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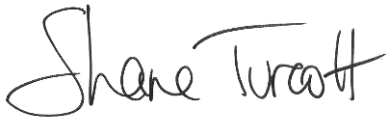
IN-SITU METALLOGRAPHY OF BOILER TUBES

EXAMPLE REPORT

OVERVIEW & OUTCOME

During a refinery shutdown, in-situ metallography inspection of a boiler had found the tubes had grossly overheated (ie. red hot, >1600ºF). As these observations were provided within 24 hours and still within the shutdown, additional testing was able to be conducted to further assess the extent of damage. Review by inspectors and engineers determined that the tubes were safe for continued service until the next scheduled major shutdown when they should then be replaced.

- Electronic Copy -



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IN-SITU METALLOGRAPHY OF BOILER TUBES

SUMMARY

Material: ASTM A106B plain carbon steel.

In-situ metallography was used to non-destructively assess the metallurgical condition of several tubes within a boiler. The evaluation included preparation of the tube surfaces, on-site examination, replication and off-site examination under an optical microscope.

Inlet Tube #17 (coolest tube) comprised of a ferritic and pearlitic structure typical for this material. The other three tubes evaluated all exhibited upper bainitic structures. These structures indicated that these tubes had experienced an excursion above 1600ºF (>871ºC), then cooled relatively quickly. No creep voids or cracking was observed.

The bainitic structures matched well with the theory of gas flow interruption during operation. An interruption in the gas flow resulted in severe overheating of the tubes. During re-introduction of the gas flow, the tubes were quenched at a moderate rate, forming the bainitic structure. Also note that significant thermal expansion had occurred, evident from the deformation of a bar well above the outlet tube (**Figure 1c**).

Upper bainite was not deemed an overly detrimental phase yet its formation had removed the original structure manufactured to conform to the mechanical requirements. Therefore, the strength of the tube material would be expected to vary and may not conform to the design properties. It is recommended that the operator further review the effects of such an altered tube structure would have upon the safe operation of the boiler. Note that the tubes appeared to have operated without issue since the excursion.

Table 1: Location of In-Situ Metallography

Tube	Coil	Description / Location
17	1	-Inlet Tube for Coil #1 -Taken near top of boiler -Expected to be coolest tube within boiler
23	1	-Mid-tube within Coil #1 -Taken ~10ft from the top (approx mid height) -Expected to be representative of Coil #1
31	1	-Diametric growth detected 10.9ft from top bend
62 (top)	2	-Outlet Tube for Coil #2 -Taken near top of boiler -Expected to be hottest tube within boiler -Deformation of bar above tubes indicated significant thermal expansion (**Figure 1**)
62 (mid)	2	-Diametric growth detected 9.8ft from top bend

Table 2: Hardness Results*

Tube	Location	Measurements (HRB)	Avg. Hardness	
			HRB	HB
17	Top	56.4, 57.4, 57.9, 57.5, 54.8	57	103
23	10ft from top	54.7, 56.3, 55.3, 56.4, 56.7	56	101
31	10.9ft from top	65.3, 63.7, 64.8, 63.9, 63.3	64	114
56	9.5ft from top	52.0, 56.5, 55.0, 53.9, 53.6	54	99
58	11.7ft fr. bottom	54.3, 57.3, 54.1, 54.8, 53.6	55	100
62	Top	57.2, 56.7, 56.2, 56.5, 57.6	57	103
	9.8ft from top	55.6, 57.5, 57.4, 55.2, 56.4	56	101

*Hardness testing using GE DynaPocket Leeb rebound tester

Figure 1: Photographs displaying the locations originally selected for evaluation. Subsequent testing was also conducted at locations exhibiting diametric growth. Due to overheating, the tubes had experienced significant thermal expansion.

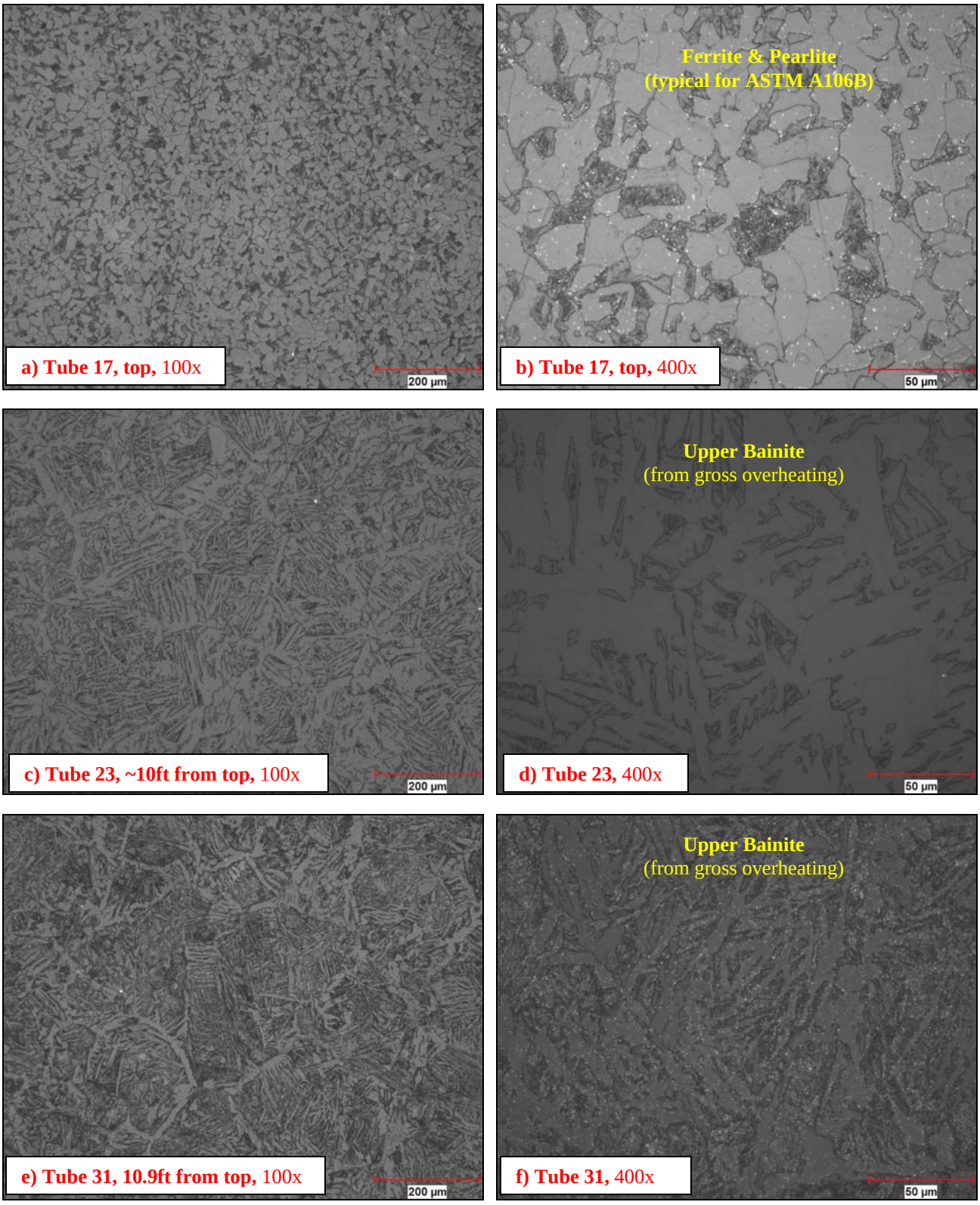
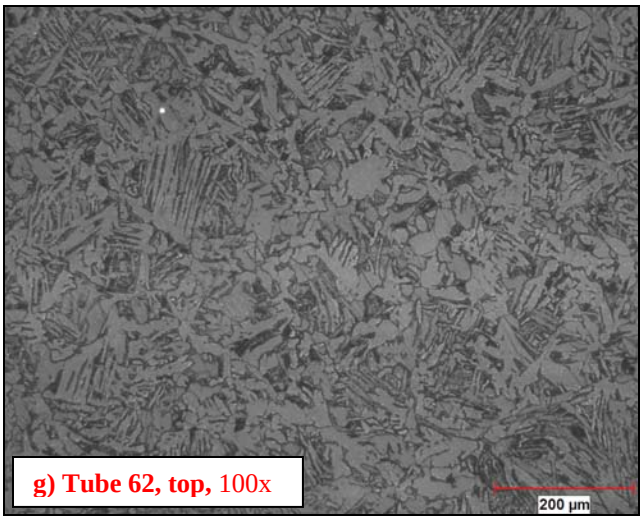
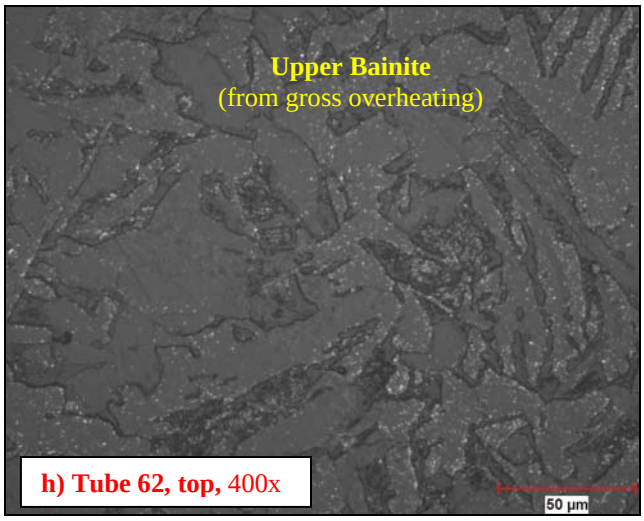
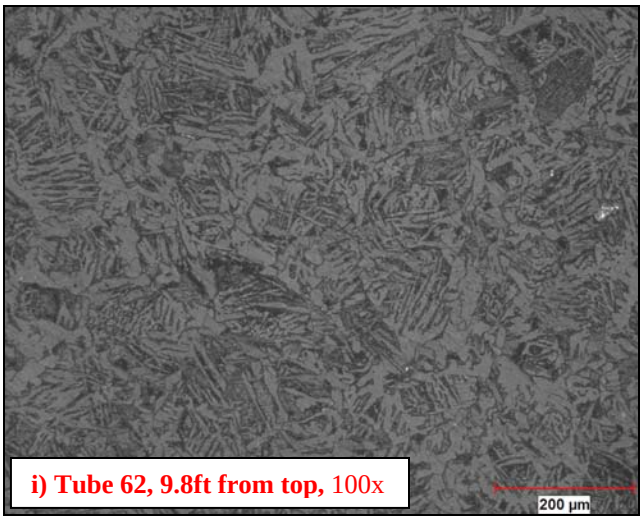


Figure 2: (a,b) The Inlet Tube #17 comprised of a structure typical for an as-manufactured ASTM A106B carbon steel. (c-j) The structures at other locations, including those exhibiting diametrical growth, comprised of upper bainite. These locations had reached temperatures above 1600ºF. Images taken from replications.







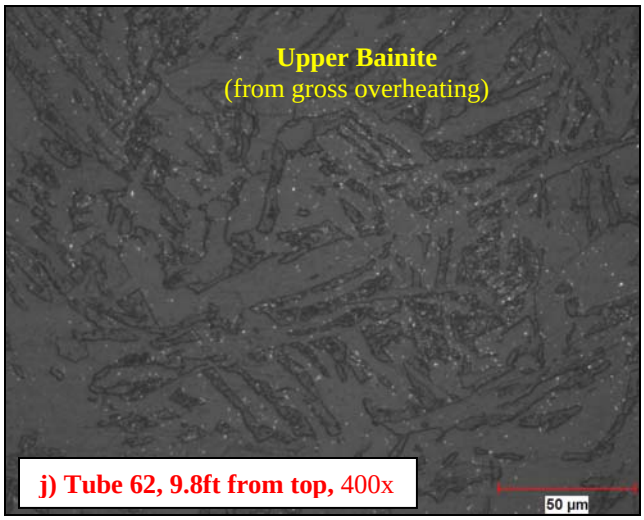


Figure 2 Continued.