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ORNL-TM-179

COPY NO. - 12

DATE - March 15, 1962

THE DEVELOPMENT OF A SUMP-TYPE SOLIDIFIED-METAL SEAL

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ABSTRACT

A solidified-metal seal for possible use in molten-salt systems has been fabricated and tested on a laboratory scale. The seal consisted of an 80 Au–20 Cu (wt %) sealant alloy in contact with INOR-8 base metal.

Eleven successive helium-leak-tight sealings were effected before termination of the test due to a leak in one of the mating parts. With better control over the heating cycle and slight modifications in seal design, it is expected that the useful life of a seal of this type could be extended even further.

THE DEVELOPMENT OF A SUMP-TYPE SOLIDIFIED-METAL SEAL

INTRODUCTION

The development of solidified-metal seals for elevated-temperature, leak-tight, quick-disconnect joints has been under way in the Welding and Brazing Laboratory of the Metals and Ceramics Division for the past several years. The work was initially concerned with high-vacuum valve and flange applications for the Sherwood Project and these results have been reported.[1] Since this type of seal also appears to be potentially advantageous in molten-salt reactor applications, the development was continued under sponsorship of the Molten Salt Reactor Project.

Since sump-type, solidified-metal seals can be constructed from relatively simple components, the initial experiments were conducted with typical demonstration assemblies. The selection of potential sealing alloys was limited to those which are corrosion resistant to molten fluoride salts of the $LiF-BeF_2-UF_4$ type. Temperature limitations on the melting point of the sealing alloy were also important in that the solidified metal must have some strength at the operating temperature range of 1200–1300°F. On the other hand, the melting point must be low enough to prevent thermal damage to the adjacent INOR-8 parent material when making and breaking the seal.

GENERAL PROCEDURE AND RESULTS

With these limitations and conditions of operation in mind, the alloy with the lowest melting point in the gold-copper system was selected for the demonstration tests. This alloy, 80 Au–20 Cu (wt %)[2] has a melting point of 1625°F and was found to be exceptionally resistant

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[1] R. E. Clausing and J. W. Tackett, Thermonuclear Semiann. Progr. Rept., Jan. 31, 1959, ORNL-2693, pp 86–90.

[2] Metals Handbook, p 1171, American Society for Metals, Novelty, Ohio, 1948.

to corrosion by molten salts.[3] Experience has also demonstrated that this alloy exhibits excellent wetting on INOR-8 base material in vacuum, dry hydrogen, and inert atmospheres.

Since this operation may be considered as a type of brazing, some solution of the base material by the molten sealing alloy and diffusion of the alloy into the base metal could be expected during the making and breaking of a sump-type seal. Therefore, a short study was conducted to determine the influence of time at temperature upon the magnitude of these effects. Small samples of gold-copper alloy were placed in contact with INOR-8 at 1725°F (100°F above the melting point of the alloy) for ½, 1, 5, and 20 hr. As would be expected, metallographic examination of these specimens revealed some general diffusion of the alloy into the INOR-8. The detailed results are shown in Table 1.

Table 1. Diffusion of Sealing Alloy into INOR-8 Base Metal at 1725°F

Holding Time (hr)	Maximum Depth of Diffusion (in.)
½	0.010
1	0.015
5	0.015
20	0.021

In view of the fact that some diffusion and, therefore, probably solution had occurred, it was apparent that the sealing alloy should be kept molten for as short a time as possible. In addition, it appeared advantageous to design the sump to give a high brazing alloy volume-to-INOR-8 surface area ratio. This would minimize changes in the remelt temperature as a result of both the solution and diffusion.

A sump-type seal assembly was subsequently fabricated and operated in an argon atmosphere, as shown schematically in Fig. 1. Induction heating was utilized to minimize the time required for making and breaking

[3]E. E. Hoffman et al., An Evaluation of the Corrosion and Oxidation Resistance of High-Temperature Brazing Alloys, ORNL-1934, p 16 (Oct. 23, 1956).

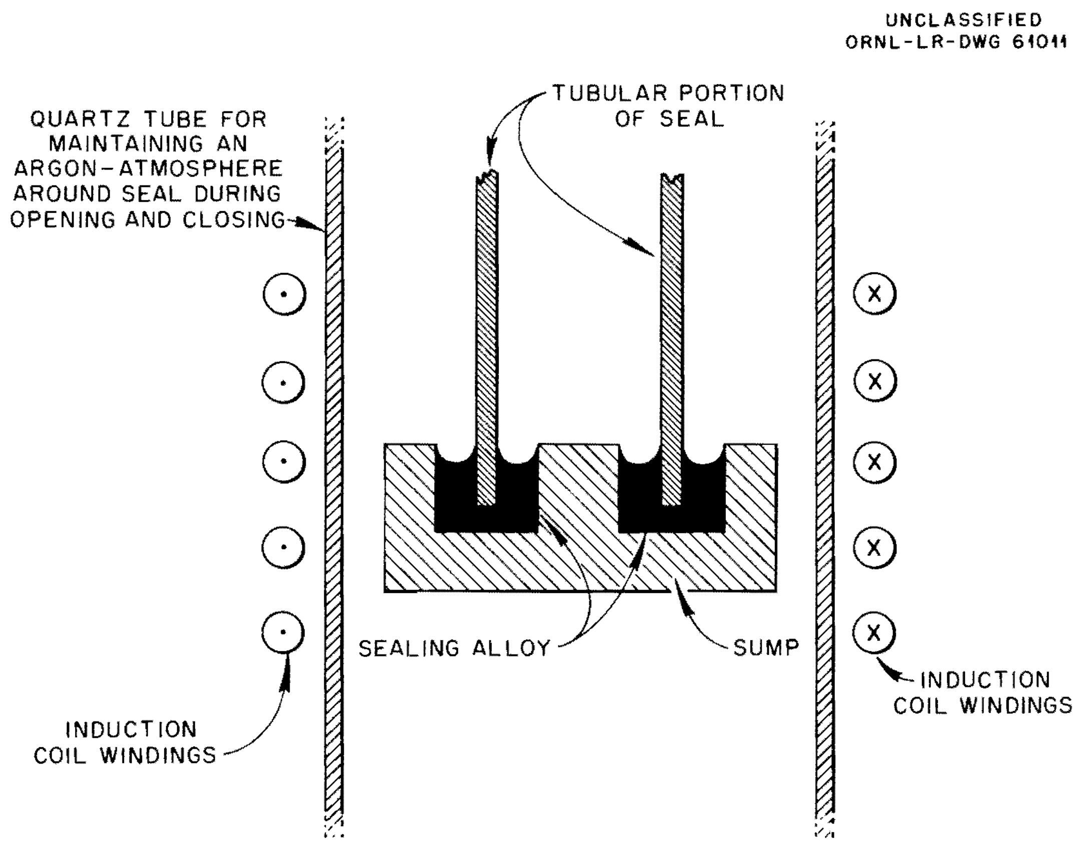

Fig. 1. Schematic Section of Sump-Type Solidified-Metal Seal.

the seal. This heating method would also be a likely candidate as the heating method in remote applications for molten-salt reactors. The seal assembly is shown in Fig. 2a and 2b in the opened and closed positions, respectively. Operation of the seal was, of course, carried out with the sump in the horizontal position; otherwise, the sealing alloy would flow away from the joint when molten. Visual observation revealed that, even though the sealing alloy had become slightly oxidized during each opening and closing, both mating components were adequately wet during sealing as evidenced by the appearance of continuous fillets and the attainment of a helium leak-tight joint. After eleven successive helium leak-tight sealings, a leak in the sump occurred allowing the sealing alloy to drain out. The test was then terminated.

A vertical section taken through the sump and fracture area was examined metallographically. The failure, as shown in Fig. 3, was found to be a crack which emanated from the lower sump edge. Figure 4a is a photomacrograph of this section, with the actual failure being the vertical crack in the center of the photograph. A close-up of this crack is shown in Fig. 4b. The appearance and propagation of cracks of this type were noted along the bottom edge of the sump throughout the test. These edge cracks appeared during the localized overheating of the edge as the seal was being made and broken. High-frequency heating with induction units of this type (150–450 kc) results in a high degree of "skin-heating" as compared to the through-heating obtained with lower frequency units. The posttest examination showed that the overheating was so severe that portions of the lower edge of the sump had been melted.

A second type of cracking can also be seen in the section shown in Fig. 4a. These cracks seemed to emanate from the bottom corners of the sump recess. In this section, both corners are from the outside edge of the sump recess. Examination of a diametral section of the sump, Fig. 5a, also revealed these same cracks. In addition, examination of this diametral section indicated that these cracks were only found on the outside corners of the sump recess – the inside corners being free of cracks. This suggested that these cracks were also caused by thermal

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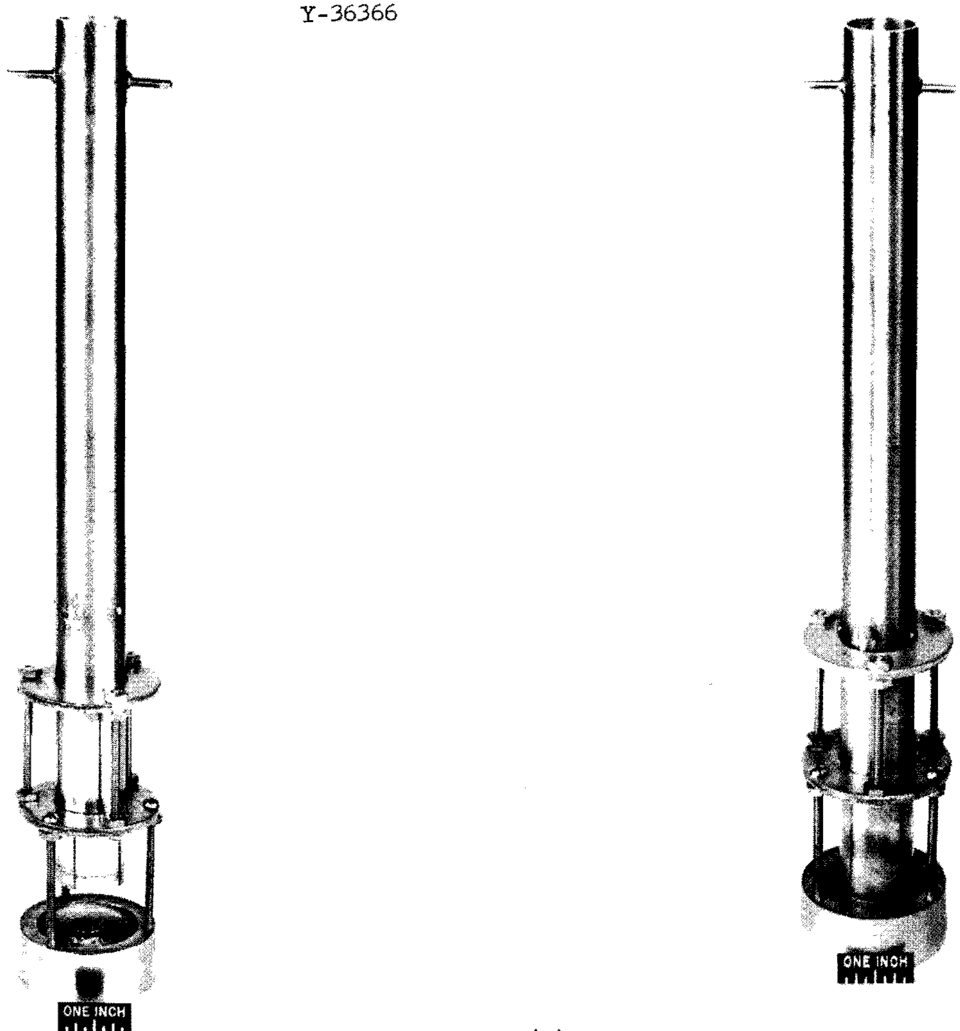

(a) (b)

Fig. 2. (a) Seal Assembly in Opened Position. (b) Seal closed.

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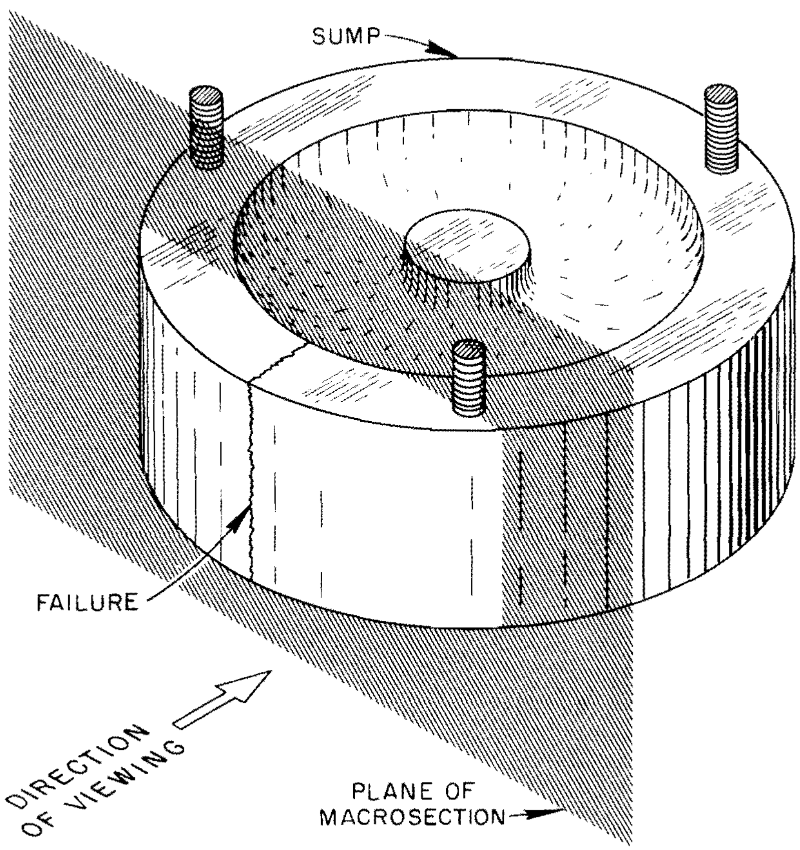

Fig. 3. Schematic Drawing Showing Orientation of the Metallographic Section in Fig. 4a.

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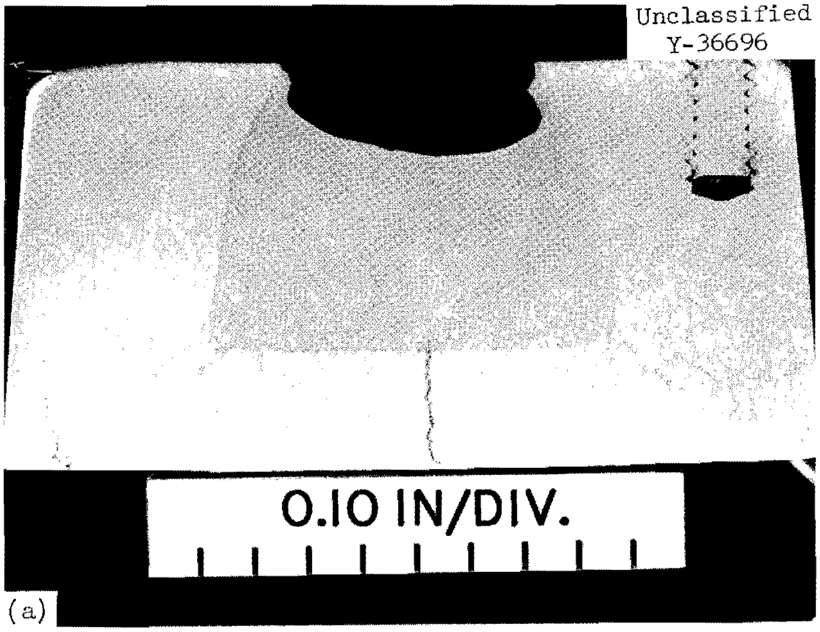

(a)

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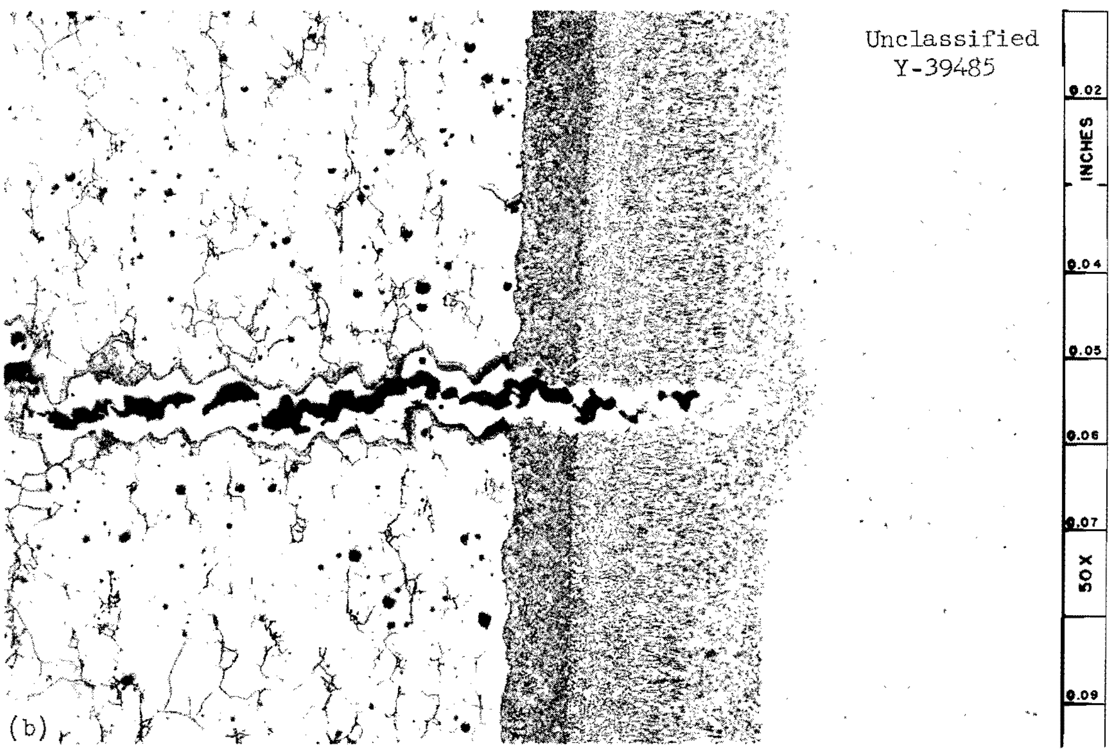

(b)

Fig. 4. (a) Metallographic Section Through Sump After Termination of Test. Several large cracks are evident. Etchant: 3 parts HCl, 2 parts H_2O, 1 part 10% CrO_3. 3X. (b) Photomicrograph of Failure. 50X. Reduced 10%.

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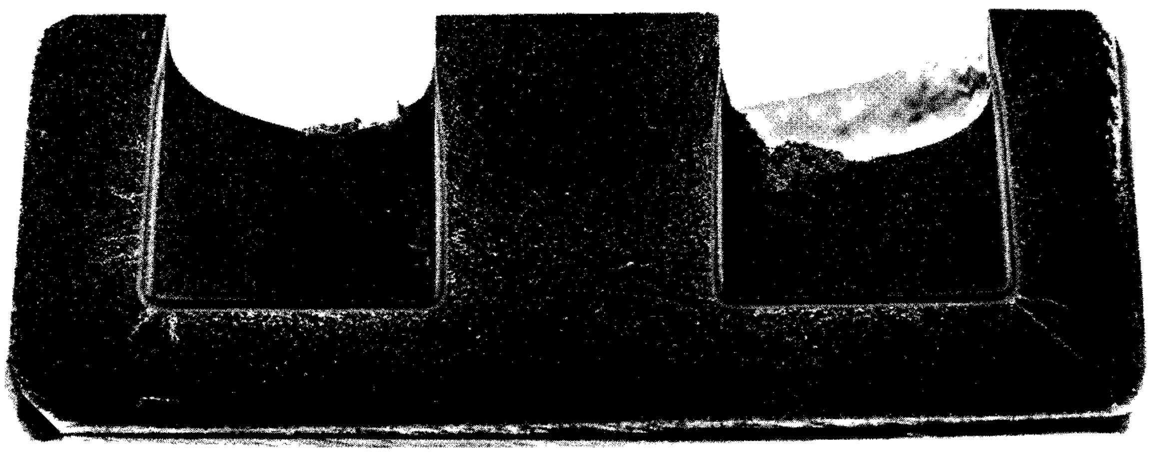

Fig. 5a. Diametral Macrosection Showing Diagonal Cracks at Outer Corners of the Sump Recess. Note absence of cracks at inner corners. Etchant: 3 parts HCl, 2 parts H_2O, 1 part 10% CrO_3. 3X. Reduced 8%.

stresses resulting from the steep temperature gradient imposed by the direct induction heating. The effect would be similar to that which caused the outer edge cracking noted above. In this case, the outer portion of the sump would try to expand while being restrained by the colder inner portion. The points of maximum stress would then be at these lower, outer corners of the sump recess. Since the radius in this corner was very sharp, it would tend to concentrate these thermal stresses, resulting in failure by cracking.

Penetration of the sealing alloy into the INOR-8 was observed in the sump to a depth of 25–30 mils (Fig. 5b) and also in the tubular portion of the seal (Fig. 6) to a depth of about 20 mils. No cracking was observed in this tube portion of the seal, however, and it is felt that it could be subjected to many more sealing cycles without difficulty.

CONCLUSIONS

As a result of this study, the utilization of sump-type solidified-metal seals for molten-salt reactor applications appears to be attractive. The successful operation of this demonstration assembly for ten cycles is very promising, and a further extension of the assembly lifetime appears definite if the sharp sump edges are eliminated and the rates of heating reduced. Also, an instrumented temperature control would have eliminated the overheating condition which occurred.

ACKNOWLEDGMENT

The author gratefully acknowledges the assistance of J. J. Woodhouse of the Welding and Brazing Group in the fabrication and operation of the seal and E. R. Boyd of the Metallography Group for the preparation of metallographic samples.

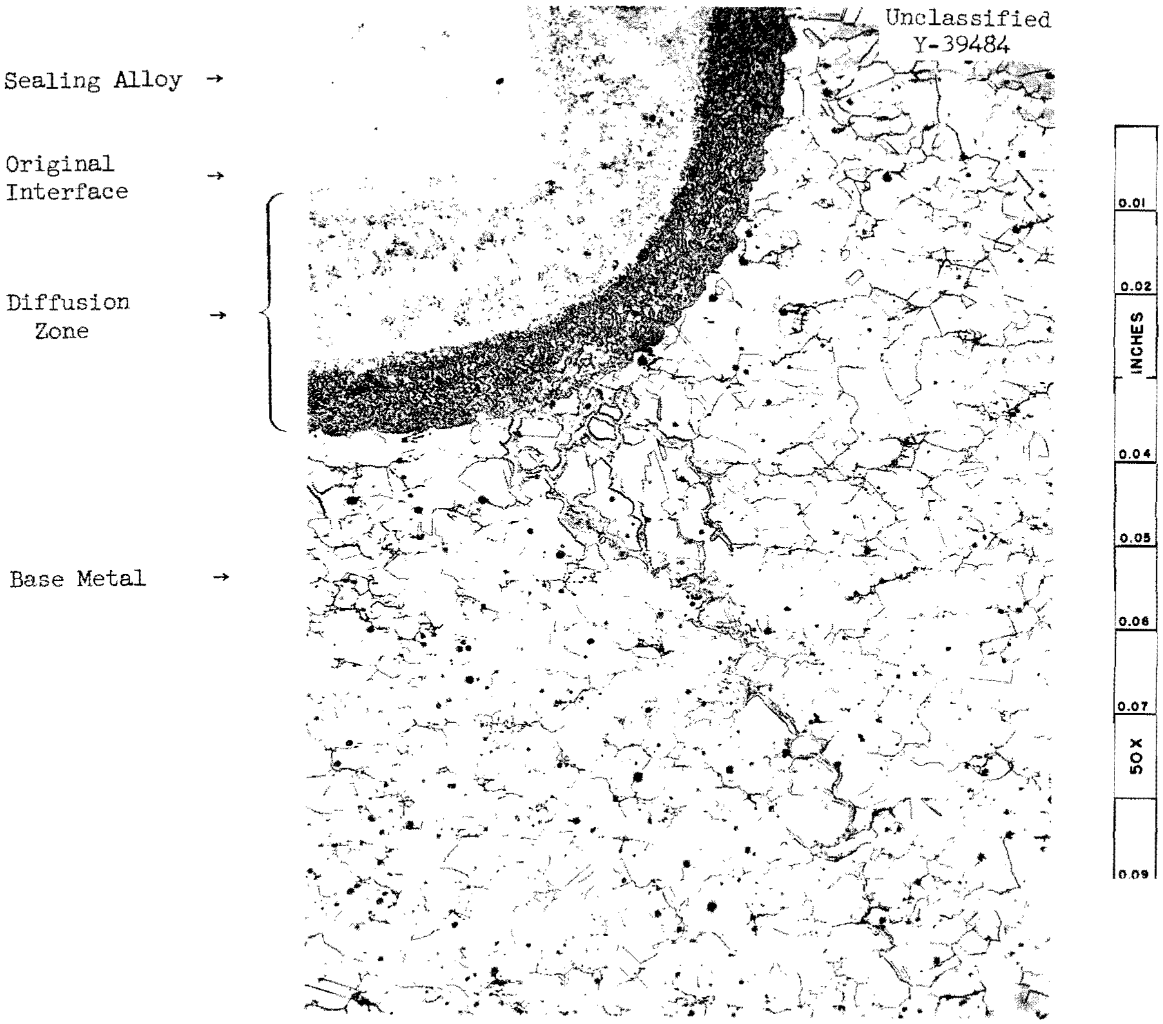

Fig. 5b. Metallographic Section of Corner of Sump Showing General Diffusion and Corner Cracks. Etchant: 3 parts HCl, 2 parts H_2O, 1 part 10% CrO_3. Reduced 14.5%.

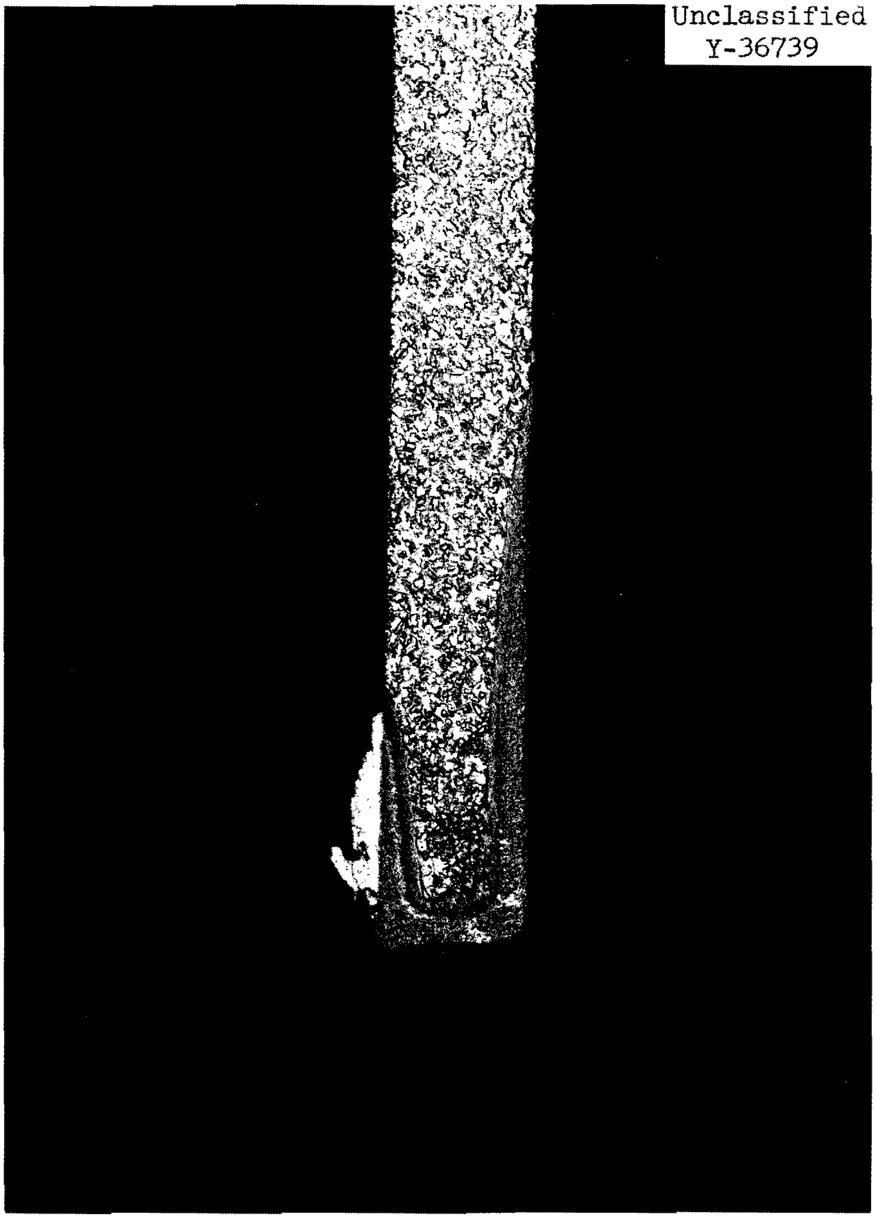

Fig. 6. Metallographic Section of Tubular Portion of Seal Showing Severe Alloying. Etchant: 3 parts HCl, 2 parts H_2O, 1 part 10% CrO_3. 12X.

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