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Damage assessment of attemperator of thermal power plant boilers

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Due to rapid growth and development and the demand for power, has pushed steam plant design into new territories of temperature and thermal cycling. Coupled with this has been the tendency for plant suppliers to buy rather than design critical items of equipment in the hope of minimising exposure to the consequences of malfunction however, this has seen an upsurge of trouble in several areas –particularly with attemperator. Although simple in concept, attemperator can cause serious problems if details of their design are not properly considered, and/or if they are not properly applied to the systems they are to serve.

This paper presents by using optical fiber based video imaging technique to identify the affected regions in the attemperator which causes the malfunctioning of the boiler which may resulting catastrophical failure and damaging its components. This will result in reduced frequency of forced outages of the plant which in turn lead to substantial savings to the utility.

Keywords: *Attemperator, IN-SITU metallography, hardness measurement, flow-induced resonance, heat treatment, superheated steam, Low Temperature Super Heater (LTSH)*

1.0 INTRODUCTION

The condition assessment of critical boiler components through periodic inspection program is an important activity in the overall power generation. Among the critical components attemperator operate at temperature ranging from 400°C to 600°C depending on the load condition and design. Although simple in concept, attemperator can cause serious problems if details of their design are not properly considered, and/ or if they are not properly applied to the systems they are to serve [1]. This paper presents by using optical fiber based video Imaging technique to identify the affected regions in the attemperator which causes the malfunctioning of the boiler which may resulting catastrophical failure and damaging its components. The damaged area of the attemperator investigated with in-situ metallography along with the hardness measurement. A suitable remedial measure is also presented for the damaged components.

2.0 ATTEMPERATOR FOR STEAM TEMPERATURE CONTROL

Attemperator, also known as De-Superheaters, are used in power boilers to control (reduce) the temperature of superheated steam to suit the requirements of downstream equipment – frequently a steam turbin [2]. Attemperation of superheated steam in utility boiler is performed by direct contact means (water injection).

Direct contact desuperheating is the most responsive, economical and by far the most common (especially in power station boilers). The basic concept of direct contact desuperheating is quite simple. On admission to the steam pipe, attemperating water is atomised to increase its

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surface/mass ratio for rapid vaporisation by the passing flow of superheated steam – the temperature of which is reduced as a consequence of providing sensible and latent heat for this process.

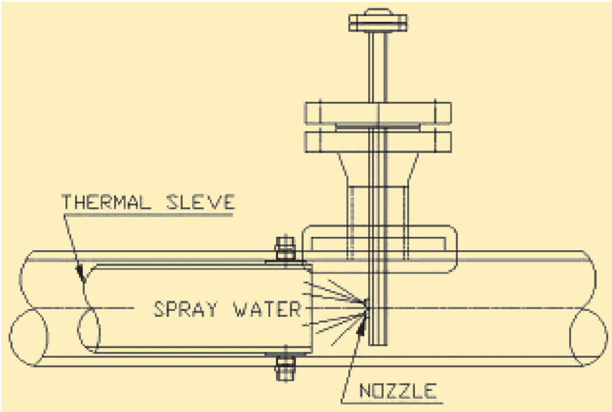

FIG. 1 GENERAL ARRANGEMENT OF ATTEMPERATOR

Although the concept may be simple, implementation requires careful consideration of quite a few important matters

- Thermal shock in the injection tube/nozzle,if it has been operating at elevated temperature before the attemperating water is introduced.
- Thermal shock in the steam pipe wall when water is admitted via the penetrating injector tube.
- Thermal shock caused if attemperating water contacts hot components.
- The atomisation of water for fast evaporation and consequent attemperation effect.
- Thermal stress induced if water accumulates in steam piping.
- Injector tube fatigue failure caused by flow-induced resonance.
- Location of sensors for accurate monitoring of steam temperature.
- Injector orientation and piping arrangement.
- Security of attemperating water isolation.
- Maintenance access [3-5].

3.0 FIBROSCOPIC VIDEO IMAGING METHODOLOGY

The visual inspection of attemperator (LHS & RHS) of boiler of 500 MW capacity of Thermal Power Station was carried out using advanced fiber optic based system. The details of the equipment used are given below.

Equipment Type	:	Remote Fiber Optic Video image scope
Make	:	Olympus –Japan
Model	:	IPLEX_FX
Probe diameter & length used	:	6 mm & 7.5 mts.

The schematic view of the equipment used is shown in Figure 2.

FIG. 2 REMOTE FIBER OPTIC VIDEO IMAGE SCOPE

The injector of attemperator was cut open and the flexible optical probe was inserted and the image acquired by the precision camera mounted at the end of the flexible optical probe was observed [6]. The video output from the camera was recorded continuously

4.0 OBSERVATION IN ATTEMPERATOR (LHS)

The video images of specific locations that have shown the characteristic which are much different from the normal were recorded during the inspection. The imaging of the broken injector observed. The typical image obtained is shown in Figure 3.

In-situ Metallography and Hardness measurement was carried out near the broken injector on pipeline (Shell) as shown in the Figure 5.

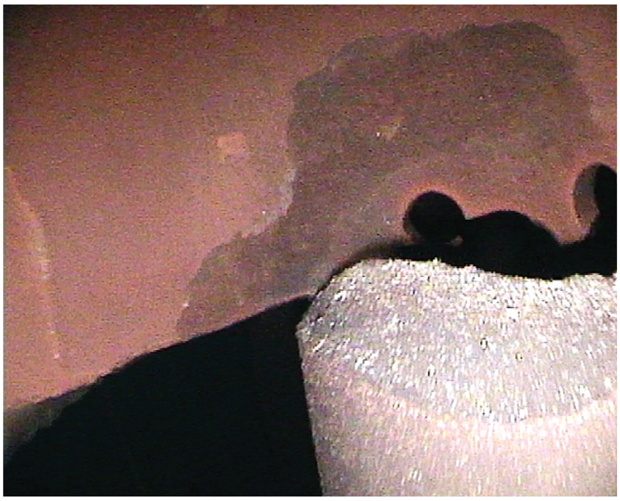

FIG. 3 IMAGE OBTAINED

FIG. 4 IMAGE OF BROKEN INJECTOR TAKEN OUT FROM ATTEMPERATOR

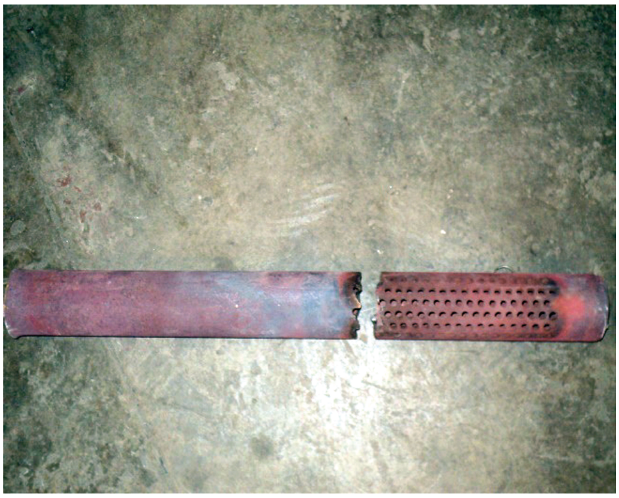

FIG. 5 IMAGE OF BROKEN INJECTOR TAKEN OUT FROM ATTEMPERATOR

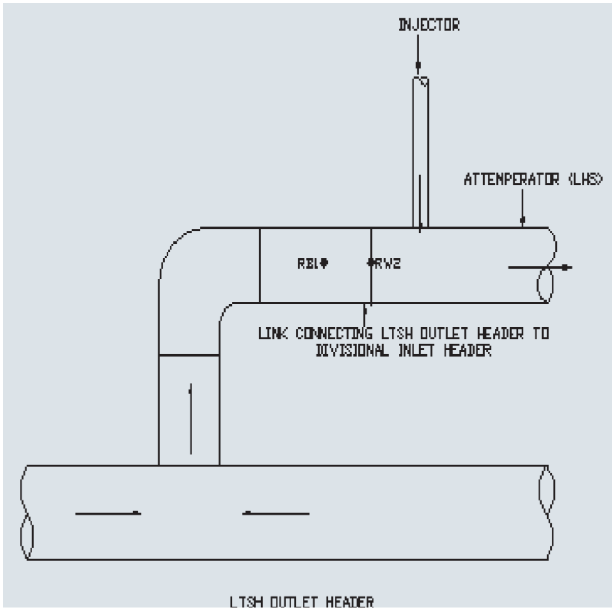

FIG. 6 ATTEMPERATOR (LHS)

5.0 INSITU METALLOGRAPHIC REPLICATION & HARDNESS TEST RESULTS

The test results are given in below Table 1.

TABLE 1

INSITU METALLOGRAPHIC REPLICATION & HARDNESS TEST RESULTS

Sl. No.	Component Details	Replica No.	Location	Microstructure details	Magnification	Hardness in HB
1	Attemperator (LHS)	R1B	At the Parent Metal near Weld (LHS)	Ferrite with bainite.	100X	172 - 174
		R2W	At the Dish End Weld (LHS)	Degenerated and coarse bainite, moderately high hardness.	100X	338 - 340

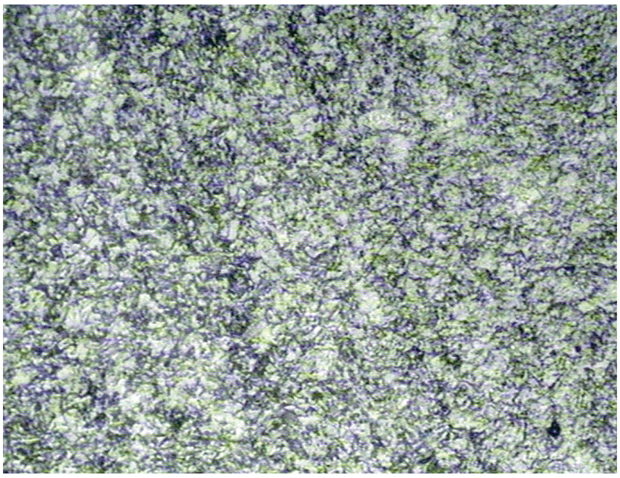

FIG. 7 REPLICA NO. R1B, MAGNIFICATION – 100X

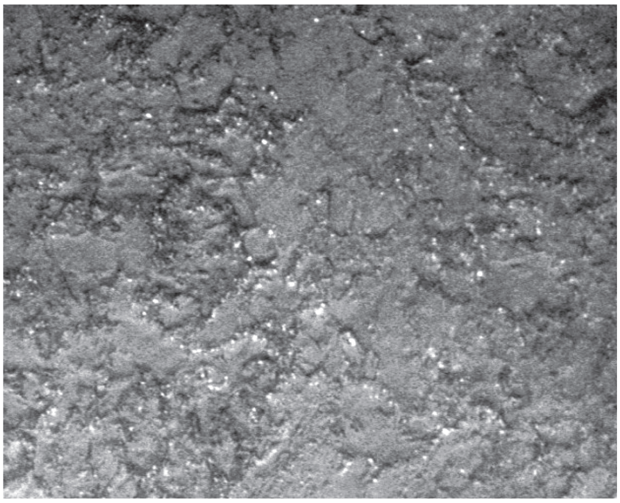

FIG. 8 REPLICA NO. R1B, MAGNIFICATION – 500X

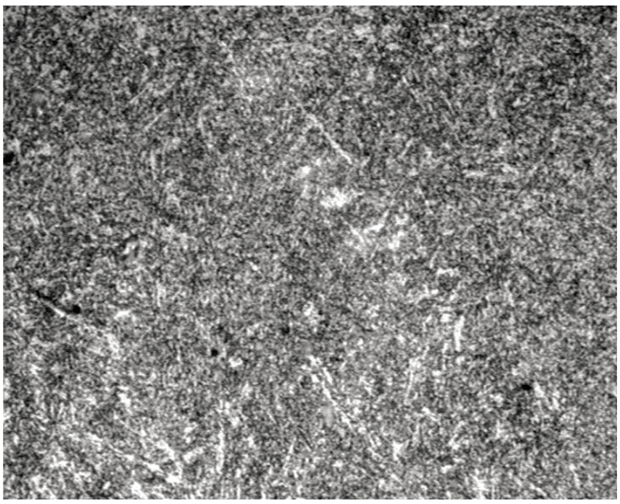

FIG. 9 REPLICA NO. -R2W, MAGNIFICATION – 100X

6.0 ANALYSIS AND EVALUATION OF CONDITION

Metallurgical analysis on the base and weld metal was conducted through in-situ metallography (replication) on external surface. The microstructure was further analysed in the laboratory and it reveals Ferrite & Bainite with slight higher hardness on base metal. The Microstructure of weld metals reveals Degenerated and coarse bainite, moderately high hardness [7].

In direct contact desuperheating, injector carries attemperating water for controlling the steam temperature and avoiding the consequences associated with droplet impact on hot pressure parts. Due to broken injector, mainly due to fatigue failure caused by flow-induced resonance, the water directly impinges on the attemperator shell. The increase in hardness is mainly due to the quenching effect due to broken injector, which makes the attemperator shell brittle which is prone to failure.

7.0 RECOMMENDATIONS

In order to restore the metallurgical structure of the attemperator shell a heat treatment procedure was suggested as given below:

In-situ heating the attemperator shell to a temperature approximately 40-75ºC (105-165ºF) below the A1 transformation temperature — about 727ºC (1340ºF) for steel at approximately 670ºC. The elimination of stress is not instantaneous (that is, the process is a function of both temperature and time). To achieve the maximum benefit, some time at temperature (typically one hour per 25 mm of cross-sectional area once the part has reached temperature) is required. In this case for two & half hours (Soaking time). This removes more than 90% of the internal stresses. After In-situ heating, the part is cooled at the rate of 100ºC per hour upto 400ºC and thereafter air cooled in still air. Rapid cooling will only serve to reintroduce stress and is the most common mistake made in stress-relief operations. The metallurgical changes from the above act can reduce the hardness of the structure, improving ductility and reducing the risks of brittle fracture [8-9].

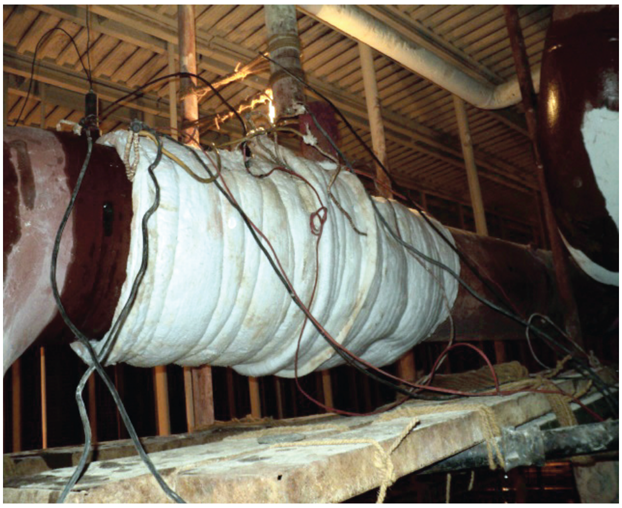

FIG. 10 IMAGE OF IN-SITU HEAT TREATMENT OF ATTEMPERATOR (LHS)

8.0 OBSERVATION IN ATTEMPERATOR (RHS)

The video images show the injector was intact & no damages were observed. The typical image obtained is shown in Figure 10.

IN-SITU Metallography and Hardness measurement was carried out near the injector on pipelineas shown in the Figure 11.

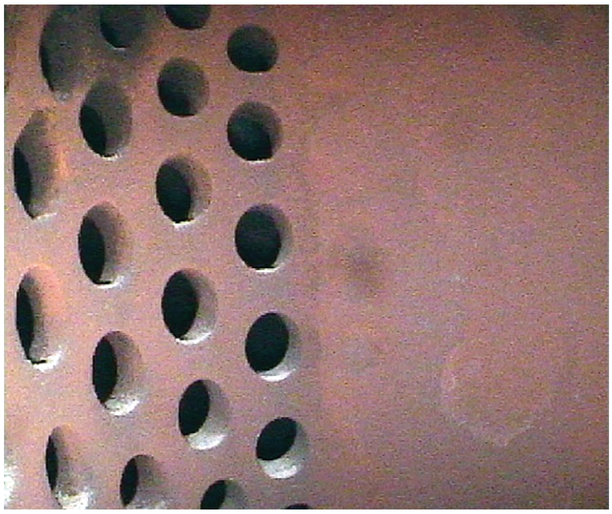

FIG. 11 IMAGE OBTAINED

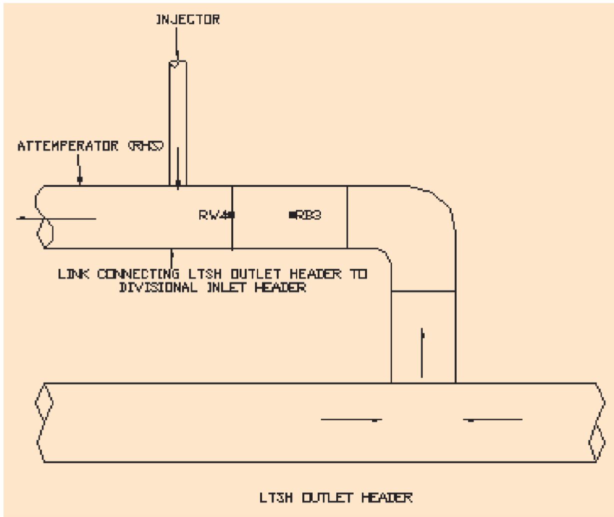

FIG. 12 ATTEMPERATOR (RHS)

9.0 INSITU METALLOGRAPHIC REPLICATION & HARDNESS TEST RESULTS

The test results are given in below Table 2.

TABLE 2

INSITU METALLOGRAPHIC REPLICATION & HARDNESS TEST RESULTS

Sl. No.	Component Details	Replica No.	Location	Microstructure details	Magnifi -cation	Hardness in HB
1	Attemperator (RHS)	R3B	At the Parent Metal near Weld (LHS)	Ferrite growth, grain boundary thickening.	100X	133 – 136
		R4W	At the Weld (LHS)	Coarse bainite with Spheroidised carbide precipitation.	100X	226 – 228

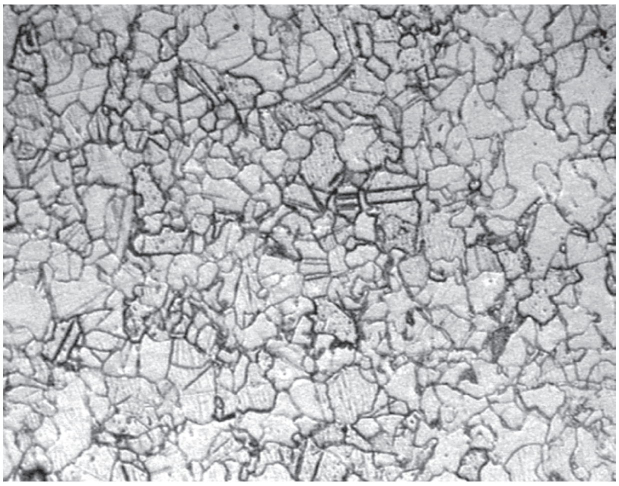

FIG. 13 REPLICA NO.-R3B, MAGNIFICATION – 100X

FIG. 14 REPLICA NO.-R3B, MAGNIFICATION – 500X

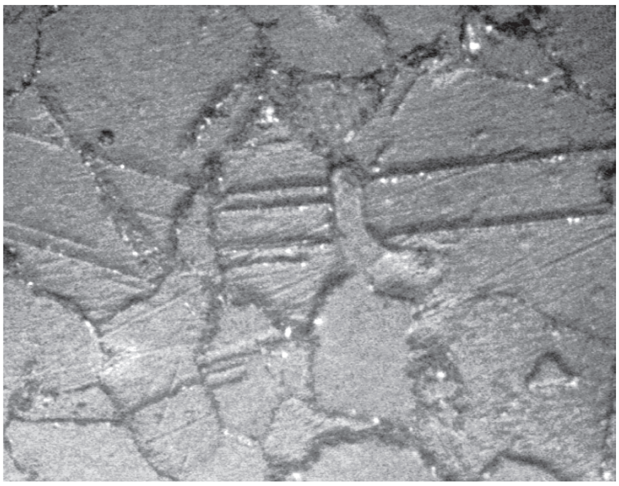

FIG. 15 REPLICA NO.-R4B, MAGNIFICATION – 100X

10.0 ANALYSIS AND EVALUATION OF CONDITION

Metallurgical analysis on the base and weld metal was conducted through in-situ metallography (replication) on external surface. The microstructure was further analysed in the laboratory and it reveals ferrite growth, grain boundary thickening on base metal. The Microstructure of weld metals reveals coarse bainite with spheroidised carbide precipitation [7]. The hardness readings were found within the acceptable range.

11.0 RECOMMENDATIONS

The metallurgical structure of the attemperator shell is normal; hence no further treatment is required.

12.0 RESULTS AND DISCUSSION

Shells of the attemperator (LHS) which have been affected due to broken injector, in this case mainly due to fatigue failure caused by flow-induced resonance , which are inaccessible could be identified by this method. Further the damage assessment can be done by mapping the hardeness measurement in the upstream and downstream locations where the injector is failed.

After the heat treatment of attemperator shell (LHS) a normal metallurgical structure consisting of ferrite & bainite observed. The hardness value achieved within normal range

13.0 CONCLUSIONS

The results indicate that the methodology adopted by CPRI was quite successful in identifying the extent of damages encountered in attemperator shell and restoring them. This study is being repeated on continual basis during subsequent overhaul.

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[10] Experience gained from Remaining Life Assessment / Condition Assessment activities over the period.