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IN-SITU METALLOGRAPHY DAMAGE SURVEY OF A FAILED STEAM BOILER

EXAMPLE REPORT

OVERVIEW & OUTCOME

Boiler tube rupture resulted in an unplanned outage, reducing the refineries' production. In-situ metallography of the surrounding area found that (a) the failed boiler tube had suffered from long-term overheating and (b) the neighbouring tubes were in good condition, having operated at lower temperatures. At the same time, boroscope inspection by the refinery found the failed tube had suffered a blockage, matching well with these findings (and 24 hours later, the failure analysis). Considering the good condition of the neighbouring tubes, it was likely that only the ruptured tube had experienced a significant blockage.

Examination also found that the material initially removed from the failed boiler tube was insufficient. Portions of the remaining tube material exhibited significant damage and, if not removed, could have resulted in another failure. In-situ metallography was used to assess how much material had to be removed to ensure a reasonable level of reliability.

These results were provided immediately on-site, allowing for decisions to be implemented during the repair. The section found to still consist of thermally damaged material was cut out and repaired.

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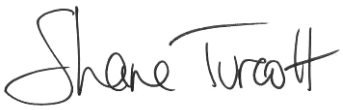

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IN-SITU METALLOGRAPHY DAMAGE SURVEY OF A FAILED STEAM BOILER

SUMMARY

A refinery steam boiler experienced failure of its Wall Tube #69, forcing the boiler to shut down. In-situ metallography was used to survey the neighbouring regions to assess the material condition and sustained thermal damage. At the time of the evaluation, the failed region of the tube had already been cut-out from the boiler. The tubes comprised of ASTM A192 plain carbon steel and had been in service for approximately thirty years.

Tube #69 exhibited severe spheroidization immediately beneath the cut-out (**Figure 3c,d**). This damage was caused by long-term overheating. Inspectors had found a blockage at the base of the tube and the observed thermal damage matched well with reduced steam flow (ie. reduced cooling). Note that spheroidization results in reduced material strength and, combined with creep damage sustained from the elevated operating temperatures, can result in failure.

Tube #69 exhibited moderate degradation 18 inches below the cut-out (**Figure 3e,f**) and slightly less degradation at 36 inches below (**Figure 3g,h**). At 4 inches above the cut-out, the material exhibited only minor degradation (**Figure 3a,b**). The tube at the bottom of the boiler was in good condition (**Figure 3j,k**).

Due to the extent of thermal damage on the Tube #69 adjacent the region cut-out, it is recommended that additional tube material be removed during the repair. It is recommended that the owner consider further removing (a) four inches above the cut-out and (b) 36 inches below the cut-out in an effort to remove the most severely damaged material.

In-situ metallography of the neighbouring Tubes #66, 67, 68, 70 and 73 found them to be in relatively good condition considering their years of service (**Figure 5**). At the locations evaluated, these tubes had experienced lower service temperatures and thus, had not likely experienced similar blockages as Tube #69.

Table 1: Summary of Tube Condition

Tube	Location Evaluated	Figure	Material Condition
#66	Failure Height	Figure 5a,b	Minor Damage
#67	Failure Height	Figure 2, 5c,d	As-Manufactured Condition (no damage)
#68	Bottom of Boiler	Figure 5e,f	Minor Damage
	Failure Height	Figure 5g,h	Minor Damage
#69 (Failed Tube)	~4 inches above cut-out	Figure 3a,b	Minor Damage
	~6 inches below cut-out	Figure 3c,d	Severe Damage
	~18 inches below cut-out	Figure 3e,f	Moderate Damage
	~36 inches below cut-out	Figure 3g,h	Minor-to-Moderate Damage
	Bottom of Boiler	Figure 3j,k	No Significant Damage
#70	Failure Height	Figure 5i,j	Minor Damage
#73	Failure Height	Figure 5k,l	Minor Damage

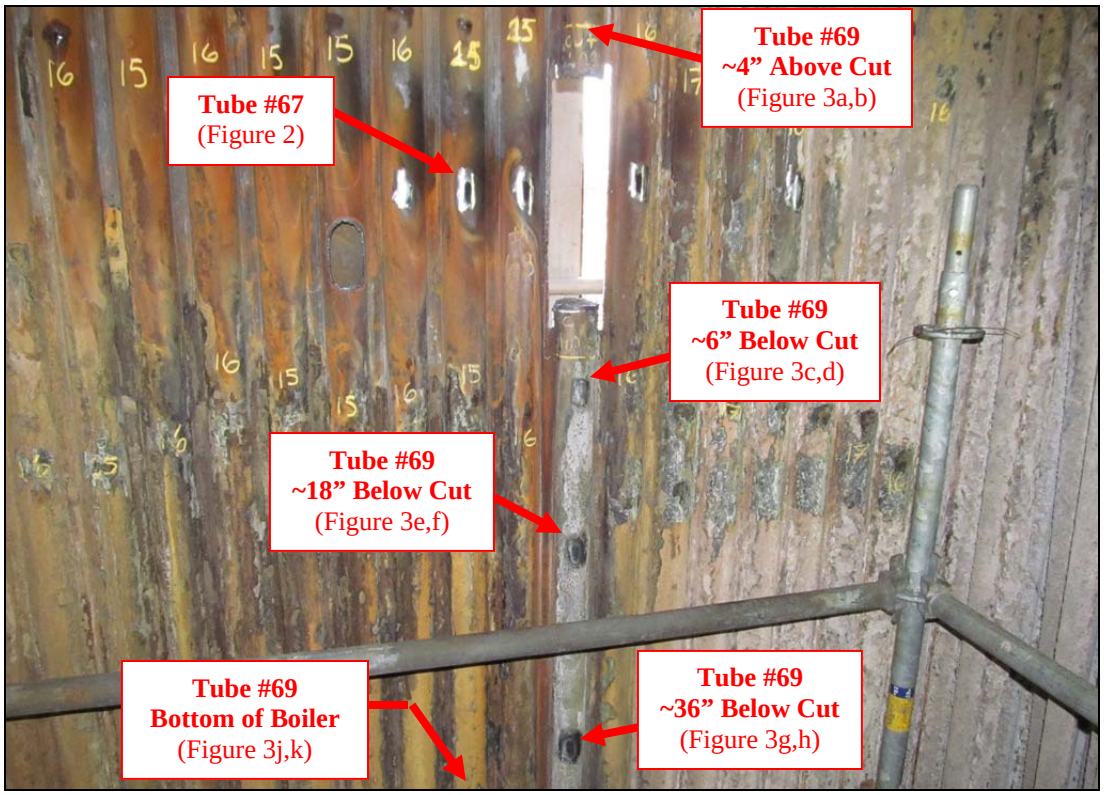


Figure 1: Photograph displaying the locations evaluated on the Failed Tube #69.

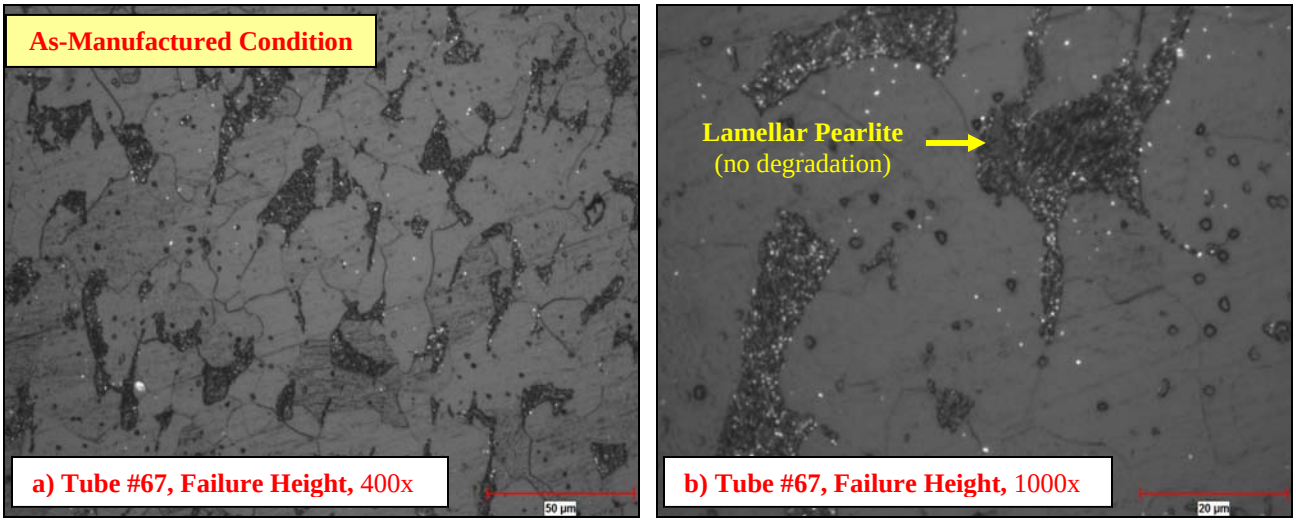


Figure 2: Micrographs taken from replicas of Tube #67 at the same height as failure of Tube #69. The microstructure comprised of ferrite and lamellar pearlite, typical for the as-manufactured ASTM A192 tube (ie. as-new structure, not degraded). This provided a benchmark to which the degradation of Tube #69 was compared against.

Images taken from replication, tube etched with 3% nital.

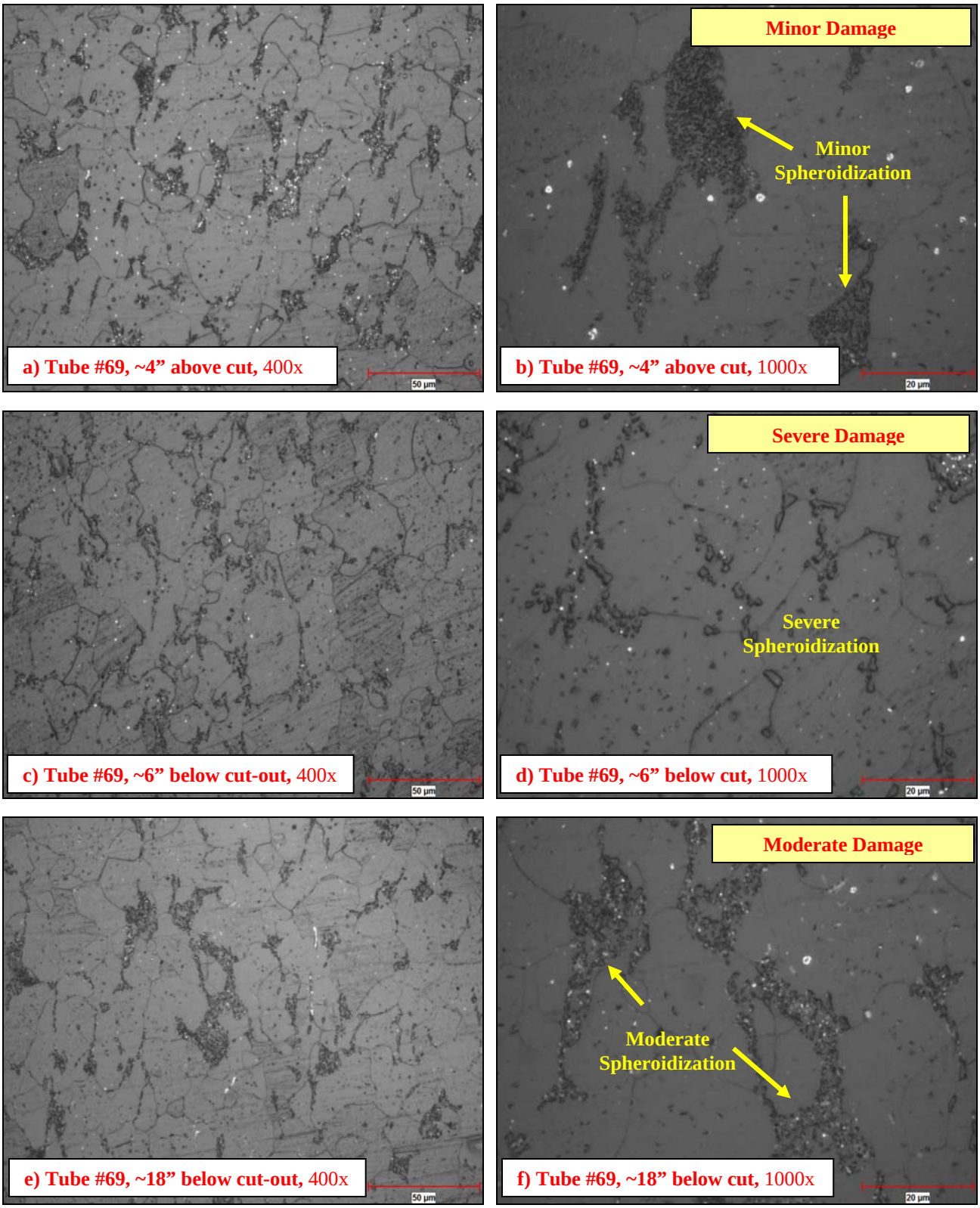
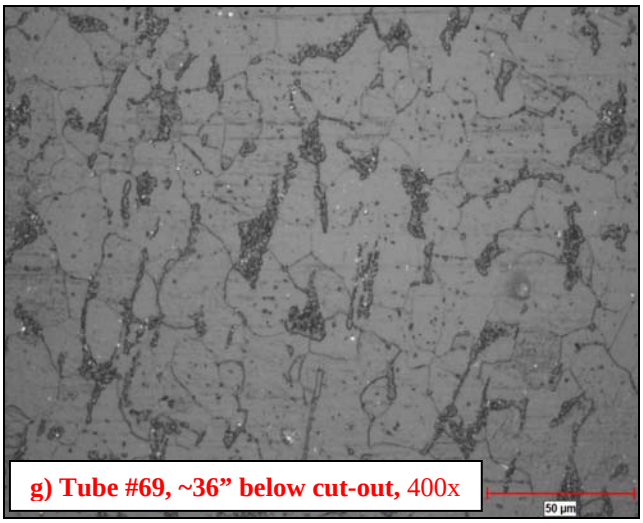
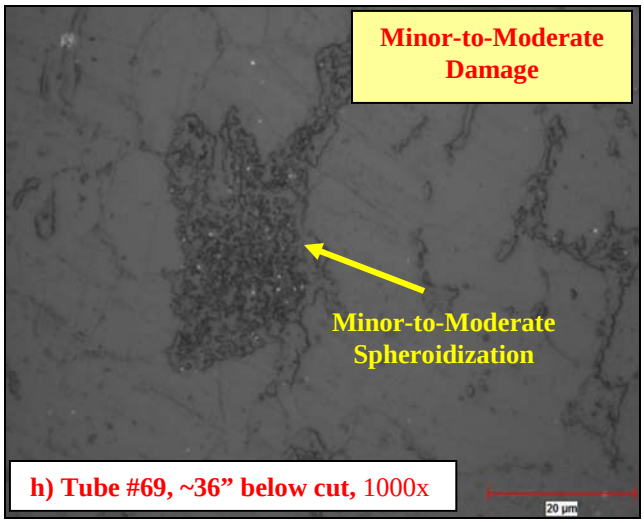
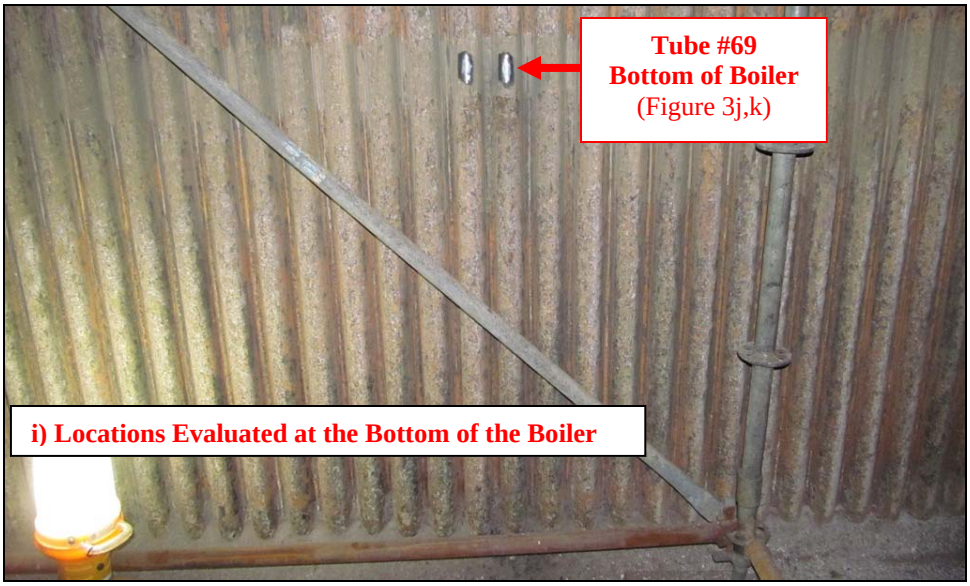
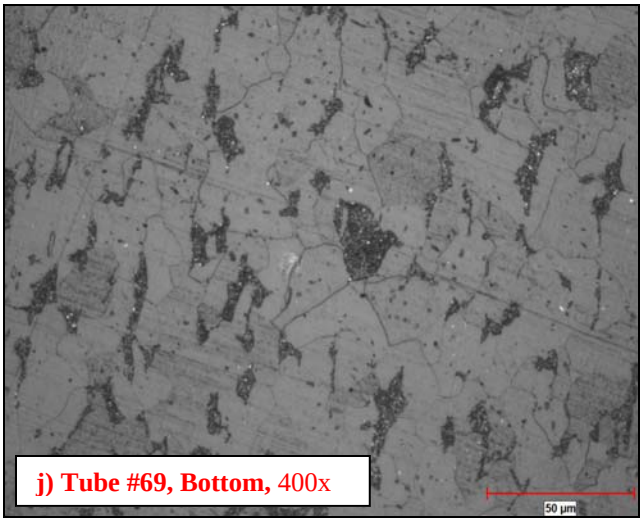


Figure 3: Micrographs of Failed Tube #69 (a,b) above the cut-out, (c-h) at various locations below the cut-out and (j,k) at the bottom of the boiler. The degradation was most severe immediately below the cut-out. Tube #69 was in good condition at the base of the boiler.









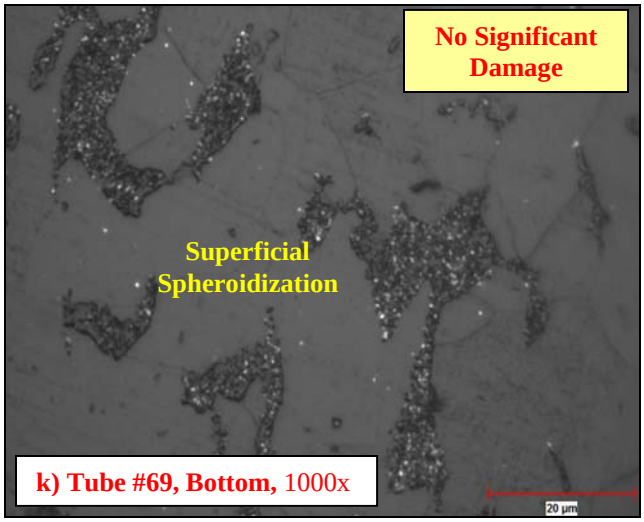


Figure 3 Continued.

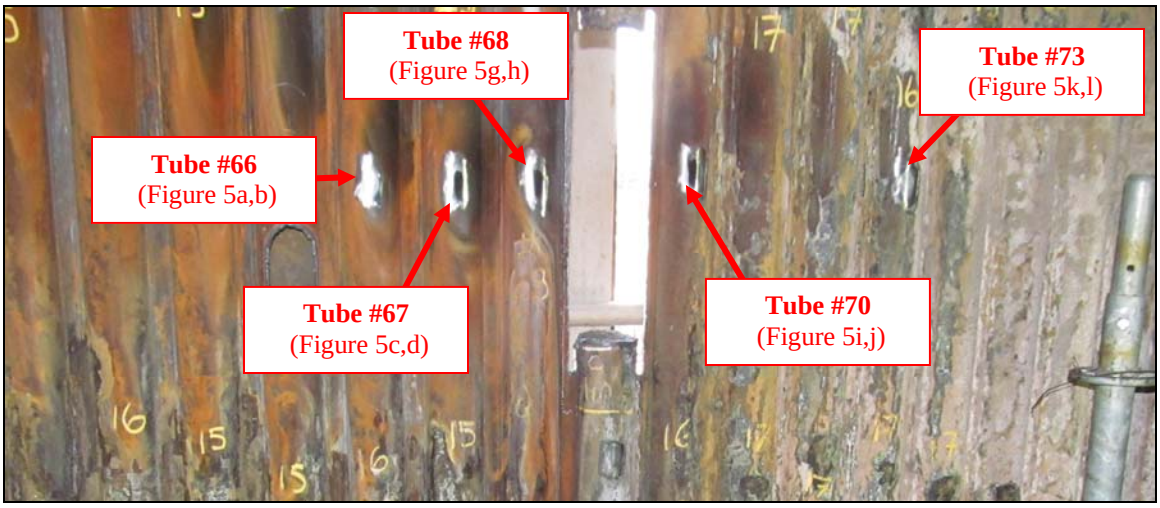


Figure 4: Photograph displaying the locations evaluated on the neighbouring tubes adjacent to the failure. These tubes were evaluated at the same height as failure, plus Tube #68 was evaluated at the boiler bottom.

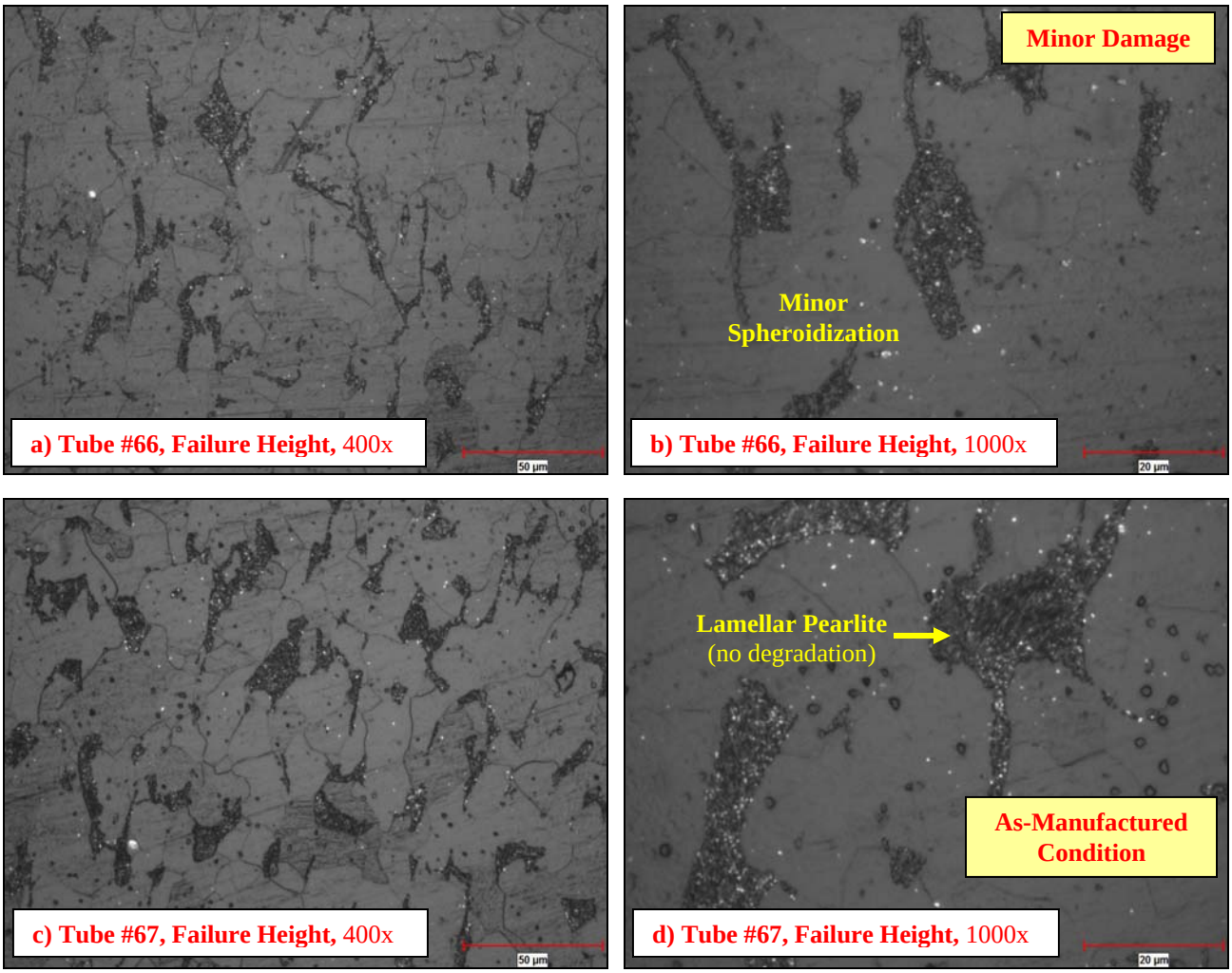
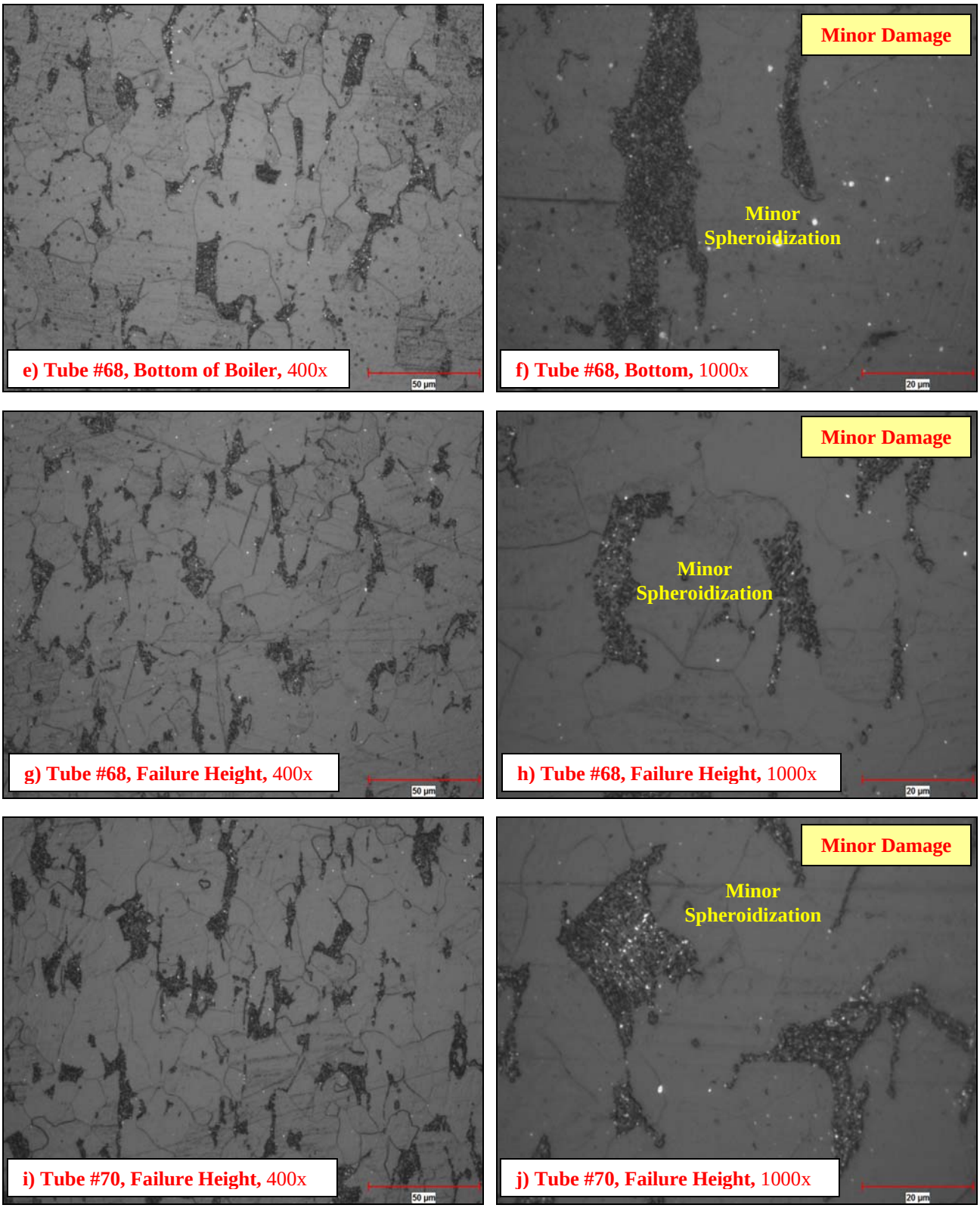


Figure 5: Micrographs of the neighbouring tubes to the failure. These tubes had not experienced the same, elevated temperatures during service as Tube #69 and were in good condition given their years of service.



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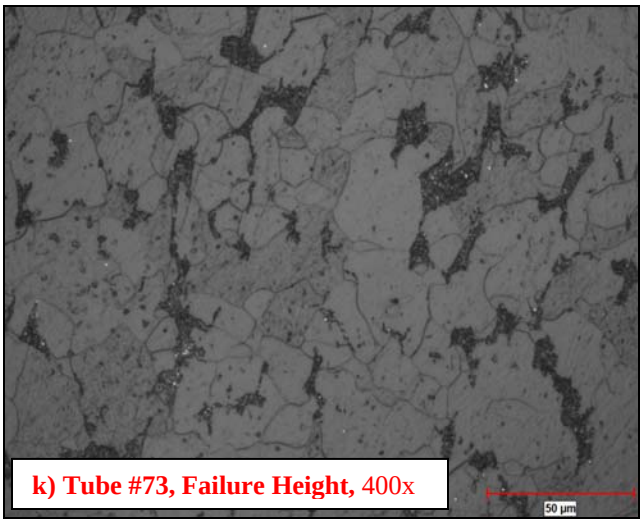

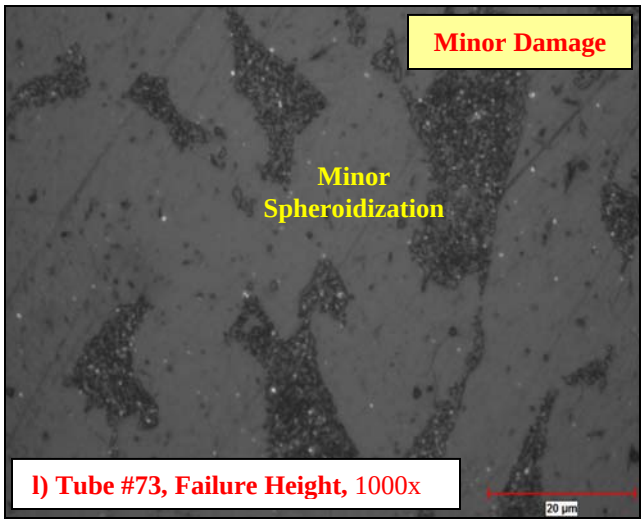

Figure 5 Continued.