CORROSION OF SOME COBALT AND IRON BASE ALLOYS IN MERCURY

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ABSTRACT

Mercury corrosion experiments at temperatures near $1100^\circ$ F ($868 \, K$) were performed with reflux capsules and forced-flow loops. The materials used in the capsule experiments were two iron-base alloys and two cobalt-base alloys. Two loop tests were made with a cobalt-base alloy, HS-25. There was significantly greater depths of corrosive attack in the cobalt alloy loop than in the reflux capsules. An explanation based on velocity effects and changes in corrosion mechanism is offered to account for these results. However, loop results could not be readily correlated with capsule results nor could the loop results be extrapolated beyond the actual test times.

INTRODUCTION

A research investigation was undertaken to study mercury corrosion. The investigation was part of a program for developing advanced space power systems using liquid metals as working fluids. Two major objectives were the identification of corrosion processes and the prediction of long-term corrosion damage of actual system components by flowing mercury.

Previous investigations (refs. 1 and 2) have indicated that convective diffusion and liquid flow velocity are factors in liquid metal corrosion. The purpose of this paper is to present new evidence indicating the significance of convective diffusion and liquid velocity in mercury corrosion of alloys with highly mercury-soluble constituents. Consideration is also given to the fact that other factors can contribute importantly in the formation and character of the corrosion layer in materials susceptible to mercury attack.
MATERIALS, APPARATUS, PROCEDURE

The mercury corrosion experiments discussed herein were performed with the cobalt-base alloys H-8187 and HS-25 (L-605) and the iron-base alloys AM 350 and SICROMO-9M (Croloy 9M). See table I for alloy compositions. Each of these materials was tested with a large number of refluxing mercury capsules. Two forced-flow, two-phase corrosion loops of the alloy HS-25 were also operated to obtain results at liquid flow velocities comparable to those expected in actual mercury boilers. Table II gives the flow velocities and temperatures for the HS-25 capsules and the two loops in the regions of maximum corrosive attack.

A detailed description of the apparatus, procedure, and results of the reflux capsule tests is given in reference 3. Like information is given for the two mercury corrosion loops in reference 4.

In the reflux capsule experiments the capsule wall served as the test specimen (fig. 1). For the purposes of this paper, only the boiler inlet region of the two NASA forced-convection loops will be described. This is the region which is relevant for comparing these loop and capsule results. Figure 2 illustrates the configuration of the boiler inlet region of NASA loop A. A helical groove was swaged into the tube wall to swirl the liquid phase and thus help produce phase separation. In NASA loop B the boiler inlet was fitted with a cylindrical insert which together with the swaged wall formed a helical channel as illustrated in figure 3.

All the capsule results given herein were obtained at a nominal test temperature of 1100°F (868 K). Test times ranged from about 300 to 5000 hours. Loop A was operated for a total time of 400 hours with a peak liquid temperature in the boiler inlet zone of about 1100°F (868 K). Loop B was operated for 1147 hours with a peak liquid temperature of 1075°F (858 K) in the boiler inlet (insert) zone. In the loop boilers, the peak liquid temperatures occurred in the region where two phase flow began.

Post-test metallographic, chemical, and physical analyses were used to determine the extent and nature of corrosive attack. The maximum depth of corrosive penetration into the original containment wall was used to gauge the degree of attack.

RESULTS AND DISCUSSION

In the capsules maximum corrosion occurred in the top portion where the solute-free mercury vapor condensed. The depth of penetration decreased in a regular manner from the point of maximum depth to the surface of the liquid pool. The composition of the