THE UNIVERSITY OF MICHIGAN

College of Engineering

Department of Mechanical Engineering

Cavitation and Multiphase Flow Laboratory

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STANDARDIZED CAVITATION VIBRATORY DAMAGE TEST PROCEDURE FOR BIRDSBORO CORPORATION USING BAFFLE-PLATE CONFIGURATION

by

Edward E. Timm
Frederick G. Hammitt

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LIST OF FIGURES

I. INTRODUCTION

It is desired by the Birdsboro Corporation to have a reliable method of quantitatively ranking similar materials for cavitation resistance. To this end, tests were conducted using the University of Michigan Ultrasonic Cavitation Facility. The purpose of these tests was to determine the feasibility of using an ultrasonic type cavitation test to generate cavitation damage data which can be used to reliably and quantitatively rank the cavitation resistance of basically similar materials.

The Ultrasonic Cavitation Facility has been previously described [1, 2] along with the experimental procedure used in this laboratory for the evaluation of cavitation resistance of metals. However, a brief review and up-dating of this material is presented herein for convenience.

The first objective of the work was to determine the statistical precision of cavitation damage measurements on identical test specimens run under identical conditions, and to develop a test configuration which minimized this variation. A second objective was to test typical cast materials to determine to what extent their cavitation resistance could be delineated. This report is divided into sections which consider the test configuration, the test conditions and their control, the test samples, the type of test results, the results of the preliminary testing to determine the suitability of the proposed methods, and finally, the results upon three cast materials supplied by Birdsboro.

II. TEST FACILITY

Tests were carried out using the Ultrasonic Cavitation Facility, of the Cavitation and Multiphase Flow Laboratory, Mechanical Engineering Department. This facility [1, 2] consists of a self-tuning power supply providing 20 kHz power to an ultrasonic transducer which in turn drives a material specimen at an amplitude of 2 mils and a frequency of 20 kHz through a velocity transforming catenoidal horn. The transducer assembly is shown in Fig. 1. The specimen vibrates in a closed container which containes water as the cavitation fluid, and which has provisions for both pressurization and temperature control.

Tests were run under two experimental configuration. The first of these consisted of merely immersing the active face of the sample in the cavitation fluid in the conventional fashion. The second consisted of surrounding the specimen with a baffle plate, details of which are shown in Fig. 2, flush with the specimens active surface, and immersing this assembly in the cavitation fluid. The latter configuration was used to obtain more uniform and reproducible damages. Specimens run to the same cumulative time (Fig. 3) indicate that increased uniformity of damage across the specimen face is attained in this fashion.

III. TEST CONDITIONS

The basic variables in any ultrasonic cavitation test of given geometry are frequency, amplitude, temperature, pressure, air content, and bubble nuclei population. It is necessary to maintain precise control over these variables to obtain repeatable results. Following is a list of the considerations given each of these in this work.

a) Frequency. The frequency of vibration of the specimen is approximately fixed by the geometry of the ultrasonic transducer and horn. It drifts slightly with temperature. However, the variation was insignificant in this work since temperature is maintained closely constant. The standard operational frequency was 20.0 $\pm$ 0.3 kHz.

b) Amplitude. The amplitude of specimen vibration is controlled by controlling the power to the transducer. For this work a calibration curve of transducer power versus specimen amplitude at various power levels was obtained by the use of a MTI photonic sensor and an oscilloscope. A standard operating condition of 2.0 $\pm$ 0.1 mils amplitude was employed.

c) Temperature. The temperature of the cavitation fluid is controlled by partially immersing the test container in a constant temperature bath. To obtain a maximum damage rate, in accordance with previous tests in this laboratory and elsewhere [3], was 120 $\pm$ 3 $^{\circ}$F, measured in the test container with a thermocouple.

d) Pressure. The Pressure in the test container is maintained by a gas blanket at 1.69 $\pm$ 0.1 psig (the vapor pressure of water at the operating temperature, measured by Heise guage. This gives a static "suppression pressure" of 1.0 atmospheres, which is the standard usually used for this type of test. The water level is maintained at above the baffle plate tops surface and at 1 1/2" above the specimen cavitated face in the conventional arrangement.

e) Gas Content. It has been found that in a closed cavitation system there exists an equilibrium gas content in the cavitation fluid. This equilibrium content is a function of both system pressure and temperature. In the system employed in this work it has been found that gas content reaches its equilibrium value for the operating condition used within 15 minutes of system start-up. Therefore, to insure consistent gas content in all tests a 15 minute prerun with a dummy specimen was made whenever the system had been idle for any appreciable time.

f) Bubble Nuclei Population. The cavitation field at the active surface of the cavitation specimen is influenced to an as yet undetermined degree by the bubble nuclei population in the cavitating fluid.

However, to standardize this variable as much as possible the gas content was standardized as described above and the distilled water used as cavitation fluid was always obtained from the same source, and replaced each day to prevent the buildup of metal particles.

It is believed that the control exercised over all these variables is such that variations in cavitation damage due to system variation is minimal.

IV. TEST SPECIMENS

In order to achieve maximum repeatibility of damage to individual specimens it is necessary to make the cavitation specimens as closely identical as possible. To this end all of the specimens for the preliminary "method" tests were machined from a single bar of type 304 stainless steel. Since surface condition and finish of the cavitated surface of the specimen is all important to the damage rate, it was decided to give this active surface a more extensive treatment than is normally employed in order to assure uniformity of cold work. Thus, the active surface of all specimens was ground and polished to mettallurgical standards until observation indicated that all cold work had been removed.

V. TYPE OF RESULTS

The test data is presented as weight loss vs. running time for each specimen; i.e.: each sample was weighed, tested for a given interval, dried, weighed again, and the consequent running time interval and weight loss were recorded. Data was thus obtained in the form of cumulative weight loss vs. cumulative time for each specimen. The resultant curve of cumulative weight loss vs. cumulative time assumes a characteristic S-shape with an initial period of increasing damage rate, and a later portion of decreasing damage rate with a relatively long intermediate period of constant damage rate. For the purposes of characterizing cavitation damage at given conditions this relatively constant maximum damage rate portion of the characteristic S-curve is approximated by a straight line and the slope of this line is taken as the damage rate.

A total of eight specimens fabricated from type 304 stainless steel were run. Of these, four were run in the conventional unbaffled configuration and four in the baffled configuration, so that comparisons could be made between these two types of geometry.

VI. RESULTS OBTAINED FROM TYPE 304 STAINLESS STEEL

Fig. 4 is the graphical representation of the data obtained for both baffled and unbaffled conditions as weight loss vs. time. In Table I are listed the individual damage rates for all eight specimens and the mean damage rates for each sample group, as well as the percent standard deviation for each group. The standard percent deviation for the four rates determined from the unbaffled tests was 8.35% while the same figure for the baffled tests was 6.05%.

VII. RESULTS OBTAINED FROM SPECIMENS SUPPLIED BY BIRDSBORO CORPORATION.

The Birdsboro Corporation supplied six specimens of cast alloys for testing. These were:

a) Two specimens of CA-15 steel, heat-treated to ASTM A-296 specifications. Both of these specimens were sucessfully run.

b) Two specimens of CF-8 steel, heat-treated at 2050 ^{o}F and water quenched. One of these specimens was sucessfully run.

c) Two specimens of CF-8 steel, heat-treated at 2000 ^{o}F, water quenched, and sensitized at 1250 ^{o}F for 25 hours. One of these specimens was sucessfully run.

Fig. 5 shows the damage curves of these specimens and their mean rates. Along with the mean rate for type 304 stainless steel run in the baffled configuration.

VIII. CONCLUSIONS

The first purpose of this work was to determine the ability of an ultrasonic cavitation test to give quantitative rankings of materials with quite similar cavitation resistance. To do this an attempt was made to hold all parameters in the cavitation test employed in this work as constant as possible and to then determine the magnitude of fluctuations in individual sample damage rates. This magnitude should then give an indication of the ability of this test to distinguish between similar materials. Measurement of this fluctuation magnitude was made by computing a standard deviation for the damage rates of the 4 samples employed in each test configuration. While with only 4 points available for calculation of the standard deviation this quantity may not be statistically as meaningful as desired, still for the purposes of comparing different test configurations and determining the optimum conditions it can be used.

Of the two test configurations considered, one had a damage rate of standard deviation of 8.35%, and the other a standard deviation of 6.05%. This difference is believed to be due to the regularizing effect the baffle has on fluid flow patterns around the active surface of the specimen, i.e., more regular fluid flow patterns give rise to a more uniform damage pattern, as can be seen from fig. 3, which in turn reduces the variation in damage pattern from sample to sample, promoting more consistent results. From this difference it is believed that the baffled test configuration shows a significant improvement over the unbaffled configuration. Thus this method has been chosen. Furthermore, it is believed that this test, in which it is indicated that about 95% of all samples tested will fall within $\pm$ 12% of the "true" cavitation damage rate, approaches the maximum possible repeatability for any feasible cavitation resistance test. However, it appears that not every variable is fixed by these tests, for, as can be noted from fig. 4 and 5, the initial shape of the damage curves varies significantly between supposedly identical specimens.

It was found that the wrought type 304 stainless steel was of intermediate cavitation resistance as compared with the cast alloys supplied by Birdsboro Corporation, Fig. 5.

ACKNOWLEDGEMENTS

The assistance of Gregory Oganowski and Richard Getz, both students in the Nuclear Engineering Department at this University, is gratefully acknowledged in the performance of these tests.

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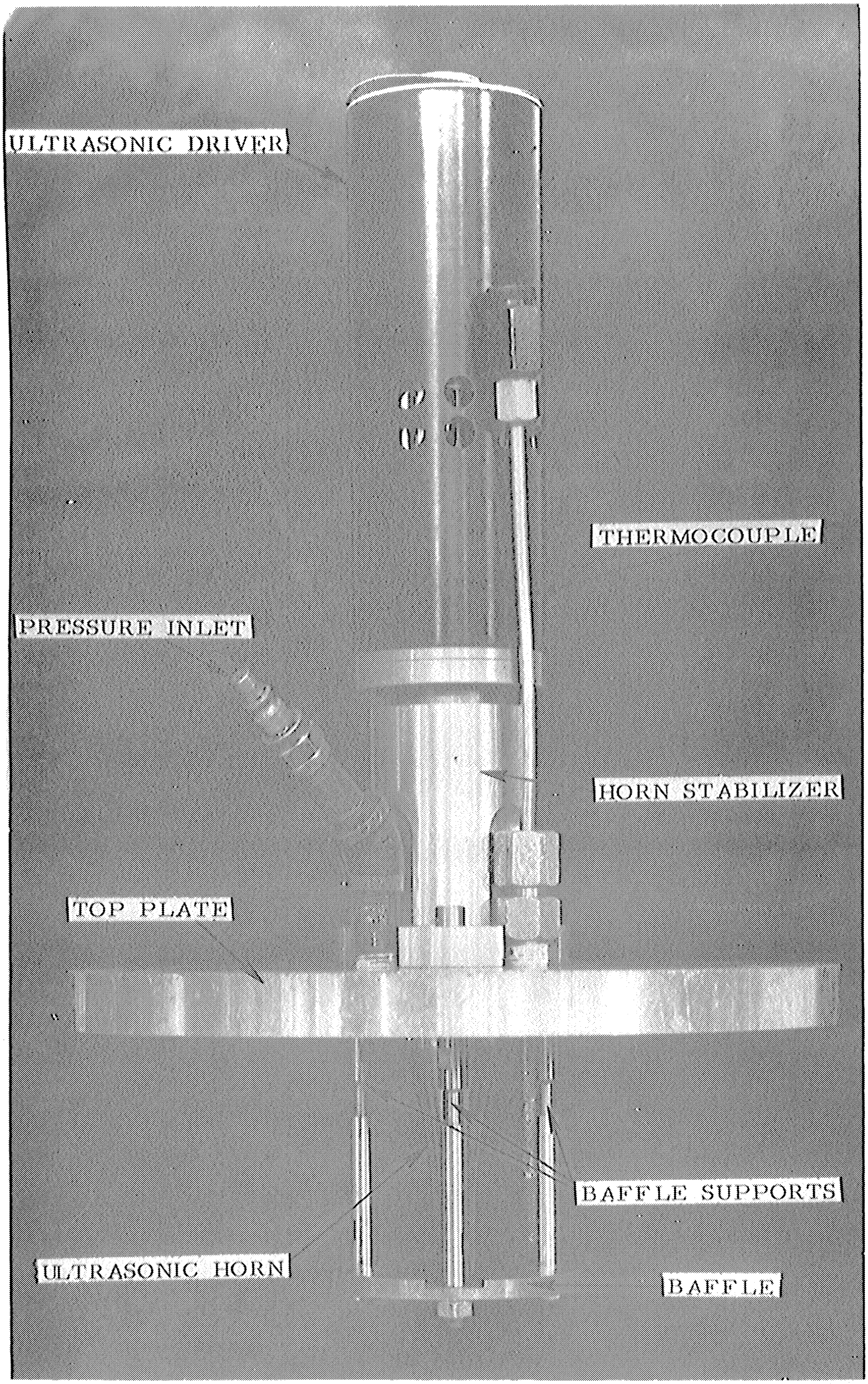

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Fig. 1. Transducer Assembly.

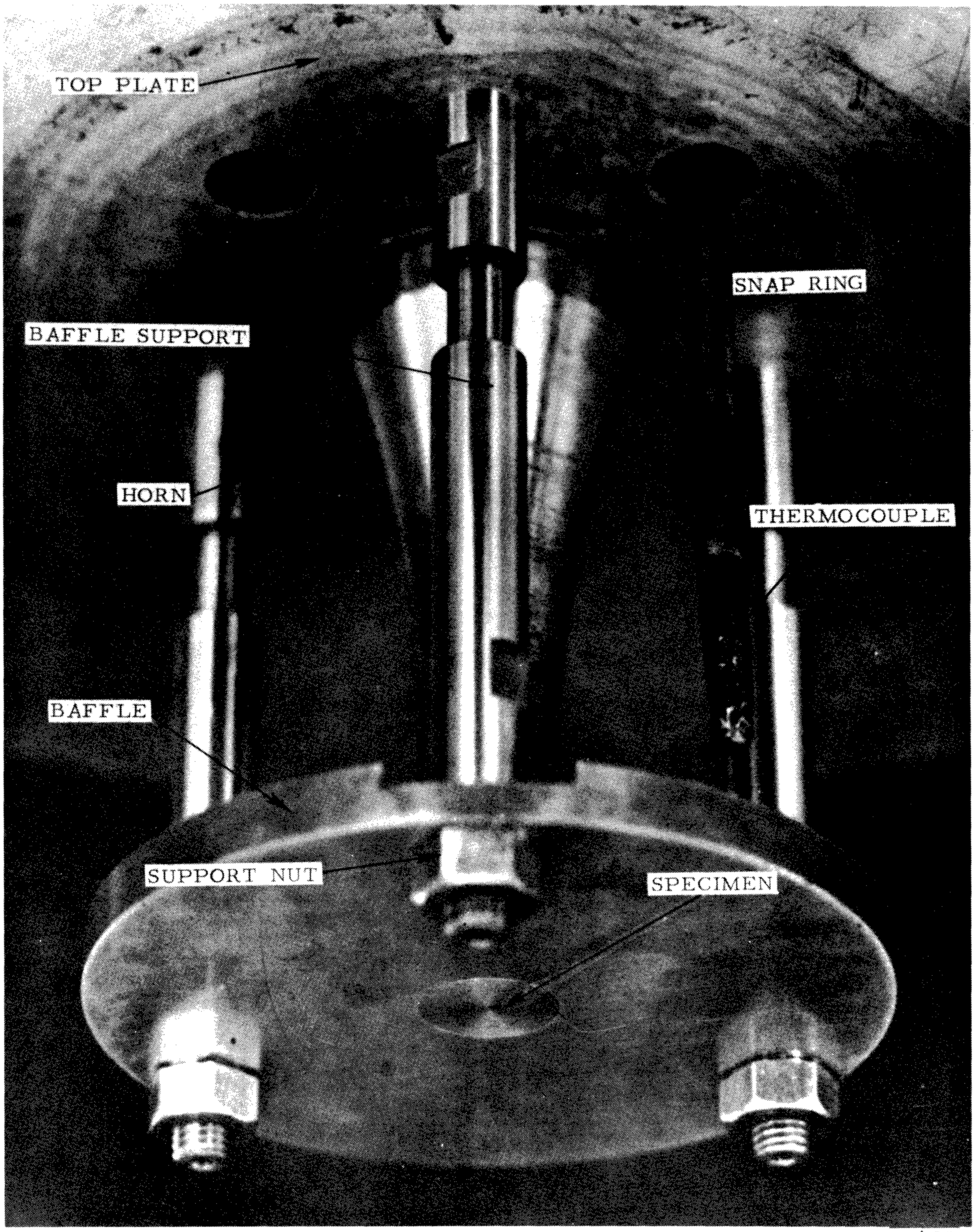
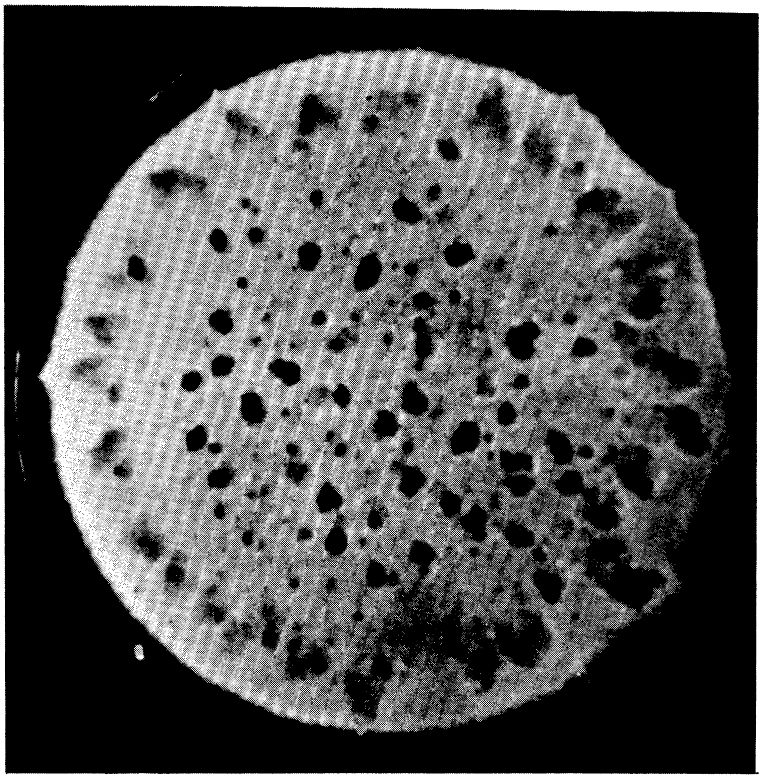


Fig. 2. Details of Baffle Plate.



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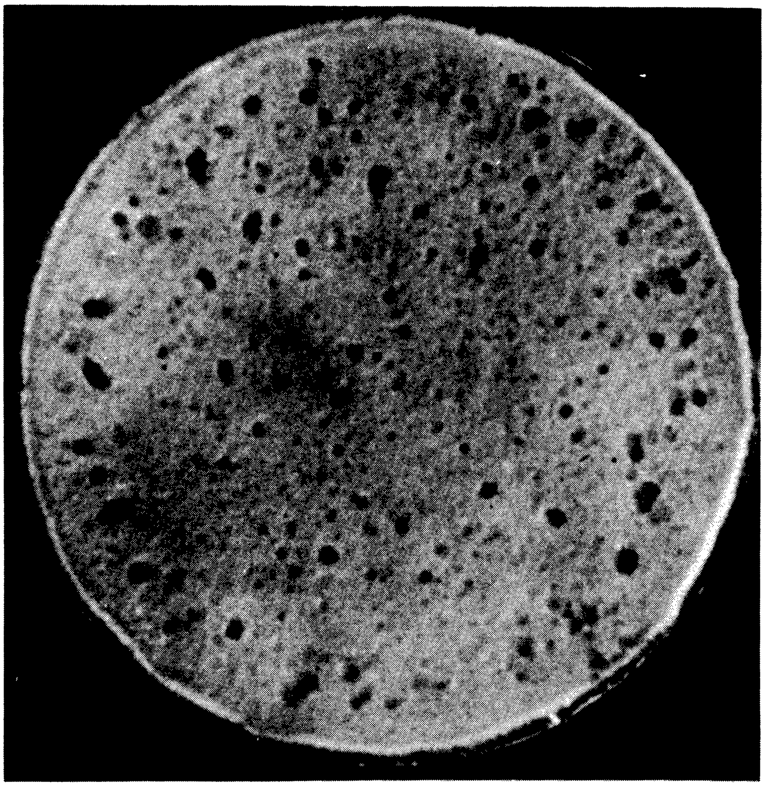

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Fig. 3. Comparative Photos.

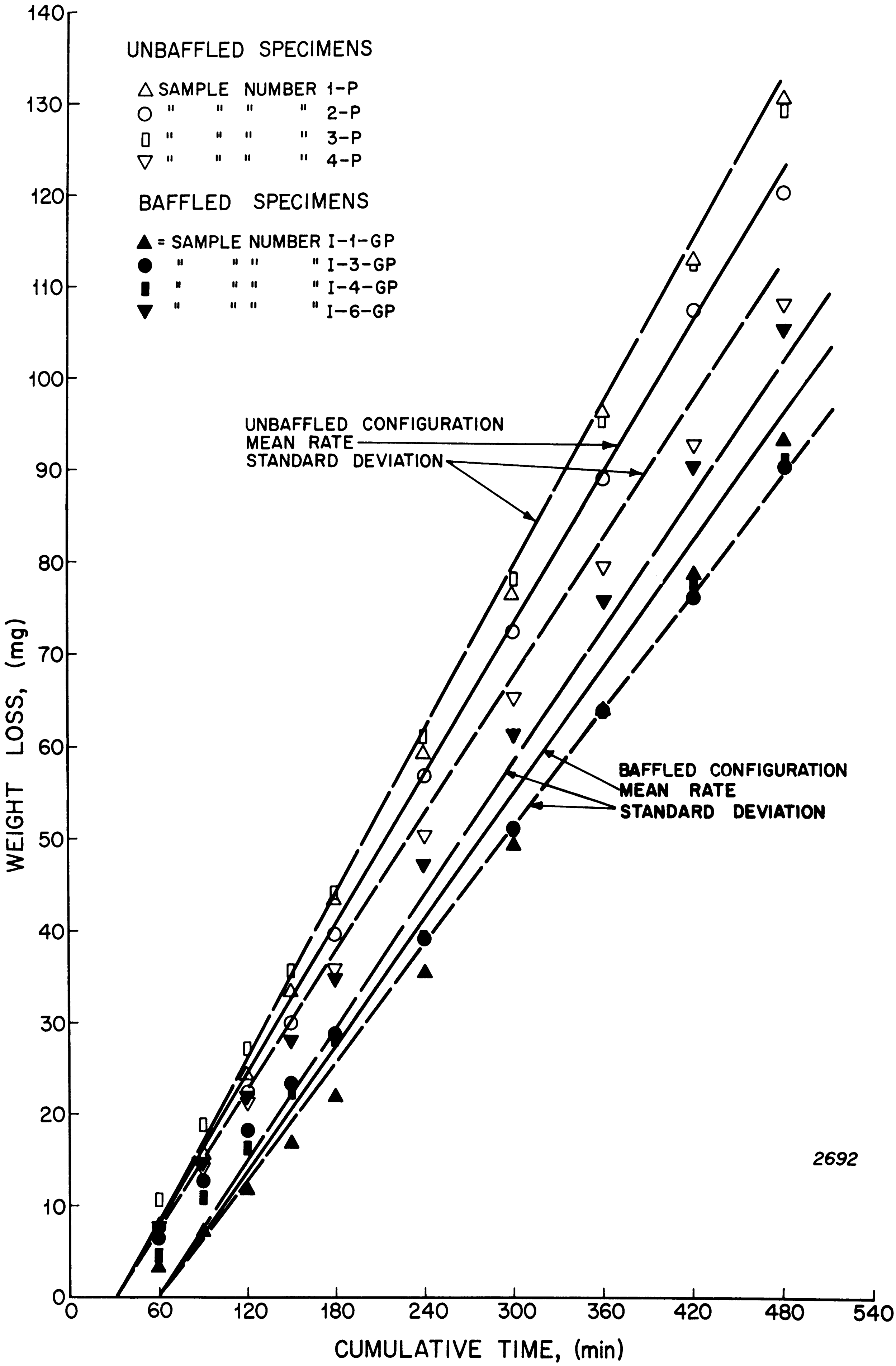

Fig. 4. Graphical Stainless Steel Data.

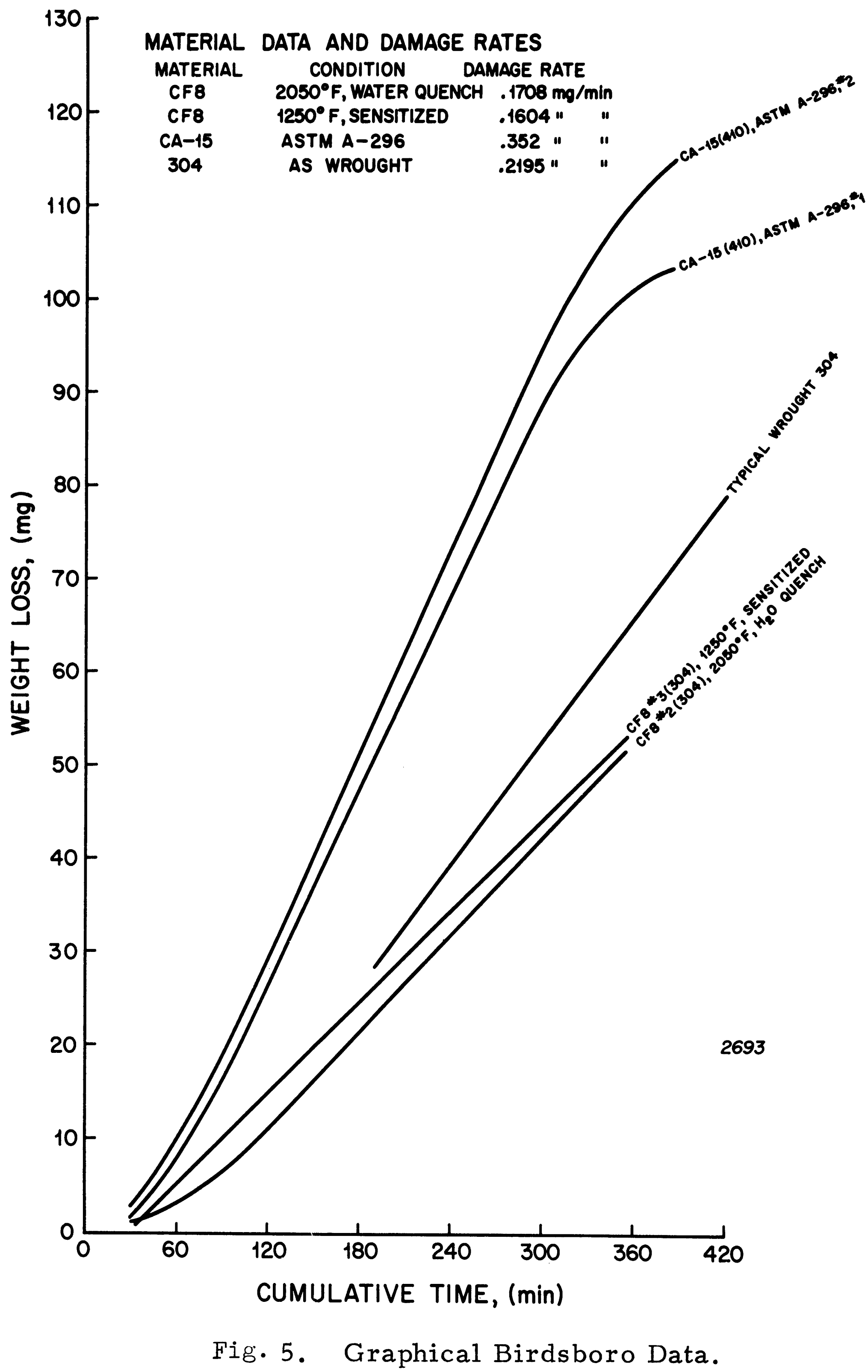

Fig. 5. Graphical Birdsboro Data.