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# CAVITATION DAMAGE IN LIQUID METALS

(Potassium Studies)

by

H. S. Preiser and S. L. Rudy

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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## research in hydrodynamics

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# TECHNICAL PROGRESS REPORT 607-2
For the Period
1 August to 31 October 1966

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(POTASSIUM STUDIES)

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ABSTRACT

Cavitation damage data are presented showing the rate of volume change as a function of test duration for 316 stainless steel in liquid potassium at 400°F, and for TZC alloy in the stress-relieved condition in 600°F potassium. The effect of potassium temperature from 400°- 1200°F on the steady-state zone rate of damage of 316 stainless steel is also given. These tests have been run in pure liquid potassium with measured oxide contamination of 18 PPM or less. The data compared to similar experiments in liquid sodium show that peak rates of damage for 316 stainless steel occur at 600°F for potassium and 400°F for sodium, and that the steady-state volume loss of 316 stainless steel at 400°F in sodium is twice that for 400° potassium.

# CAVITATION DAMAGE IN LIQUID METALS (POTASSIUM STUDIES)

Technical Progress Report
For the Period

1 August - 31 October 1966

## I. INTRODUCTION

This is the second progress report of an investigation on the cavitation damage resistance of refractory alloys in high-temperature liquid potassium. The investigation is being carried out in a modified controlled-environment test chamber, which is adequately described in the previous progress report (Reference 1). Using this facility, the effect of testing time on the cavitation damage rates of 316 stainless steel and TZC were obtained. Further, the effect of temperature of liquid potassium on the cavitation damage of 316 stainless steel is also presented in this report.

## II. EXPERIMENTAL RESULTS AND DISCUSSION

For the initial testing, 316 stainless steel was chosen as the control material. The rate of cavitation damage with respect to testing time was carried out at a potassium temperature of 400°F with retort pressure at 14.7 psia. A total of four specimens were run to substantiate the results. Specimen No. 1 was not usable after only a short testing time due to failure of the amplitude monitoring system. Therefore, data so obtained could not be accepted reliably. Specimens Nos. 2 and 3 (316 stainless steel) were tested with a new strain gauge amplitude monitoring system, which was calibrated as described previously with a filar microscope. Actual specimen displacement is approximately $1.4 \times 10^{-3}$ inch double amplitude, which was selected as the standard for the entire test series. Specimen No. 4 was run to obtain additional data points during the first two hours of testing on the volume loss curve where the greatest change in damage rate occurs. Steady-state conditions were achieved with 316 stainless steel in $400^{\circ}$F potassium after 7 to 8 hours testing time as shown in Figure 1. The surface configuration of 316 stainless steel in steady-state condition is a dull, silver grey matte finish as shown in Figure 2.

For the next series of tests, 316 stainless steel specimens, Nos. 2 and 3 in steady-state condition, were run at standard amplitude and at varying potassium temperatures. Results of the rate of volume loss as a function of liquid temperature are plotted in Figure 3. It should be noted that the peak damage rate occurred at $600^{\circ}$F. After completion of the tests on 316 stainless steel for control data, TZC alloy in the recrystallized condition* was tested at $600^{\circ}$F in liquid potassium for rate of volume loss with testing time. The test temperature of $600^{\circ}$F for the TZC experiment was selected on the basis that peak rates of damage were observed at this temperature for 316 stainless steel. By using the temperature which yields the greatest volume loss with a given test duration, errors are reduced and test duration to achieve steady state is shortened. With a potassium temperature of $600^{\circ}$F, TZC specimens Nos. 6 and 7 in the recrystallized condition were tested for a total of 8 hours at standard amplitude

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* Heat treatment: 1 hr at $3400^{\circ}$F - VC.

with retort pressure at atmospheric. The steady-state condition was achieved in 6 to 7 hours, as shown in Figure 4. Metal was removed from the TZC specimens in small fragments, producing a reflective and irregular crystalline configuration, much like chipped flint, due to its brittleness. This fragmentary erosion is not evident in the more ductile materials such as 316 stainless steel which erodes more uniformly on the cavitating surface.

A comparison of the rate of volume loss data vs. test duration for potassium and for sodium (Reference 2), obtained under almost similar conditions of amplitude and temperature, indicates that the rate of damage of 316 stainless steel in liquid sodium is larger by a factor of two. (See Figure 5). It is also interesting to note that the peak damage rate of 316 stainless steel for sodium was found to occur at 400°F, (Reference 2), while for potassium it occurred at 600°F.

## Other Information

The potassium in the test retort is filled at the beginning of the week and allowed to remain in the retort for an entire week. At the end of the week, a sample of the potassium is taken and held for future oxygen analysis and the potassium charge is then dumped. A new charge of potassium is added to the retort at the start of a new week.

Two random samples of potassium, used as described above, were sent to Atomic Power Development Associates, Inc. for analysis, and the results are reported in Table 1. As can be seen, oxide impurity is being maintained well within the 50 ppm limit imposed for these experiments.

One equipment modification was necessary during the experiment. The voice-coil amplitude pick-up device described in the previous progress report (Reference 1) did not perform properly due to loosening and breakage of the resonating rod at the point of attachment to the transducer stack. A simple strain gage cemented to the stack has provided an adequate monitoring signal for determining amplitude of vibration of the specimen. A new calibration curve was made and the amplitudes reported in these experiments were measured by the strain gage system.

## III. WORK TO BE COMPLETED DURING THE NEXT REPORTING PERIOD

It is planned to complete Phase 1 of the program by obtaining rate of volume loss with temperature for the remaining metals:

TZC - recrystallized and stress-relieved
T-111 alloy
Cb-132M - recrystallized and stress-relieved.

REFERENCES

1. Preiser, H. S., and Rudy, S. L., "Cavitation Damage in Liquid Metals (Potassium Studies)," HYDRONAUTICS, Incorporated Technical Progress Report 607-1, NASA CR-72088, September 1966.

2. Thiruvengadam, A., and Preiser, H. S., "Cavitation Damage in Liquid Metals," HYDRONAUTICS, Incorporated Technical Report 467-Final, NASA CR-72035, November 1965.

TABLE 1

Oxide Impurity Levels in Potassium

| Sample No. | Time Taken | Date Taken | Time Potassium was Held in Retort | Box $O_2$ (ppm) | Box $H_2O$ (ppm) | Potassium Temp. °F | Oxygen Impurity (ppm)* |
|---|---|---|---|---|---|---|---|
| 5 | 4:45 p.m. | 9-6-66 | 4 days | 39 | 105 | 400 | 8 |
| 6 | 4:50 p.m. | 10-7-66 | 5 days | 18 | 1.1 | 500 | 18 |

* Unamalgamated residue calculated as oxygen from $K_2O$.

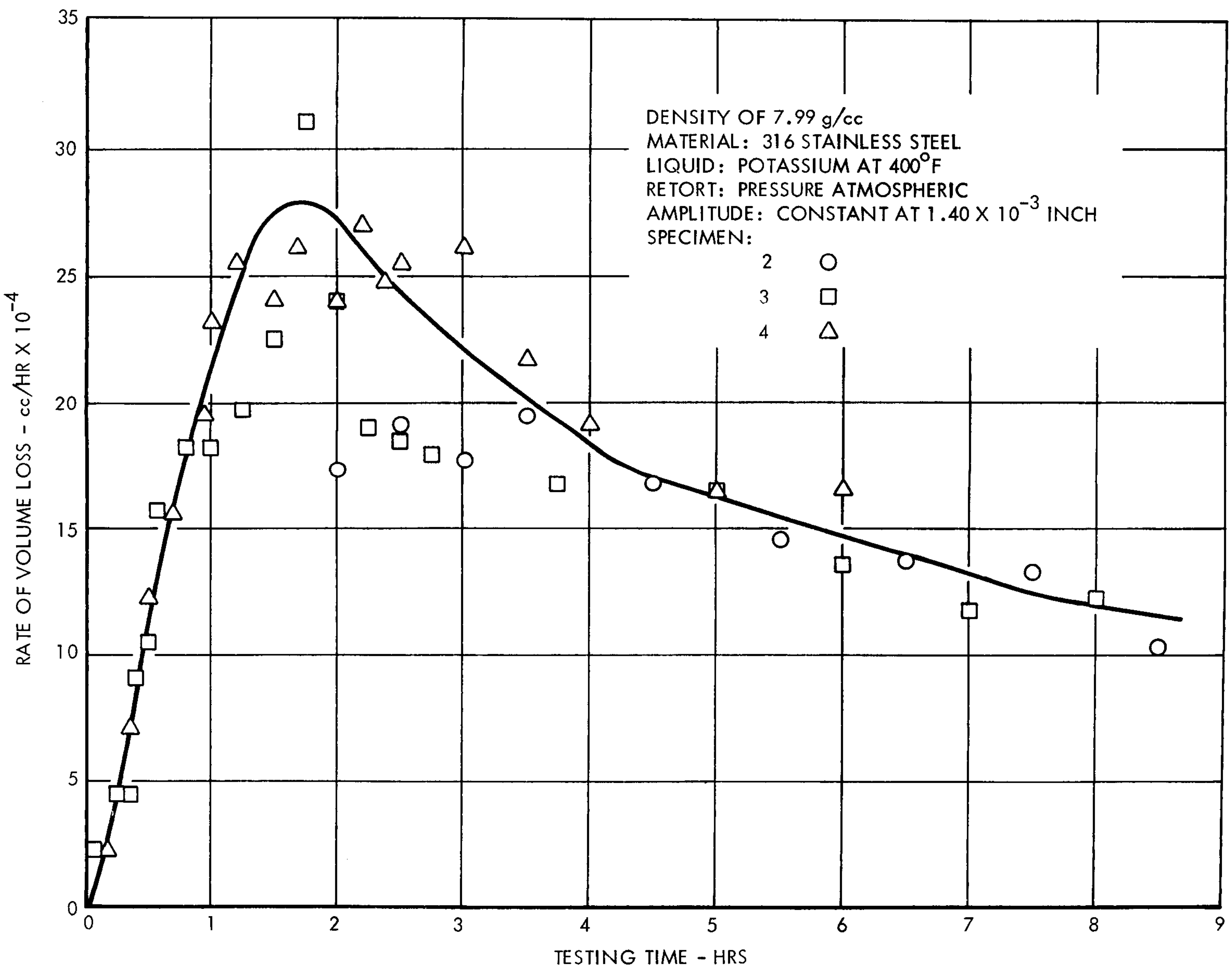
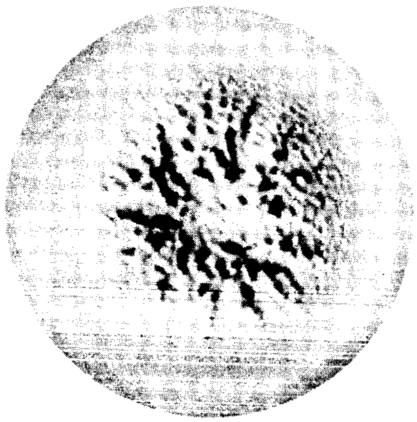
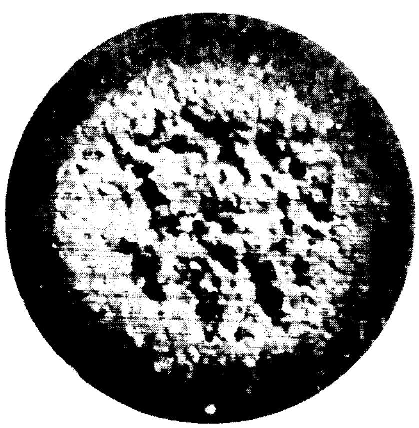



FIGURE 1 - EFFECT OF TESTING TIME ON CAVITATION DAMAGE RATE OF 316 STAINLESS STEEL IN LIQUID POTASSIUM



316 STAINLESS STEEL



TZC

FIGURE 2 - APPEARANCE OF 316 STAINLESS STEEL AND TZC IN STEADY STATE

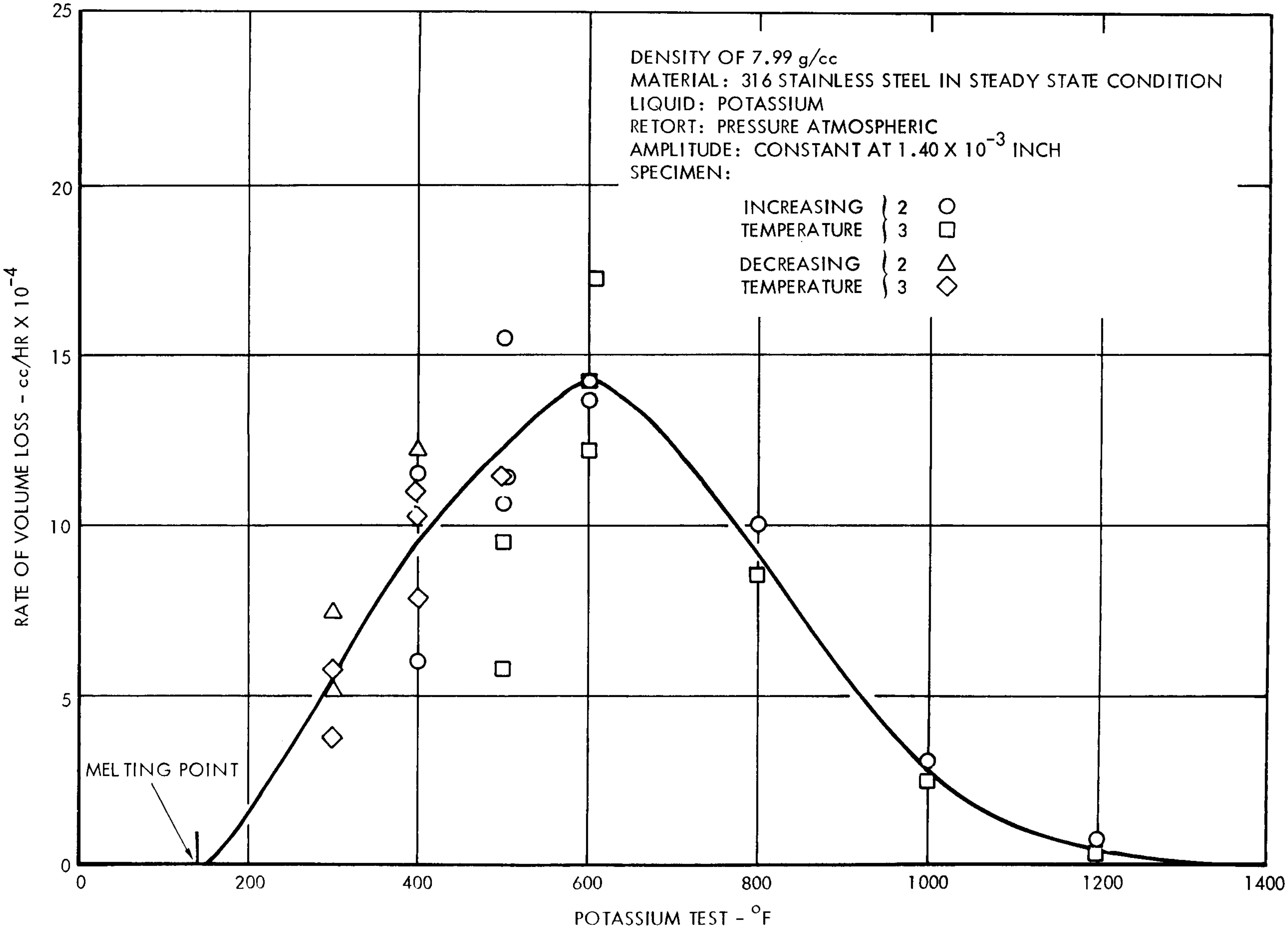



FIGURE 3 - EFFECT OF TEMPERATURE ON THE CAVITATION DAMAGE RATE OF 316 STAINLESS STEEL IN LIQUID POTASSIUM

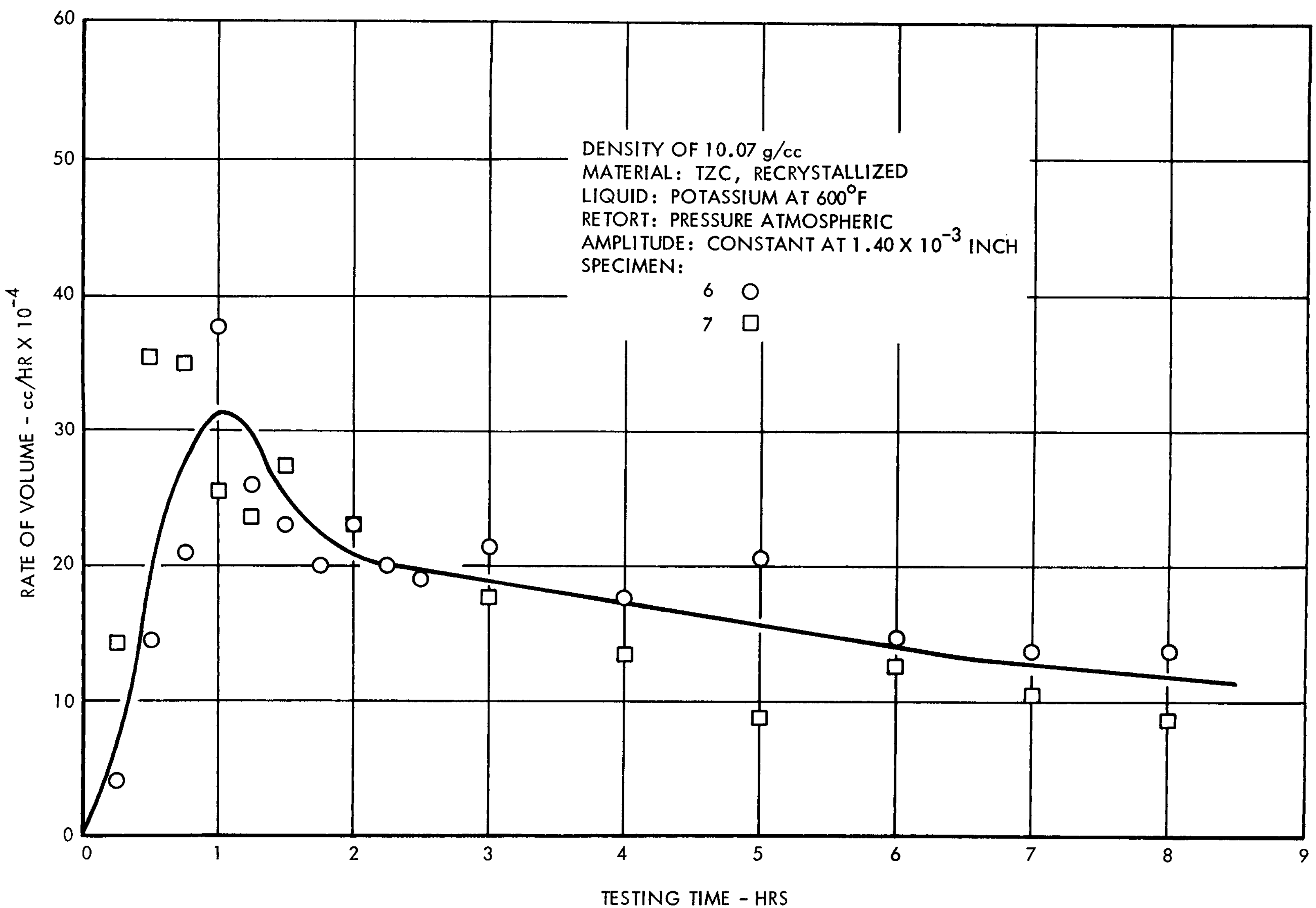



FIGURE 4 - EFFECT OF TESTING TIME ON CAVITATION DAMAGE RATE OF TZC IN LIQUID POTASSIUM

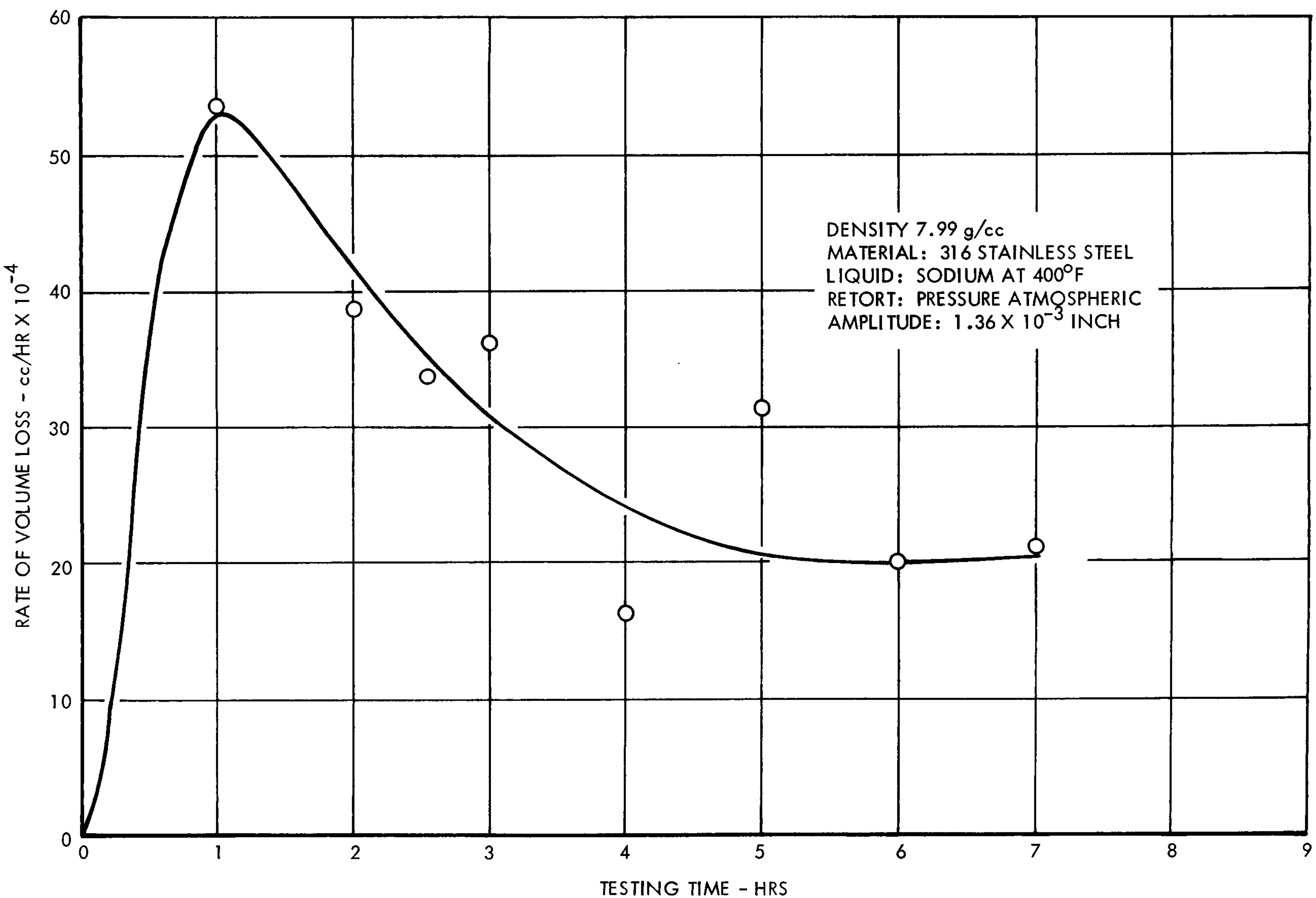



FIGURE 5 - EFFECT OF TESTING TIME ON CAVITATION DAMAGE RATE OF 316 STAINLESS STEEL IN LIQUID SODIUM - REF 2

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