16 e.g.) under these conditions for fluids other than water (such as glycerine, petroleum derivatives, mercury, etc.) and for water at temperatures other than 72° F (22°C), as recommended in Standard Method. Such tests have shown that the erosion rate peaks strongly at a temperature about midway between boiling and freezing points for all liquids so far tested. Thus for water at 1 atm. the maximum erosion rate occurs at $\sim$122°F ($\sim$ 50°C). The decrease in erosion rate as the temperature is reduced from this value is much less severe than the decrease toward higher temperature (which can be by a factor of $10 - 10^3$). Hence there is strong economic incentive in conducting water tests with especially resistant materials (stainless steel, stellites, etc) at a temperature higher than that recommended in the Sandard Method. This can of course be done without any change in apparatus other than the addition of a suitable temperature control.

2.2.2 The major apparatus change necessary to conduct tests under the more difficult conditions of temperature, pressure, and liquid (Fig. 2) is the provision of a sealing method for the horn assembly to the liquid-containing vessel, and a sufficiently strong and temperature-resistant container. The seal is probably best made at the first vibration node (where vibration amplitude is a minimum) above the horn tip (which is an anti-node). It is necessary that the attachment be as flexible as possible (relative to the high-frequency vibration) so as to avoid excessive damping at this point. A possible mode of attachment is through the use of a steel bellows.

2.2.3 Other than as already stated, sections 4. Apparatus, and 5. Test Specimen of the Standard Method apply. It is of course also possible to adapt the special provisions for the stationary specimen test to any conditions of temperature, pressure, and liquid, only provided the mechanical problems be properly handled.

2,2.4 Calibration of Apparatus (6.0 of Standard Method) is possible at this time only by comparison with published data.

2.2.5 Procedure (7.0 of Standard Method) applies with the exception of 7.3. Under certain conditions this step may not be practical (or necessary). Opening and disassembling the test vessel for this purpose may distort the erosion results by causing extraneous oxidation, etc., through an additional exposure to air.

References

1. ASTM, "Standard Method of Vibratory Cavitation Erosion Test," Designation G 3 -72, under jurisdiction of ASTM Committee G-2 on Erosion and Wear, published July 1972.

2. J.Z. Lichtman and D.H. Kallas, "Erosion Resistance of Coatings," Materials P tection, 6, 4, April 1967, p. 40-45.

3. K. Endo, T. Okada, M. Nakashima, "A Study of Erosion Between Two Parallel Surfaces Oscillating at Close Proximity," Trans. ASME, J. Lub. Tech., 8, 3, July 1967, p. 229.

4. F.G. Hammitt, J.F. Lafferty, R. Cheesewright, M.T. Pitek, D.J. Kemppainen T.M. Mitchell, "Laboratory Scale Devices for Rain Erosion Simulation," Proc. Meersburg Conf. on Rain Erosion and Allied Phenomena, August 1967, p. 87-123, RAE, Farnsborough, England, edit. A.A. Fyall, etal.

5. C.M. Preece and B. Vyas, "Electrochemical Aspects of Cavitation Erosion," Proc. of the 4th Meersburg Conference on Rain Erosion and Allied Phenomena, RAE, Farnsborough, England, edit. A.A. Fyall, etal.

6. J.M. Hobbs and D. Rachman, "Environmentally Controlled Cavitation Test (Improvements in a Cavitating Film Erosion Test)," ASTM STP 474, 1970, p. 29-4

7. E. van Rensen, "The Behavior of Fiber-Reinforced Composite Materials Under Erosion and Cavitation Stress," May 1974, FTD-HC-23-2674-74, Foreign Technology Division, Wright-Patterson AFB, Ohio; see also Proc. 4th Meersburg Conf. on Rain Erosion 1974 (in German).

8. S.G. Young and J.R. Johnston, "Effect of Temperature and Pressure on Cavitat Damage in Sodium," Characterization and Determination of Erosion Resistance, ASTM STP 474, p. 67-102.

9. J.M. Hobbs and A. Laird, "Pressure, Temperature and Gas Content Effects in Vibratory Cavitation Erosion Test," ASME 1969 Cavitation Forum, p. 3-4.

10. F.G. Hammitt and D.O. Rogers, "Effects of Pressure and Temperature Variat in Vibratory Cavitation Damage Test," Journal Mech. Engr. Sci., 12, 6, 1970, p. 432-439, I Mech. E. (U.K.).

11. F.G. Hammitt and N.R. Bhatt, "Cavitation Damage at Elevated Temperature a Pressure," ASME 1972 Polyphase Flow Forum, p. 11-13.

12. R. Garcia, F.G. Hammitt, R.E. Nystrom "Comprehensive Cavitation Damage for Water and Various Liquid Metals Including Correlations with Material and F Properties," ASTM Spec. Tech. Publ. 408, 1967, p. 239-279.

13. R. Garcia and F.G. Hammitt, "Cavitation Damage and Correlations with Mater and Fluid Properties," Trans. ASME, J. Basic Engr., D, 89, 1967.

14. Personal communication of J.M. Hobbs to F.G. Hammitt, 1974.

15. Personal communication of C.M. Preece to F.G. Hammitt, 1974.

References

16. R.E. Devine and M.S. Plesset, "Temperature Effects in Cavitation Damage," Report No. 85-27, Div. of Engr. and Applied Science, Calif. Inst. of Tech., Pasadena, Calif., April 1964.

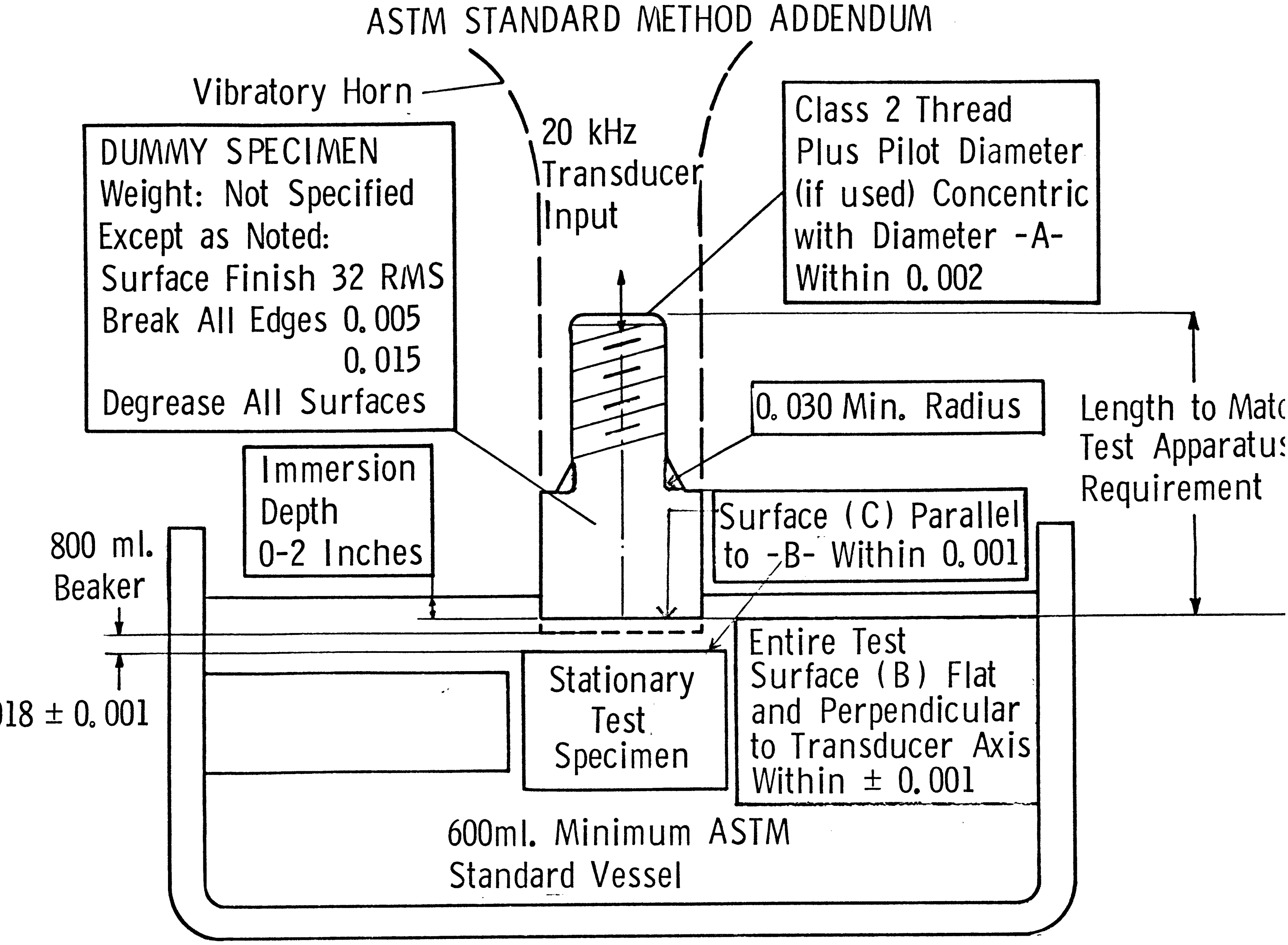

Fig. 1. Important Parameters of Close - Clearance, Stationary Specimen Vibratory Test Facility.

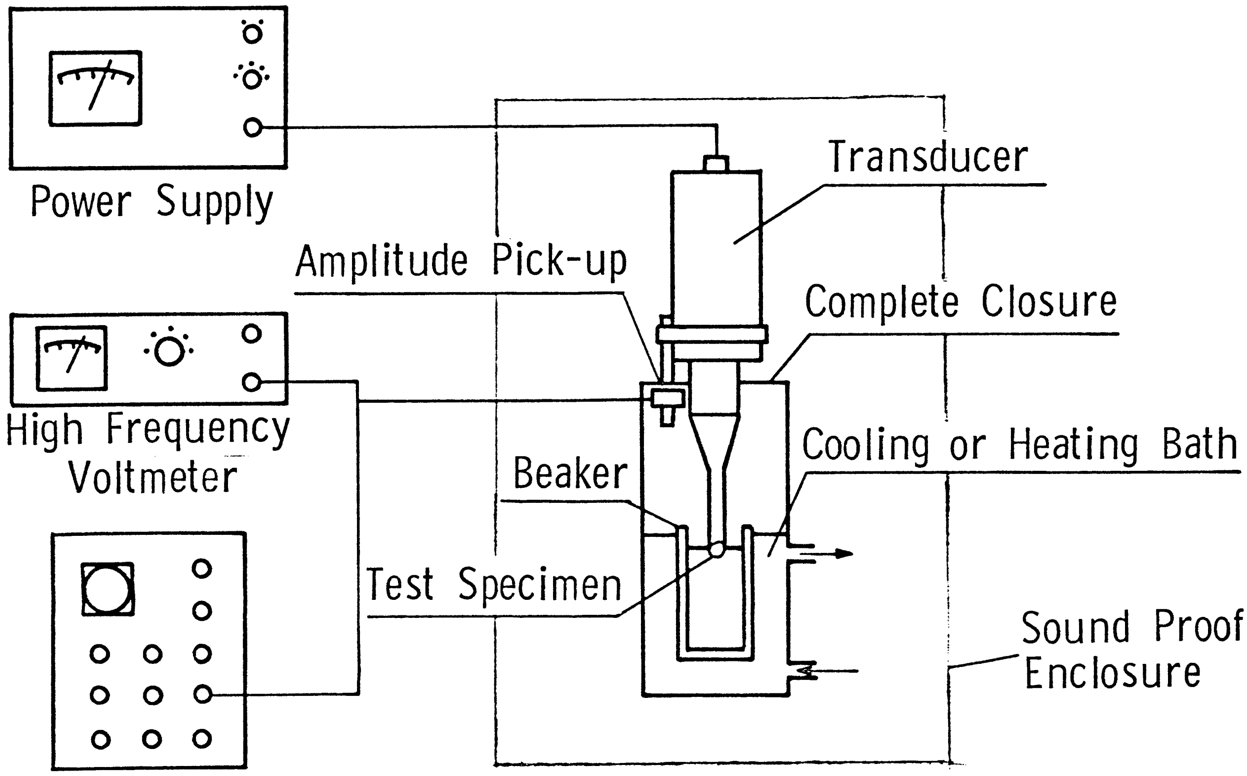

Fig. 2. Schematic of Vibratory Cavitation Erosion Apparatus.