have ignored the effects of air content. The differences between damage measured in the several cases are not extreme and are restricted to the first 30-min interval of test.

However, since the effects are not universally agreed upon, it is of advantage to remove the question from the test. As a tentative standard procedure, we specify that the test liquid be boiled for 15 min prior to the test proper.

While the test water is being prepared, the specimen must be readied for testing. It has been found that cavitation attack tends to localize damage at surface imperfections on the face of the test specimen. A perceptible scratch within the area of most intense attack often becomes a disproportionately large pit during the vibratory test.

It is recognized that it is not possible to bring the test surface of all types of material to a mirror-polish superfinish. However, the test surfaces of different specimens can easily be made equal in average finish, thus supplying a common reference level.

The test surface of the specimen should be polished to a roughness of approximately 3 microinches root-mean-square, using triple-zero (000) emery paper.

The physical and chemical peculiarities of many materials tested by the vibratory method create an error in damage evaluation. If the test material is uniformly porous, during the test the specimen may absorb a considerable amount of the test liquid, which is driven deep into the material by the nearly 8000 gravities peak acceleration. At the end of the first test interval, such a specimen may reveal an actual increase in mass, despite visibly extensive damage and material loss. Attempts to remove the absorbed liquid by the application of high heat may heighten the rate of oxidation of some materials. Removal of the liquid by chemical drying or slow heating adds much to the over-all time required to complete the resistance test.

A further effect has been seen in the case of metals which have a higher affinity for oxygen. While the specimen is being vibrated in the test, the material may oxidize heavily on surfaces and at grain boundaries in contact with the test liquid. If the material is somewhat porous, the oxygen gained by chemical combination during the test becomes a noticeable factor.

By experimental trial, a pretest treatment was found by which materials could be brought to a condition sufficiently stable that spurious physical and chemical effects would not detract from the precision of damage measurements. The test specimen is to be preoxidized by boiling in a sample of the test liquid for about 15 min prior to the test. When the specimen is removed from the boiling liquid, it should be placed immediately in a second sample of cool test liquid and allowed to soak long enough for the specimen to return to the ambient temperature. When cool the specimen should be removed from the liquid and dried carefully on all exterior surfaces with a lintless tissue wetted with CP reagent acetone. As soon as the surface moisture is removed the specimen should be weighed and quickly placed in the transducer for the test.

At the end of each 30-min test interval the specimen should be removed from the transducer, surface-dried with CP reagent acetone on a lintless tissue, and weighed at once. As soon as it is weighed the specimen should be returned to the vibrator and the test continued.

All weight measurements should be made to the nearest 0.1 milligram.

Summary

To summarize: The magnetostrictive type of vibratory apparatus, which has a water-cooled centrally supported pure nickel tube as a transducer, is recommended by the committee for accelerated cavitation-resistance testing. A test specimen having a flat circular surface $^5/_8$-in. diam is suggested. The test liquid should be contained in a cylindrical flat-bottomed pyrex glass vessel approximately $3^1/_2$-in. diam and the container placed in a thermally regulated heat-exchange bath for control of the test-liquid temperature.

The following test conditions are suggested as tentative standards for vibratory, accelerated-cavitation testing:

Test frequency of 6500 ± 50 cps.
Test amplitude of 0.00342 ± 0.00005 in.
Test liquid, fresh distilled water.
Test liquid temperature of 76 F ±1 deg F.
Test pressure, the prevailing barometric pressure, with the test results to be corrected to a reference pressure.
Submergence of test specimen of 0.125 in.
Test liquid depth of 4.5 in. below the test specimen.
Test time of 120 min divided into four equal intervals.

The following procedures are suggested as tentative standards for vibratory resistance tests:

The distilled water should be prepared for test by boiling for 15 min to reduce the air content to a minimum.

A root-mean-square roughness of three microinches should be obtained on the flat circular test surface of the specimen, using triple-zero emery paper.

The specimen should be stabilized in state of oxidation and water content by the following sequence: Boil for 15 min in distilled water, soak to ambient temperature in distilled water, and surface-dry with CP reagent acetone immediately before each weighing and testing.

The specimen should be taken from the vibratory apparatus at the end of each 30-min interval of testing, surface-dried, and weighed. All weights should be taken to the nearest $^1/_{10}$ milligram.

Discussion

S. L. Kerr.[4] The authors are to be commended for the remarkable progress which they made in arriving at a standard procedure for vibratory-cavitation testing. At the Cavitation Seminar, November, 1955, they were designated as a special committee to produce such a standard if possible and within one year had completed their task.

Standardization of the test procedure with the magnetostriction apparatus for measuring the weight loss of cavitation test specimens and thus establishing a relative resistance scale, is highly desirable.

A number of experiments, beginning with those by the writer in 1935 and 1936,[5] have established relative resistance scales with the weight loss of individual specimens related to each other within a given laboratory or within a given program. Such individual relative scales have been developed from work done in Great Britain, France, Germany, Canada, and the United States. It is interesting to note that the displacement of any given material on any of these individual relative scales has been very slight even though there were wide variations in frequencies and other factors in the tests.

With a standardized procedure, however, these *individual* laboratory resistance scales can probably be converted into *absolute resistance scales*, thus permitting a more direct comparison between different tests in different laboratories. Much of the "scatter" of points in any series of tests should be eliminated with standardization of testing technique.

[4] Consulting Engineer, Flourtown, Pa. Fellow ASME.

[5] "Determination of the Relative Resistance to Cavitation Erosion by the Vibratory Method," by S. L. Kerr, Trans. ASME, vol. 59, 1937, pp. 373–397.

It also should be pointed out that the initial resistance of materials to cavitation erosion in the first 30 min of operation can be explored still further by making measurements at intervals of 5 to 10 min. This particular factor also may be related to fatigue action and could be used for inspection work on prewelded surfaces or special surfaces where heat-treatment is required to secure the maximum resistance to cavitation erosion.

With standard techniques as outlined in this paper, it should be possible to correlate the behavior of materials in fluids other than distilled water. Further research under varying back-pressure conditions may give a clue to the proper sigma value and the intensity of cavitation pressures.

The major step, however, is to standardize on technique and the authors have done this in a very commendable fashion.

W. J. Rheingans.[6] As mentioned by the authors, the ASME Cavitation Committee of the Hydraulic Division held a two-day Symposium in 1955 on Accelerated Cavitation Testing Machines. Practically all engineers who ever were connected with accelerated cavitation testing, as well as those who were actively engaged in such work at that time were present at the meeting.

The current paper is a result of the two days of discussion plus further research work and amplification by the authors.

The paper suggests, for the first time, certain standard test conditions to be used in making accelerated cavitation tests with vibratory apparatus, to make possible a direct comparison between tests in various laboratories. It is hoped that these standards will be adopted in the interests of uniformity.

The writer has had considerable experience with accelerated cavitation tests in the past 10 years, and would like to emphasize that consistent results in any given laboratory can be obtained only by adhering rigidly to the test procedures outlined by the authors.

The paper probably would be more complete if the authors included the atmospheric correction factor for tests at various barometric pressures.

It also would be interesting to obtain data on test results of identical test specimens in several different vibratory test machines using the test conditions and procedures outlined by the authors. If such a series of tests gave identical results, they would indicate the benefits to be derived from adopting the suggested conditions and procedures.

The authors are to be congratulated upon having developed test procedures and a set of standards which will tend to give not only consistent results in a given laboratory but give comparable results in different laboratories.

[6] Manager, Hydraulic Department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis. Mem. ASME.

Authors' Closure

The authors appreciate the thoughtful remarks of the discussers since they have been actively associated with accelerated cavitation testing for many years. Due credit should be given to Mr. Kerr who, as a consulting engineer, had contributed a proposal in 1949 for a co-operative agreement among the three industrial research laboratories.