Analysis on Water Wall Tube Explosion in a Power Plant

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Abstract. Combined with the influencing factors of water wall tube explosion, this paper analyzes the water wall tube explosion of a power plant, and finds out that the water wall tube explosion may be caused by hydrogen embrittlement or local overheating, and expounds the measures to reduce the water wall tube explosion and reduce the risk of water wall tube explosion.

1. Introduction
In recent years, large capacity thermal power units have been developed rapidly. Due to various reasons such as manufacturing, installation, operation, maintenance and management, the operation level of large capacity thermal power units in China is still relatively low. The water wall of boilers often overheats, and tube explosion accidents occur in serious cases. Therefore, a lot of experimental research has been done in colleges, universities and scientific research institutes. However, the phenomenon of water wall explosion still occurs frequently in large capacity utility boilers. Based on the previous literature and the actual situation of a power plant, this paper studies and analyzes the water-cooled wall tube explosion.

2. The factors of water wall explosion

2.1. Material defects
The quality of metal material is the basis of the quality of water-cooled wall. If the material is misused or the quality is unqualified, it will inevitably cause the serious consequences of water-cooled wall explosion.

2.2. Welding defects
In the process of unit maintenance, the water wall is almost replaced. Therefore, the quality of the welding joint for replacing the water wall directly affects the safe operation of the unit. If there are cracks, incomplete penetration, incomplete fusion, slag inclusion and other harmful defects in the welded junction, it is likely to cause tube explosion in operation.

The welding defects not only exist in the weld of replacing the water wall tube, but also in the weld between the water wall fin and the tube. Due to the lack of attention to the welding quality of fins and tubes, the weld between the tubes and fins has become a weak link in the water wall.

2.3. Wear and thinning of pipe wall
The main reason for the wear of water wall is the high-speed movement of fuel in the furnace, which is easy to cause the tube wear. Another major cause may be corrosion thinning. There are many
reasons for water wall corrosion. For thermal power plants, high temperature sulfur corrosion is the most likely and harmful. High temperature sulfur corrosion refers to the chemical reaction between metal and sulfur-containing medium at high temperature to generate sulfide. The high temperature sulfur corrosion on the fire side of the water wall tube is formed under the condition that the carbon monoxide reduction environment exists due to the high sulfur content of the coal used in the boiler and the partial lack of oxygen in the boiler, and the coal powder which is not completely burned washes the surface of the water wall.

2.4. Metal overheating
The water wall tube is directly radiated by the high temperature of the flame in the furnace. When the operation condition is abnormal, for example the tube is blocked or the water circulation is poor, it will cause the water wall tube to run over temperature. The overheating of the water wall tube can be divided into long-term overheating and short-term overheating.

Long term superheat refers to the long-term operation of the water wall tube over the allowable operating temperature. Long term superheat of the tube will increase the sensitivity of material gap and decrease the high-temperature endurance strength, resulting in tube burst.

The short-time overheating refers to the deterioration of cooling conditions, the sharp rise of temperature and the sharp drop of short-time tensile strength of steel during the operation of water-cooled wall tubes. The first plastic deformation occurs on the fire side, the tube wall thins and the explosion occurs.

Whether it is long-term overheating or short-term overheating, it is because of the poor working condition of the water wall and the poor water circulation, resulting in the temperature rise.

2.5. Acid alkaline corrosion of metals
When there are deposits (scale or slag) in the water wall tube, the corrosion of the water wall is easily caused under these deposits, which is called acid-base corrosion. This is because the acid and alkaline salts of the medium in the water wall tube destroy the metal protective film. Generally, the lower the pH value is, the more serious the metal corrosion is. Especially when the water contains dissolved oxygen, the change of pH value has a greater impact on the metal corrosion. When the pH value is very low, the corrosion rate will increase rapidly with the decrease of pH value, resulting in the occurrence of hydrogen embrittlement. With the increase of pH value, the corrosion rate will decrease.

3. Analysis of water wall tube explosion in a power plant
The water wall of No.1 Boiler in a power plant was burst. According to the observation of the cut water wall tube, there are pits with different depths in the tube wall, See Fig. 1-3 for the condition of inner wall and outer wall of the pipe and the metallographic inspection results.
Through observation, it is preliminarily determined that these pits may be caused by acid-base corrosion or electrochemical corrosion.

The water-cooled wall sample is sent to the Electric Power Research Institute for analysis and test, and the results are shown in Table 1

| number | SO₃% | CaO% | Ti₂O% | Cr₂O₃% | MnO₂% | Fe₂O₃% | NiO% | CuO% | ZnO% | Weight g/m² |
|--------|------|------|-------|--------|-------|--------|------|------|------|-------------|
| 1      | 4.2  | 1.9  | 0.2   | 1.3    | 3.6   | 84.8   | 0.9  | 0.6  | 1.1  | 274.4       |
| 2      | 0.1  | 0.3  | 0.1   | 0.1    | 1.4   | 96.6   | 0.7  | 0.2  | 0.3  | 269.5       |
| 3      | 1.7  | 0.2  | 0.9   | 2.5    | 90.0  | 0.7    | 0.6  | 1.1  | 242.0 |            |
| 4      | 2.4  | 0.3  | 0.1   | 1.3    | 92.8  | 0.5    | 0.2  | 0.3  | 258.0 |            |

According to the analysis results, it can be seen that the main component of the corrosion scale sample is Fe₂O₃, which has the characteristics of high iron and belongs to the basic characteristics of high temperature corrosion of water wall tubes, and the content of chlorine is not available. Therefore, it can be concluded that the cause of water wall tube explosion may be caused by electrochemical corrosion or local overheating.

4. Improvement and preventive measures

4.1. Strictly control material quality

In terms of material purchase, regular large-scale products shall be selected. If necessary, they shall be stationed in the factory for on-site acceptance to ensure that the chemical composition and physical and chemical properties of the materials meet the requirements of relevant standards. After the
materials enter the factory, they shall be accepted in the factory. Agencies with corresponding
inspection qualifications shall be entrusted to inspect the chemical composition and mechanical
properties of the materials, and they can only be used after passing the inspection.

4.2. Strictly control the welding quality
In order to avoid welding problems in the welding process of water wall pipes, relevant departments
must supervise the welding process, starting from materials, personnel qualification, welding process,
inspection and other aspects, and strictly control each process.

4.3. Prevention of wear and corrosion
The effective measure to avoid the abrasion of water-cooled wall pipe is to spray the surface of water-
cooled wall pipe with anti-wear coating. For the seriously worn parts, the measures of combination of
spray protection and anti-wear baffle can be taken. At the same time, the quality of coal should be
monitored, and the quality and granularity of coal powder should be strictly controlled.

4.4. Prevent local overheating
Strengthen the boiler operation management, strictly monitor the operation condition of the water wall
to prevent the over temperature, over pressure and over load operation. Strengthen chemical
supervision, ensure the quality of steam and water, prevent scaling in water wall pipe due to poor
water quality, and cause local overheating.

4.5. Strictly control pH value of boiler water
The quality of boiler water affects the service life of water wall tube, so the quality of medium in
water wall tube should be strictly controlled to make it within the scope of national standard. The
boiler operators shall regularly discharge the sewage to prevent the water slag or scale in the pipe from
adhering to the pipe wall, causing acid-base corrosion or local overheating.

5. Conclusion
Through the above analysis, it can be concluded that the electrochemical corrosion of the water wall
leads to hydrogen embrittlement, which leads to local stress too large and brittle fracture. Due to the
large amount of scaling in boiler 1, the main reason is that the water vapor quality exceeds the
standard. After scaling, the heat transfer efficiency decreases, leading to local overheating and tube
explosion. In order to avoid this phenomenon, it is necessary to strictly monitor the quality of steam
and water, and to ensure the allocation rate, input rate and qualification rate of online chemical
instruments. It is suggested that chemical cleaning should be carried out in the next overhaul of the
boiler to eliminate the scale in the water wall and ensure the safe and economic operation of the boiler.

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