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Case Study: Failure Analysis of a Boiler

One failed stay rod from a house boiler was submitted for determining the cause of failure. Water had been leaking through the tell tale hole of the stay rod for several months. A sketch showing four stay rods that had been replaced in the one year old boiler was also submitted. The sketch, additionally, showed a schematic arrangement of the stay rod in the boiler, Appendix -1.

Mill Test report of the one inch round bar material, from which the stay rod was cut, was attached. The material had been accepted to ASME SA-36 specifications, Appendix -2.

Key Words Boiler, rod, water, leakage

Circumstances Leading to Failure Fabrication Weakness and stress generated over time.

Visual Examination of General Physical features. The submitted section of the stay rod included the fillet weld that integrated it to the plate section of the outer wall. The fire box side wall joint was not provided. The rod had heat scale intact and no external deposits or pitting was observed. The fillet weld was found to be concave. No pores or cracks were observed on the weld. The weep hole on the outer side was bigger than the specified diameter of 1/8 inches. It was apparent that the hole had been drilled in two settings. Sharp tool marks on the inside surface of the hole were visible, Figure 1. no deposits were found in the hole.

Radiography The submitted rod section was radiographed using Iridium 192 radiation source. Radiographs represented two longitudinal planes perpendicular to each other. The images, particularly the one designated 0, showed the presence of a transverse crack initiating at the lower edge of the weld pool and terminating into the tell tale hole. The crack location is shown in sketch, Appendix -3 The radiography parameters are given in Appendix -4.

Macro Examination A cross section specimen was prepared for macro examination to reveal the profile of the weld near the fracture outline. The actual profile of the weld was found to be different from the provided sketch, Figure 2.

Micro Examinaton Longitudinal sections of the rod were cut and prepared for examination under an optical microscope at higher magnifications. The section showed inclusions aligned in the direction of rolling, Figure 3. Notch sensitive banded micro structure containing alternately soft (ferrite) and hard (pearlite) layers was evident, Figure 4. No cracks were observed to have initiated from the bore.

Fracture Analysis A Test specimen was cut and the end surface was carefully machined to reveal the fracture surface of the crack. The fracture face of the crack showed fatigue markings, Figure 5

Discussion Radiography clearly showed that the path of the leak was provided by a crack that connected the weep hole to the water jacket through the annular space. The actual weld profile as revealed in the macro examination was very different from the sketch submitted by the client. One possibility for such a profile could be oversize holes in the plate leading to substandard fit up. Sharp corner of the weld pool with the surface of the rod, within the annular space, served as the needed stress raiser for the crack to initiate. The crack initiation took place either during the cooling of the weld pool or soon after.

The fracture surface morphology shows a progressive mode of propagation of crack by fatigue. Necessary cyclic stresses were probably provided by a combination of mechanical vibrations, generally induced by the burner system, and operational heat cycles.

Banded structure apparently resulted from segregations in the billet from which the bar was rolled.

Conclusion On the basis of the above discussion, it is concluded that the leak was caused by a crack that initiated at a fabrication weakness and grew under cyclic stresses generated during operation.