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CONDITION ASSESSMENT AND REPAIR WELDING OF HIGH TEMPERATURE HEADERS

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Abstract

High Temperature headers in power plants are subjected to severe operating conditions. This includes thermal and mechanical fatigue and high temperature degradation (creep). As the age of these plants increase and the operating conditions become more severe, i.e., cycling and load following operations, these headers are subject to accelerated deterioration. The ligament between tube bore holes, which is one of the most highly stressed areas in the header, is susceptible to cracking. If cracking progresses to a point where the performance and integrity of the header is affected, header replacement is an expensive option when material, labor and lost production costs are considered.

This paper will discuss the option of a repair welding program. This will include the nondestructive examination techniques currently available to evaluate the condition of the header. A discussion of a special ultrasonic procedure for quantifying ligament crack depths will be included. A case history illustrating the nondestructive examination techniques and the implementation of the repair will be presented.

Background

High temperature outlet headers utilized in utility power boilers are designed and fabricated in accordance with Section I of the ASME Boiler and Pressure Vessel Code.

These headers are utilized to collect superheated steam and directed towards the turbine generator. Typical examples are Secondary Superheater Outlet Headers and Reheat Outlet Headers. There are several different designs for these headers. They include single and dual header arrangements and single and dual exit points. As these headers are in the highest temperature portion of the boiler, they are normally operated in the creep environment. Common material types for these headers include 1¼Cr-1/2Mo and 2¼Cr-1Mo low alloy steels. Some more recent replacement headers have been designed out of P99 which is a 9 Cr - 1/2 Mo alloy steel material. As these headers are critical components, they are normally subjected to the ongoing condition assessment programs which are being implemented to extend the life of the many aging power plants.

One of the most highly stressed portions of these headers is the ligament area between the two bore holes. These ligament areas are highly susceptible to hoop stresses, thermal fatigue, creep and ultimately cracking.

Condition Assessment Program

A condition assessment program for these high temperature headers involved several examinations. A typical program will include wet fluorescent magnetic particle examination of the tube stub to header welds and all girth or seam welds. Metallurgical evaluation by either replication or sample removal are performed. These samples are analyzed in a laboratory to determine if any creep degradation has occurred. The internal diameter of the headers are also examined. This is typically done with a remote camera or borescope. These examinations look for discrepant conditions such as heavy scale or exfoliation and cracking in the ligament areas. If cracking in the ligament area is identified, a special ultrasonic examination procedure can be performed in order to determine the extent of the cracking.

This technique uses specially developed transducers and wedges in conjunction a calibration standard which has been machined from a header which was removed from service. In addition, state-of-the-art digital signal processing equipment is used to "fingerprint" known defects in headers. The computer has been trained to recognize the difference between geometric reflectors and defects. Although this is not an exact science, it is another tool that can be utilized to better quantify the extent and location of the cracking.

Repair Welding

Repair welding can be an extremely cost effective alternative to header replacement. If properly performed, repair welding can quickly and efficiently return a header to service and significantly extend the life of the header. However, if repair welds are improperly performed, they can significantly reduce the remaining life of the header. Specially developed techniques and properly monitored implementation must be utilized for repairs to be effective. Continual monitoring of the repair process must be performed by experienced personnel to obtain a high quality repair.

Case History

As part of a condition assessment program, an eastern utility identified ligament cracking in their reheat outlet header in 1985. At that time, six of the severe crack locations were repair welded. The details of the procedure utilized during that repair were not available; however, minimum preheat was applied. A postweld stress relief heat treatment was not performed. In 1990, a reinspection of this header revealed additional cracks and recracking of the repair welded areas. TEI was contracted to evaluate the existing condition and provide repair recommendations.

The initial phase of this examination involved a detailed review of all the existing nondestructive examination data. This review revealed significant discrepancy between the data obtained in 1985 and that obtained in 1990. These discrepancies were primarily associated with an ultrasonic crack depth determinations. TEI performed an independent evaluation of the cracking using our specialized digital signal processing technique. The crack depth data would be utilized to determine which areas were repair welded. The accuracy of this technique would be verified during the excavation of the cracks during the repair.

Due to the limited time frame associated with the scheduled outage, the criteria for which areas would be repaired and which would be left as is had to be determined. This involved performing minimal wall thickness calculations in the ligament area to help determine the allowable crack depth. These calculations resulted in a total of 50 areas being selected for repairs by welding.

The first phase of the actual repair involved removal of the tubes from the header which were in the way of the repair locations. Second, several samples were removed from the ligament area for further metallurgical evaluation. The analysis of these samples will be discussed later in the paper. Next the area selected for repair were air arc gouged to remove the cracking and prepare the weld joint. This crack removal was performed very carefully to determine the actual crack depth and crack configuration. A photograph during this process is provided in Fig. 1. As noted, the crack depths were very carefully monitored. It was determined that the ultrasonic inspection procedure utilized accurately determined the crack depth within 10%. The final weld joint preparation involved an open root such that a full penetration weld could be achieved.

Prior to the repair welding, the areas were preheated utilizing resistance pads to the required temperature. This preheat temperature was very closely monitored with the use of Tempilstiks and was maintained during the entire repair welding process. The repair was performed utilizing the shielded metal arc welding process. An initial attempt at the root pass utilizing Tungsten inert gas welding was made; however, this was not successful as it was impossible to the clean the ID surface sufficiently. The repair welding was performed utilizing a proprietary specialized technique which will reduce the residual welding stresses and result in a beneficial microstructure. This involves the use of a high preheat in conjunction with a stringer bead buttering technique.

Following the completion of the repair of the ligaments, the tubes were reinserted into the header. A photograph of a typical final weld configuration is provided in Fig. 2. Following the installation of the tube stub, the entire area was stress relieved in accordance with Section I of the ASME Code. After the completion of the stress relief heat treatment, all the repair areas were subjected to detailed nondestructive examination. There were no discrepancies noted during these evaluations.

The entire repair process was very carefully monitored by experienced engineering personnel. This ensured that each portion of the process was very carefully followed. In addition, it allowed for modification to be made "on the fly" instead of delaying the process for "engineering" evaluation of discrepant conditions.

Metallurgical Evaluation

Samples which were removed from the header were subjected to a detailed metallurgical evaluation. This included material identification, determination of the effects of the metallurgical changes that tend to occur gradually at elevated temperatures in a header and evaluation of the previous repair welds. Material identification was performed prior to the repair welding such that the proper electrode could be selected. The existing condition evaluation was performed to determine if significant creep damage had occurred which would have altered the scope of repair. This evaluation determined that there was not extensive creep damage and the header was readily repair welded. Evaluation of the previous repair revealed several interesting conditions. A photograph of the cross section is provided in Fig. 3. As is evidenced, the previous repair did not completely remove the existing cracking. In addition, the recracking of the repair weld in a relatively short period of time indicated that a repair was performed with insufficient preheat and no post weld stress relief. This information was valuable when developing the repair program for the current repair.

Conclusions

The repairs described above have recently been reinspected after three years of continued service with no evidence of recracking. That repair was performed in an existing outage schedule and did not result in any unscheduled downtime. The repair was performed at a fraction of the cost of replacement of the header. The header replacement, which had been discussed when the cracking was identified has been postponed until further evaluations of the repairs have been made.

Repair welding of high temperature outlet headers in conjunction with the implementation of a routine inspection program, is a viable option to header replacements.

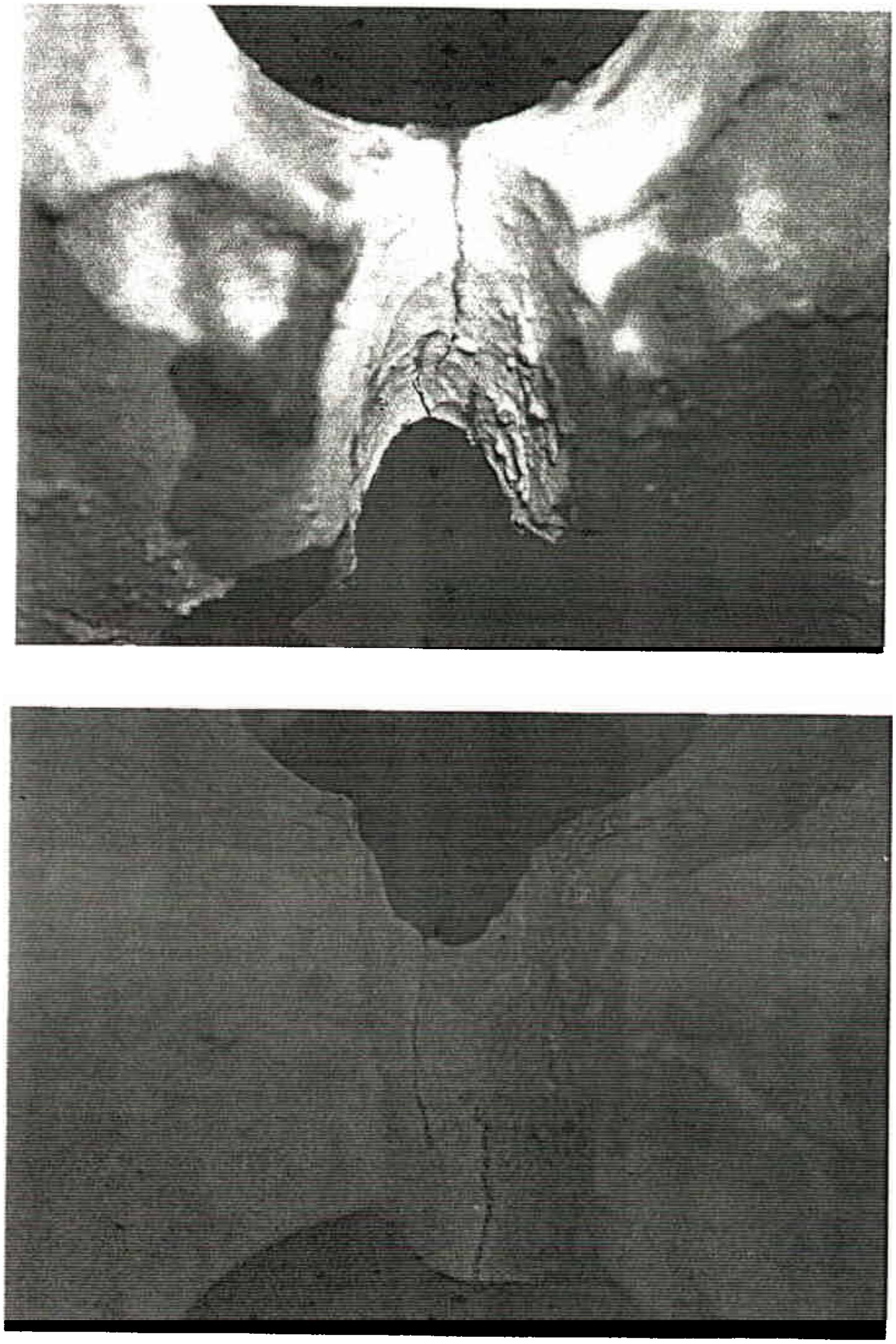

Figure 1. Typical cracking configuration.

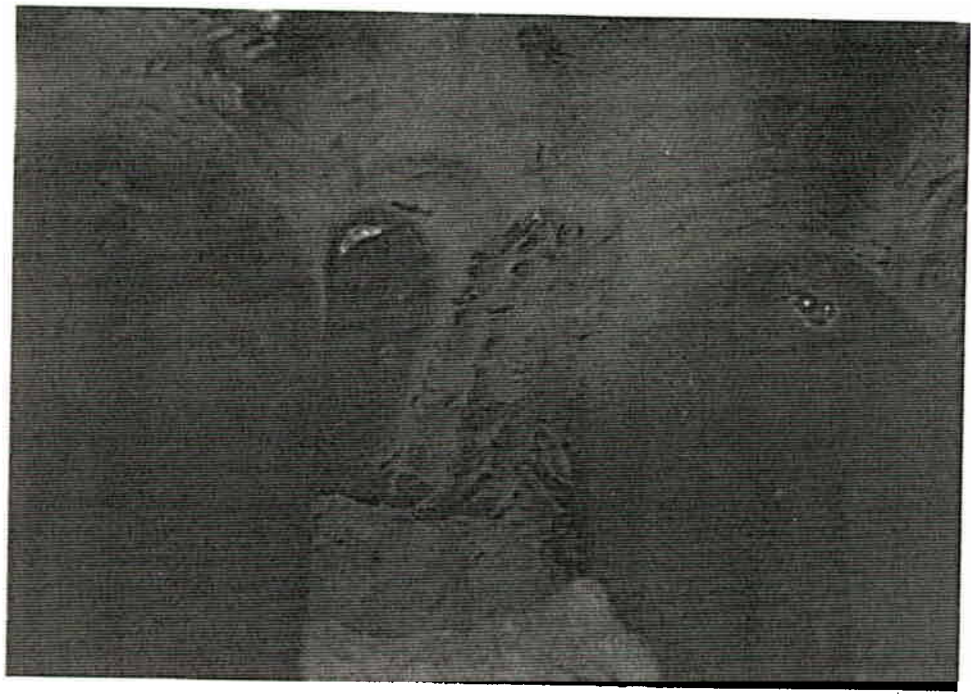

Figure 2. Typical final weld configuration.

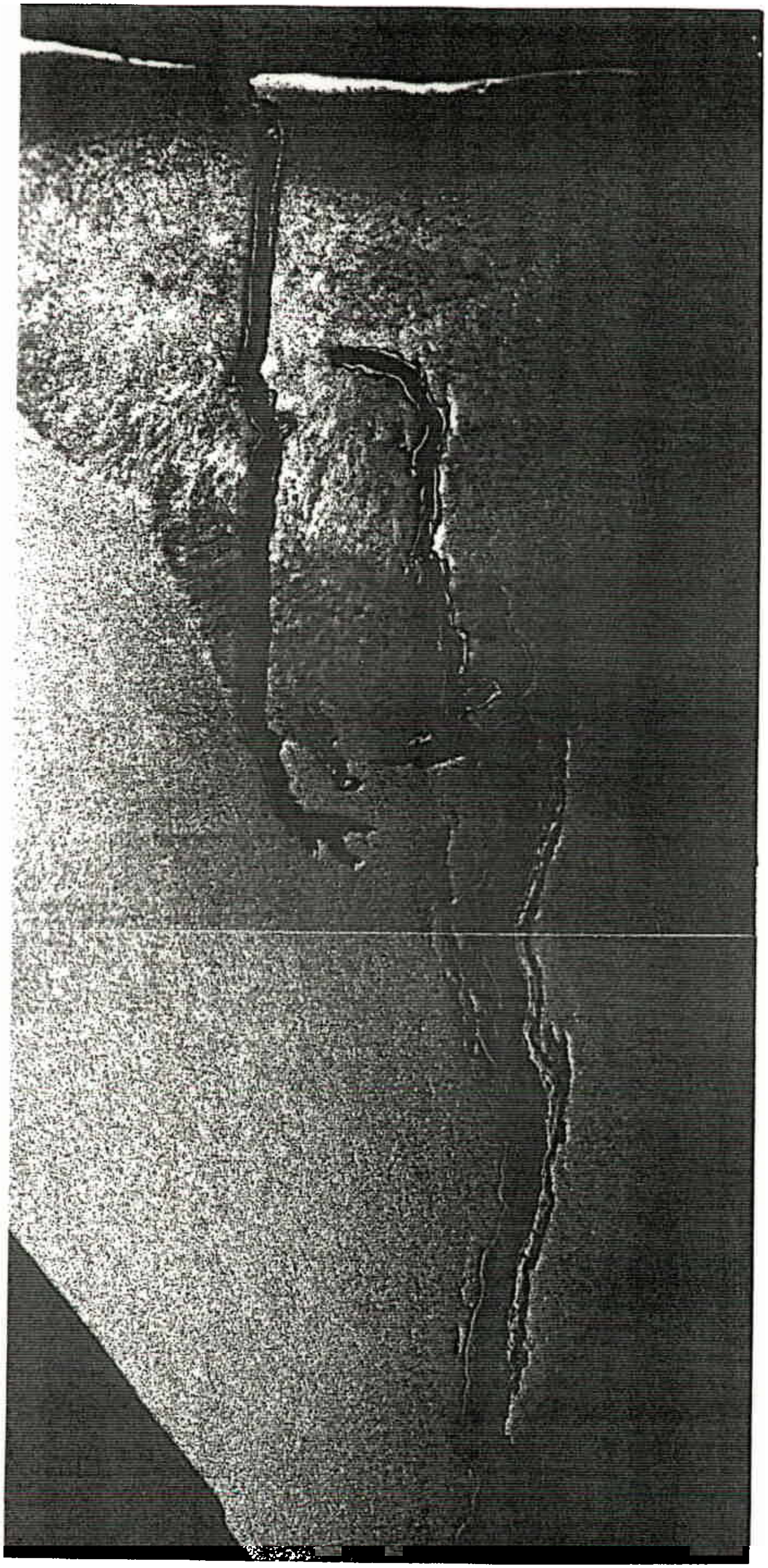

Figure 3. View of sample.