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CAUSES OF DAMAGE TO TUBE 1794-C

INTRODUCTION

Tube 1794-C was removed from the pile as a leaker on July 15, 1954. The tube had been in-pile since startup and had contained a charge of 32 "C" metal slugs just prior to discharge. The tube was slit and examined at the 105-DR underwater viewing facility by Pile Coolant Studies tube examination personnel.

SUMMARY

A report is made of the examination of tube 1794-C which revealed areas of severe pitting damage. This damage was apparently caused by cocked slugs abrading the tube. The attack was great enough to cause perforation of the tube at about 27 feet from the rear Van Stone flange. Examination of the slugs showed that a considerable number had been cocked. Evidence of severe tube scarring and rib grooves was found on the slugs.

Strikingly similar examples of pitting and grooving were observed on flow laboratory minitubes and slugs exposed in high velocity water. It is concluded that the damage observed both in- and ex- pile was caused by the chattering of misaligned low density slugs in a high velocity stream. If the number of in-pile occurrences of this attack becomes excessive it is recommended that the water flow rate in tubes containing "C" metal slugs be maintained as low as is practical and consistent with corrosion limitations.

IN-PILE OBSERVATIONS

Tube 1794-C was found to be in good condition except for a ten foot section near the center of the tube. In this section, extending between 21 and 31 feet from the rear Van Stone flange, a number of bullet-shaped depressions were observed. The depressions, which occurred on the upper half of the tube, appeared to be formed by cocked slugs that had been wearing into the tube. From the appearance of these depressions it was concluded that the slugs had been cocked away from the ribs at one end, perhaps the upstream end. The opposite ends of the slugs abraded the ribs and even the tube wall between the ribs. At least nine positions of slug cocking were observed in this tube. A photograph of one slug depression and the rib abrasion caused by the adjacent slug is shown in Figure 1.

The "C" slugs from tube 1794-C were examined and photographed by Fuel Examination personnel. At least eight slugs showed signs of cocking and deep rib grooves. The bullet-shaped marks noted on the tube wall were mirrored on the slug surfaces. On the ends and sides of the slugs opposite this characteristic mark deep rib grooves were observed. The grooves occurred on the cap ends; the tube wall scars occurred on the can ends of the slugs. From flow laboratory observations it was deduced that the can ends of the slugs were upstream. Figure 2 is a photograph of the can end of a slug that was cocked during exposure. Note how the marks on the slug match the marks on the tube section of Figure 1.

EX-PILE OBSERVATIONS

Tube and slug damage very similar to that described above was observed on minitubes and minislugs discharged from a flow laboratory test. In this experiment the effect of velocity on 2-S aluminum corrosion was determined by exposing minislugs to process water at a temperature of 95 C and at velocities of 45, 30, 22, and 12 feet per second. The slugs and the tube exposed to water at 45 feet per second were found to be severely damaged. At the high velocity the light aluminum slugs apparently "floated" in the water stream; the upstream ends rode against the top of the tube and the downstream ends rode on the ribs. Slight vibration or chattering of the slugs produced eroded or abraded areas on the tube wall, slug surfaces and tube ribs. An example of attack is shown in Figure 3. As in the case of the in-pile observations the slugs exhibited bullet-shaped marks on one end and rib grooves on the opposite end. Figures 4 and 5 show the characteristic marks and rib grooves observed on some of the minislugs which were cocked. None of the slugs or tubes exposed at water velocities of 30 feet per second or lower showed any damage from slugs being cocked or evidence that any slugs had been cocked.

DISCUSSION

Whether or not this phenomenon becomes a serious in-pile problem depends on its reoccurrence. Large numbers of tubes containing low density slugs have been irradiated at Hanford. Even though these tubes operated at lower velocities than tube 1794-C, the fact that no damage of this type has been observed before points up the fact that the problem is not too serious. Reoccurrence of the situation in tube 1794-C probably depends upon the causes of slug cocking. If tube 1794-C was a "freak", i.e., the slugs were cocked by a unique charging pattern or by the tube ribs not being level or by some other abnormal condition, then no real problem exists. If however, the slug cocking was caused by some normal condition such as by routine charging or by "floating" in a high velocity stream then a reoccurrence can be expected.

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Figure 1. Section from tube 1794-C, discharged 7-15-54. Note: Hole in tube occur at blunt end of bullet-shaped depression. Note abrasion of wall between ribs.

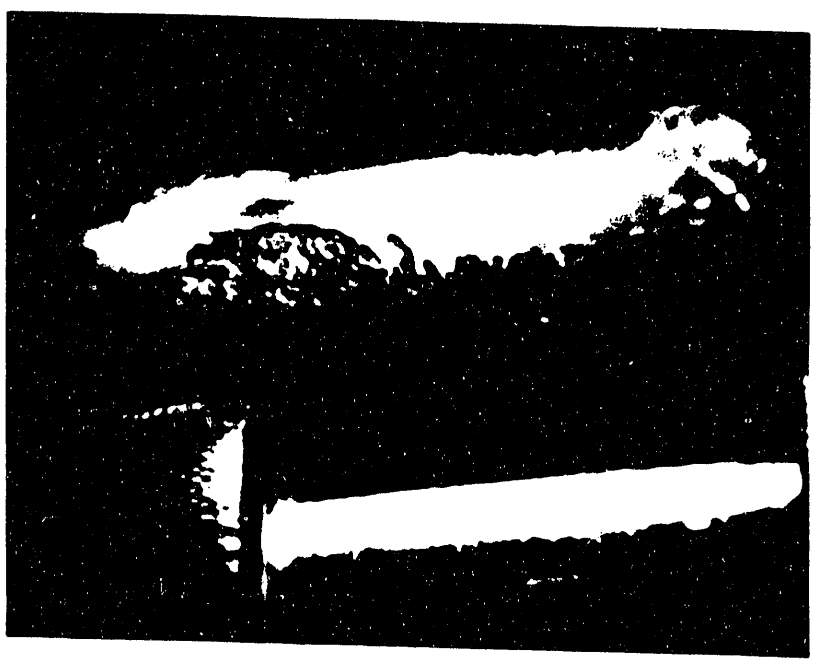

Figure 2. "C" slug discharged from tube 1794-C on 7-15-54. Note shiny area wher slug touched tube wall.

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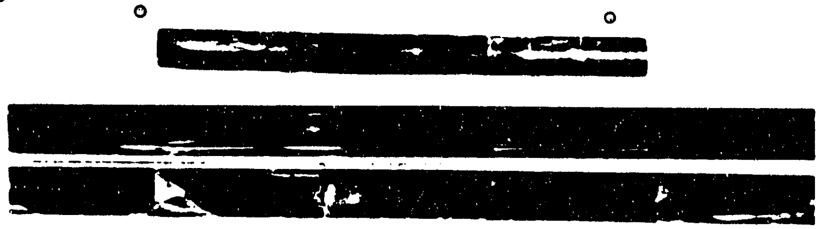

Figure 3. Minitube and slugs exposed to water at 45 feet per second.

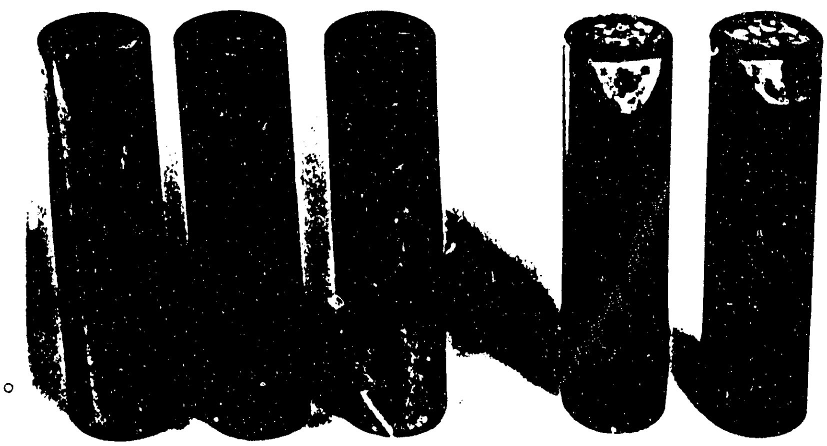

Figure 4. Aluminum minislugs exposed in high velocity water stream. Note bullet-shaped marks where slugs touched tube walls. Slugs on right were not cleaned.

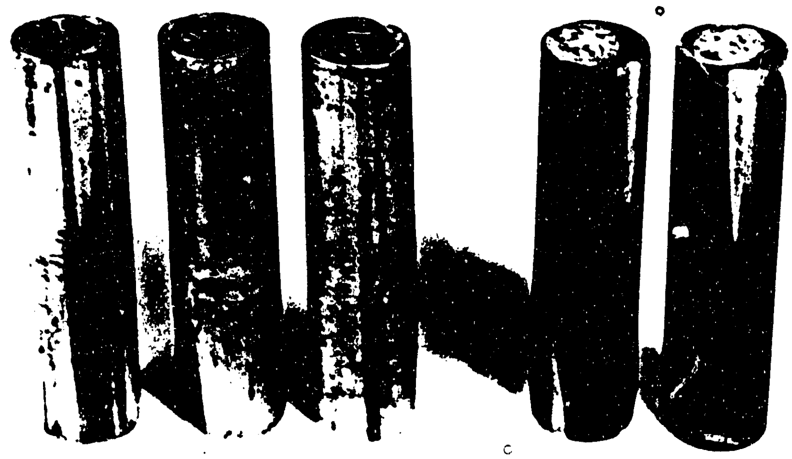

Figure 5. Opposite side of slugs shown in Figure 4. Note rib grooves occurring predominantly at downstream ends.

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One or two more occurrences will be sufficient to consider the problem serious.

It should be pointed out that slug cocking per se did not produce the damage observed in the incidents reported here. Although slug cocking is a necessary vehicle the damage is actually caused by chattering or fluttering of the slugs.

As slug cocking is a necessary factor in the type of damage reported here one of the promising avenues of attack would be the elimination of factors tending to promote cocking. The use of enriched heavy metal slugs to eliminate "floating" in a high velocity stream, or a redesign of low density slugs to intrinsically eliminate cocking are two possible solutions. However each of these suggestions require a change in the slug itself and would therefore require development work. Another solution to the problem would be the elimination or reduction of factors tending to promote slug chattering. As chattering is brought about by extreme water turbulence around cocked slugs and as chattering becomes more violent at increased water velocities the most practical way to eliminate or reduce it is to reduce water velocity. The maintenance of water velocities as low as possible is believed to be the best and most practical solution to the problem.

CONCLUSIONS AND RECOMMENDATIONS

It can be concluded from the observed in-pile and flow laboratory data that:

1. The leak in tube 1794-C was caused by the abrasion of a cocked slug against the tube wall.
2. The damage observed both in this incident and in scaled-down laboratory tests was produced by the chattering of slugs in a high velocity stream.

If reoccurrences show a serious problem exists the following corrective measures can be taken:

Reduce the water flow in tubes containing "C" metal to the lowest permissible flow. In the case of tube 1794-C the tube operated at 42 gpm minimum water flow with temperatures of 14 C inlet and 63 C outlet. The flow could be reduced to approximately 26 gpm without exceeding the outlet water temperature limit of 95 C.

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