# Failure Analysis and Research on the Explosion and Leakage of the Secondary Superheater Tube in a Power Plant

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**Abstract.** During the operation of boiler 1, the secondary superheater pipe elbow section failed due to explosion and leakage. In order to find out the cause of the explosion and leakage of the elbow section of the secondary superheater tube, a comprehensive test analysis was carried out on the failure cause of the elbow section of the secondary superheater tube with the appearance analysis, chemical composition analysis, microstructure detection and mechanical property detection.The results show that the leakage of the elbow section of the secondary superheater tube is due to the long-term overheating of the elbow section of the secondary superheater tube during the operation process, resulting in a serious reduction of spheroidization strength, which was not enough to withstand the leakage caused by the internal medium pressure, and the leakage of the adjacent superheater tube was caused by the leakage steam blowing away the adjacent superheater tube.

**Keywords.** Superheater; Overheating for a long time; Creep hole; Burst tube

## 1. Introduction

During the operation of Unit 1 in a power plant, the induced draft fan current suddenly increased to 300A, the flue gas temperature deviation in front of the low-temperature superheater increased to 200 ℃, and the reheat steam temperature at side A suddenly decreased to 503 ℃. The local inspection found that the 46-49m leakage noise at side A of the boiler was loud, and the load was reduced to 165MW. In order to reduce the large area damage of the boiler heating surface caused by leakage, the unit was shut down and checked to confirm that the high temperature superheater outlet pipe leaked and burst. The No. 1 boiler is a subcritical natural circulation boiler produced by Beijing Babcock Vilcox (B&W) Co., Ltd. with the model of B&BW-1025/18.44-M, single drum, single furnace chamber, and intermediate primary reheat. It has a balanced ventilation, solid slag removal, fully suspended structure, and adopts a primary air positive pressure direct-fired pulverizing system. The burners are arranged in front and back walls, and the flame is arranged in front and back opposed suspension combustion. It is arranged with four layers of burners, D, A, B, from top to bottom C. There are four front and rear walls of each layer of burner, and the tail flue is arranged in inverted L shape. The furnace is composed of 700 membrane water-cooled walls. The superheater is composed of ceiling superheater, wall superheater, primary superheater, platen superheater and secondary superheater.The unit has operated for 193400 hours.To find

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out the secondary superheater pipe elbow section (12Cr2MoWVTiB, Φ51×9.0mm), the failure reason of the secondary superheater pipe bend section was analyzed by comprehensive test.

## 2. Test materials and Methods

In this paper, the mechanism and failure reason of superheater tube explosion and leakage were studied by means of macroscopic morphology analysis, chemical composition analysis, metallographic structure analysis and mechanical property test [1-4].

## 3. Test results and Analysis

### 3.1. Macromorphology observation and analysis.

Observe the macro morphology of the secondary superheater elbow section, as shown in Figure 1-2. The explosion of the secondary superheater pipe was located at the elbow section, with a length of about 130mm, and the pipe diameter had no obvious expansion; The edge of the blast hole was rough and blunt, and there were traces of being blown away by steam. The pipe wall had no obvious thinning. The oxide skin of the outer wall near the blast hole was in the shape of "old tree bark", and there were no defects such as mechanical damage and corrosion damage. It had the typical characteristics of long-term overheating tube explosion.

**Figure 1.** Macromorphology of blow-out pipe

**Figure 2.** Crater morphology

### 3.2. Microstructure detection and analysis

The microstructure of the bend section of the secondary superheater tube was analyzed, as shown in Figure 3-4. The metallographic structure at the blast hole had been seriously aged, its structure was ferrite+granular carbide, the bainite morphology had completely disappeared, the carbide had gathered and grown up to be granular, the coarse carbide was distributed on the grain boundary in spherical and chain shape, and there were a large number of grain boundary creep holes and creep cracks. The metallographic structure on the opposite side of the crater was ferrite+granular carbide.

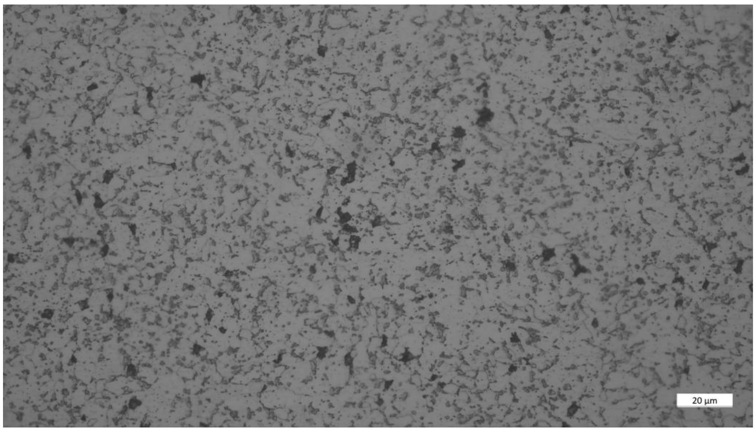

**Figure 3.** Intermittent metallographic structure at the crack.

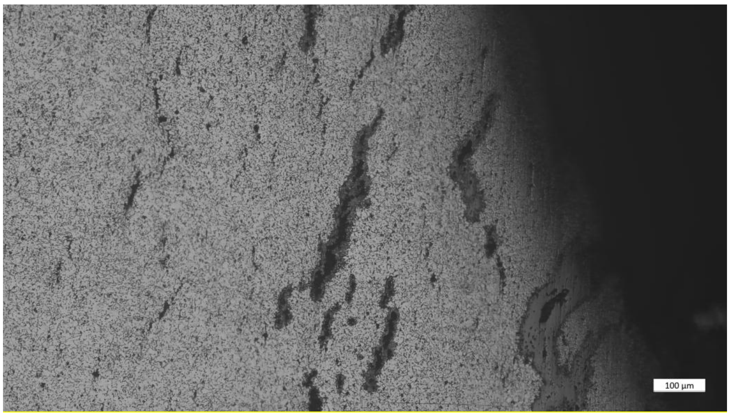

**Figure 4.** Creep holes and cracks

### 3.3. Chemical composition detection and analysis

Take samples of the secondary superheater tube with leakage for chemical composition detection. It can be seen from Table 1 that the content of each element in the secondary superheater tube conforms to the chemical composition of 12Cr2MoWVTiB steel in the standard GB/T 5310-2017.

**Table 1.** Formatting sections, subsections and subsubsections.

| Detect elements | C | Si | Mn | P | S |
|---|---|---|---|---|---|
| Measured value | 0.17 | 0.54 | 0.54 | 0.011 | 0.013 |
| Standard | 0.08～0.15 | 0.45～0.75 | 0.45～0.65 | ≤0.025 | ≤0.015 |

| | | | | | |
|---|---|---|---|---|---|
| requirements | | | | | |
| Detect elements | Cr | Mo | V | Ti | B |
| Measured value | 1.74 | 0.52 | 0.38 | 0.11 | 0.0032 |
| Standard requirements | 1.60～2.10 | 0.50～0.65 | 0.28～0.42 | 0.08～0.18 | 0.0020～0.0080 |
| **Detect elements** | **W** | —— | —— | —— | —— |
| Measured value | 0.41 | —— | —— | —— | —— |
| Standard requirements | 0.30～0.55 | —— | —— | —— | —— |

### 3.4. Mechanical property test and analysis

Take samples of the secondary superheater tube with leakage for tensile test at normal temperature. It can be seen from Table 2 that the tensile strength of the secondary superheater tube was lower than the lower limit required by the standard.

**Table 2.** Test results of mechanical properties of secondary superheater tubes at room temperature.

| **Test items** | **Yield strength/MPa** | **Tensile strength/MPa** | **Elongation after fracture/%** |
|---|---|---|---|
| GB/T 5310—2017 | ≥345 | 540～735 | ≥18 |
| Measured value | 330 | 529 | 26 |

## 4. Analysis of test results

From the macroscopic morphology analysis, the explosion of the secondary superheater pipe was located in the elbow section, and the pipe diameter had no obvious expansion; The edge of the blast hole was rough and blunt, the pipe wall was not significantly thinned, the oxide skin of the outer wall near the blast hole was in the shape of "old tree bark", and no defects such as mechanical damage and corrosion damage were found, which had the typical characteristics of long-term overheating tube explosion[5-7].

According to the analysis of metallographic structure, the metallographic structure at the blast hole had been seriously aged, its structure was ferrite+granular carbide, the bainite morphology had completely disappeared, the carbide had gathered and grown up to be granular, the coarse carbide was distributed on the grain boundary in spherical and chain shape, and there were a large number of grain boundary creep holes and creep cracks. The metallographic structure on the opposite side of the crater was ferrite+granular carbide[8-10].

From the chemical composition analysis, the chemical composition of the secondary superheater tube section mets the requirements of the standard for 12Cr2MoWVTiB material, and the misuse of material was excluded.

From the analysis of mechanical properties, the tensile strength of the secondary superheater tube section had been lower than the lower limit required by the standard.

## 5. Conclusions

To sum up, the main reason for the leakage of the elbow section of the secondary superheater was that the secondary superheater tube was overheated for a long time, resulting in serious aging of the metallographic structure of the tube, serious degradation of the mechanical properties, and insufficient to withstand the effect of the internal medium pressure, resulting in the leakage, and the leakage of the leaking steam blowing the adjacent superheater tube, resulting in the leakage of the adjacent superheater tube.

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