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CAVITATION VIBRATORY DAMAGE TEST PROCEDURE USING BAFFLE-PLATE CONFIGURATION

by

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INTRODUCTION

The establishment of a standard reliable cavitation test procedure is a goal long sought and in fact a primary objective of a committee of ASTM* at this time. The work of this committee[1] indicates that the most likely feasible standard test at present is the conventional ultrasonic vibratory test. However, repeatability with this test even with specimens fabricated from the same bar stock is less than desired. One cause of this lack of precision is the non-uniformity of damage produced on the specimen face. This often is characterized by radial striations of undetermined number depending upon material properties, surface roughness, horn frequency and amplitude, water temperature and pressure, etc.[2, e.g.]. The final form of the damage is apparently the result of the essentially unpredictable interplay of many minor influences, and yet the type of damage incurred strongly affects the damage rate through influences on the local flow pattern and on the material surface properties. Thus it appears highly desirable to modify the test in such a way that more uniform damage will be produced for which the rate would then presumably not be so strongly influenced by minor test variations. To accomplish this goal, Plesset[3] has introduced a rimmed specimen. The influence of the rim in restricting radial flows across the surface is to obviate to a large extent the radial striations in damage pattern otherwise developing and to produce a more uniform damage. However, specimen fabrication is more difficult, and it is not easily possible to furnish a ground or lapped specimen surface which may be required in some cases. The present paper describes a new test configuration designed to produce much the same type of uniform wear achieved with the Plesset rimmed specimens, but without the consequent fabrication difficulties.

*ASTM Committee G-2 on Erosion by Cavitation or Impingement.

TEST CONFIGURATION

The modified test configuration* differs from that used in the conventional vibratory test [1, e.g.] only in that the specimen is positioned within and concentric with a circular hole in a baffle plate so held that the radial clearance with the baffle plate can be a minimum (3 mils in present test). The arrangement is shown in Fig. 1. The horn, transducer, assembly and flange are unchanged from the conventional arrangement, but the baffle plate is mounted firmly to the flange to maintain the required parallelism with the specimen face, the desired distance from the flange, and concentricity with the horn and specimen axis. Preliminary tests showed that optimum results were obtained if the specimen face in the static condition were flush with the lower surface of the baffle plate. Presumably the plate acts in much the same way as the rim in Plesset's specimens to restrict radial flow. Consequently it had been initially supposed that the specimen surface should be somewhat withdrawn above the baffle plate surface. However, it was found that optimum uniformity of damage occurs in the flush condition. Water level in the test is maintained 1 1/2 in. above the top surface of the baffle plate.

Our vibratory facility to which the baffle plate arrangement was added was designed for high-temperature tests with various fluids[2] and hence includes a sealed flange which also supports the horn. Hence tests at higher than atmospheric temperature and pressure are notinconvenient, and were used in the present instance to increase damage rates.

*Patent Applied for (1967).

TEST PROCEDURES AND RESULTS

Previous work in this laboratory [4] and elsewhere showed that a maximum damage rate was achieved with a conventional vibratory facility in water at atmospheric pressure at about 120^{o}F water temperature. Also, since the damage-temperature curve peaks at about this value, there is less sensitivity to temperature variation than is the case for cold water, so that minor temperature variation becomes a negligible factor in damage rate reproducibility. Hence this temperature was used in the present tests with a gas pressure of 1.7 psig (vapor pressure of water at 120^{o}F) to maintain a suppression pressure of one atmosphere (to simplify comparison with other atmospheric tests).

To evaluate the effect of the baffle-plate configuration, a series of 4 tests were conducted in the baffled and conventional arrangements respectively, using type 304 stainless steel specimens cut from the same piece of bar stock. A fresh charge of distilled water from the same source was used each day, and gas content was always brought to equilibrium by a prerun of 15 minutes with a dummy specimen (previous tests had shown this was sufficient to achieve the same equilibrium gas content regardless of its initial value). Horn operating frequency was always 20.0 $\pm$ 0.3 kHz, and amplitude was 2.0 $\pm$ 0.1 mils as measured with an MTI photonic sensor* and oscilloscope.

The results of these tests are shown in Fig. 2 for both baffled and conventional arrangement. The cumulative weight loss vs. time curve assumes a characteristic S-shape for both configurations with an initial period of increasing damage rate, and a later portion of decreasing rate, with relatively long intermediate period of approximately constant damage rate. This relatively constant maximum damage rate portion of the characteristic S-curve has been approximated by a straight line, and the slope of this line taken as the damage rate.

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*Fotonic Sensor Model KD-38, Instruments Division, Mechanical Technology, Inc.

The resultant rates for each specimen, the average rate for each configuration, and the percent standard deviation for each configuration computed for the 4 specimens in each case are listed in Table I. The percent standard deviation for the baffled configuration is 6.05% and that for the conventional arrangement 8.35%, indicating the improved repeatability of the baffled test, even though the statistical sample is smaller than might be desired. The average weight loss rate for the baffled test is only slightly less than that of the conventional arrangement (83% of the conventional test rate), so that the test is not appreciably lengthened by using the baffled arrangement.

Fig. 3 shows a typical damaged surface from each configuration. The improved uniformity of the damage pattern for the baffled system is obvious.

CONCLUSIONS

Preliminary tests with a modified cavitation damage vibratory system, using a baffle-plate around the vibratory specimen, have shown that damage uniformity is greatly improved, repeatability of damage rates improved (based on 4 specimens tested in the new and 4 in the conventional configuration), and damage rate is only slightly reduced, as compared to the conventional arrangement. Hence it is suggested that the modified arrangement may be a more suitable standard test than the conventional configuration.

ACKNOWLEDGEMENTS

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2. R. Garcia and F.G. Hammitt, "Cavitation Damage and Correlations with Materials and Fluids Properties", Trans. ASME, J. Basic Engr., 89, D, 4, 753-763, 1967.

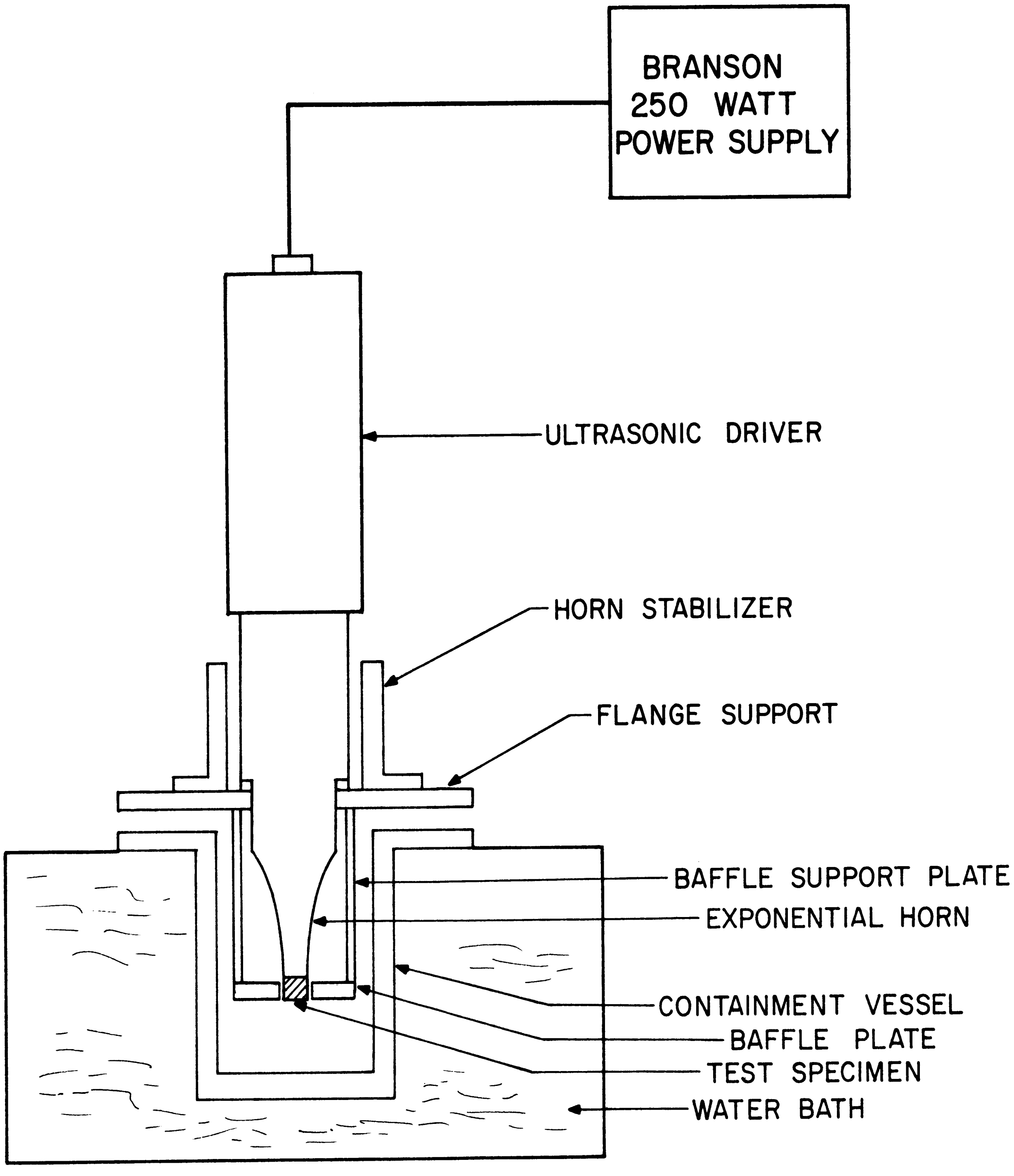
3. M.S. Plesset, "On Cathodic Protection in Cavitation Damage", Trans. ASME, J. of Basic Engr, 82, D, 808-820, 1960..

LIST OF FIGURES

TABLE I

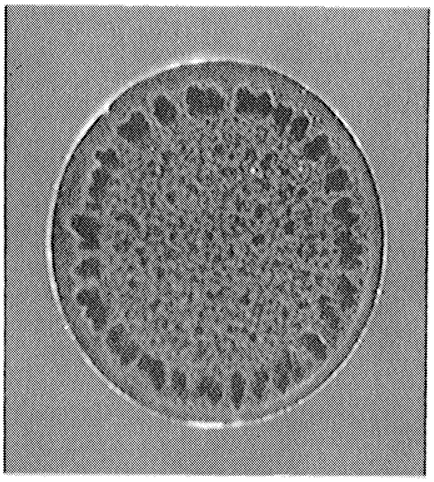
SUMMARY OF TEST RESULTS

Configuration	Specimen No.	Mean Damage Rate	Percent Standard Deviation
Conventional	1	0.2945 mg/min	
	2	0.2775 "	
	3	0.2845 "	
	4	0.2418 "	
	Average	0.2745 "	8.35%
Baffled	5	0.2426 "	
	6	0.2147 "	
	7	0.2195 "	
	8	0.2388 "	
	Average	0.2289 "	6.05%

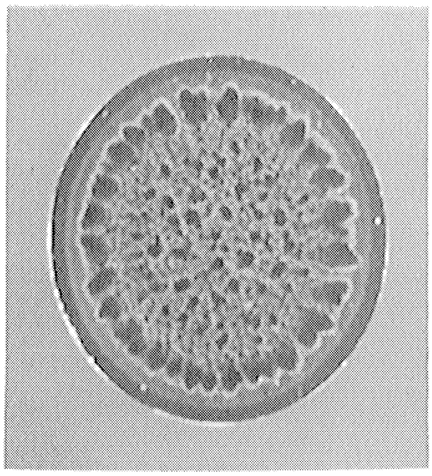

BRANSON
250 WATT
POWER SUPPLY
ULTRASONIC DRIVER
HORN STABILIZER
FLANGE SUPPORT
BAFFLE SUPPORT PLATE
EXPONENTIAL HORN
CONTAINMENT VESSEL
BAFFLE PLATE
TEST SPECIMEN
WATER BATH

2691

Fig. 1



BAFFLED CONFIGURATION



UNBAFFLED CONFIGURATION

FIG. 2 Comparision of Baffled and Unbaffled Specimens

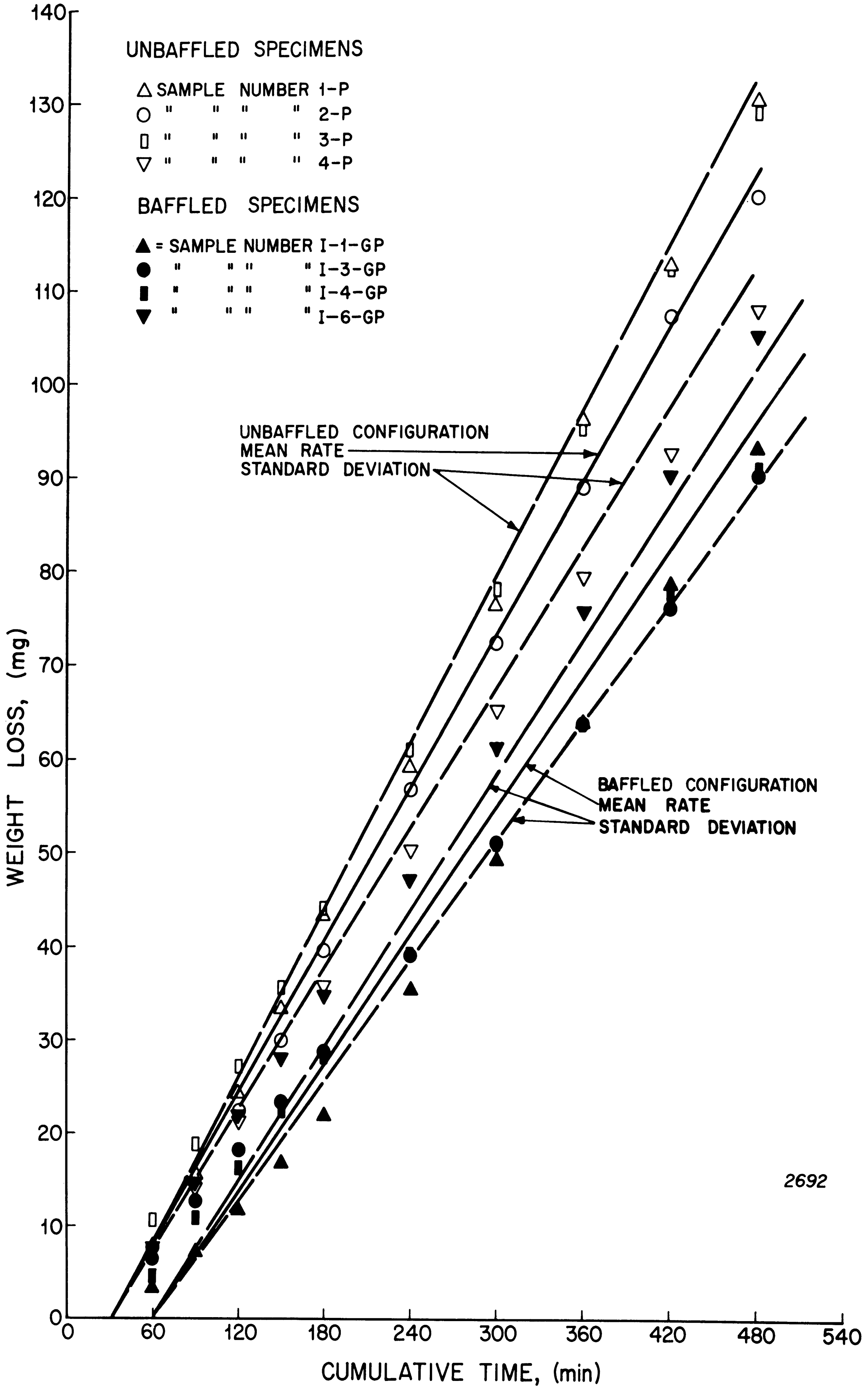

UNBAFFLED SPECIMENS
△ SAMPLE NUMBER 1-P
○ " " " " 2-P
▯ " " " " 3-P
▽ " " " " 4-P
BAFFLED SPECIMENS
▲ = SAMPLE NUMBER I-1-GP
● " " " " I-3-GP
▮ " " " " I-4-GP
▼ " " " " I-6-GP
UNBAFFLED CONFIGURATION
MEAN RATE
STANDARD DEVIATION
BAFFLED CONFIGURATION
MEAN RATE
STANDARD DEVIATION
WEIGHT LOSS, (mg)
CUMULATIVE TIME, (min)
2692
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
0
60
120
180
240
300
360
420
480
540

Fig. 3