

# Risk Analysis of Water Tubes in Boiler using FMEA

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## Abstract

Failure Mode and Effects Analysis (FMEA) technique is used to identify potential failure modes for a product or process before the problem occur, to assess the risk associated with those failure modes and identify and carrying out measures to address the most serious concerns. The Failure Modes and Effects Analysis (FMEA) method has been used to study the reliability of many different power generation systems. This paper now applies that method to a water tubes (WT) in boilers. The aim of this study was to reduce the breakdown and specific power consumption for continuous power generation in the plant. In this study we work on the "Failure mode and effect analysis" technique in plant. Comparison is made between the quantitative results of an FMEA and reliability field data from real water tube systems. These results are discussed to establish relationships which are useful for future water tube designs.

**Keywords:** Failure Mode and Effect Analysis, Reliability Analysis, Risk Analysis of water tubes in boiler.

## 1. Introduction

With rapidly growing Indian economy demand for electricity is increasing day by day. Although government has put most efforts to meet out this demand by building new plants but still gap between demand and supply is not shorting. Government has also taken initiatives by setting benchmark parameters for running power plant to follow these parameters to improve plant efficiency. In India more than 75% of electricity is based on coal so it draws a lot of attention to improve efficiency of thermal power plant as there is a large scope of saving energy in thermal power plant. Suratgarh Super Thermal Power Plant is one of the power plant s in Rajasthan with capacity 1500 MW. It is bitumen coal based plant. Thermal plant runs over Rankine cycle which consist boilers, turbines, condensers and feed pumps. Water tube is a part of boiler. For continuous generation of electricity, power plant engineers keep attention on how to minimize plant breakdown by reducing failure modes. More power consumption and failure modes in water tubes are big problems for power plant engineers. There are number of failure mode due to corrosion, erosion, misalignment of tubes, leakage of water, high pressure and temperature etc. This require correct operation and routinely and timely maintenance for running continuously.

## 2. FMEA and Methodology of FMEA

(Chin kwai-Sang, Wang Ying-Ming, 2009) Failure Mode and Effects Analysis (FMEA) technique is used to identify potential failure modes for a product or process before the problem occur, to assess the risk associated with those failure modes and identify and carrying out measures to address the most serious concerns. The purpose of FMEA is to analyze the design characteristics relative to the planned manufacturing process to ensure that the resultant product meets customer needs and expectations. When potential failure modes are identified, corrective action can be taken eliminate or continually reduce the potential for occurrences. The FMEA approach also documents rationale for a particular manufacturing process. It uses occurrence and detection probabilities in conjunction with a severity criteria develop a Risk Priority Number (RPN) for ranking corrective action considerations (Chin and Wang, 2009).

FMEA is needed to identify potential failure modes that may adversely affect safely, government regulations compliance or customer satisfaction and the rate of severity of their effects, the purpose of FMEA is

- a) To identify critical characteristics and significant characteristics.
- b) To concentrate engineers focus on eliminating product and process defects and prevent problem from occurrence.
- c) To identify potential design deficiencies before releasing hardware for production.
- d) To identify potential process deficiencies before production begins.
- e) To rank order potential design & process deficiencies for prioritizing corrective actions.

Failure mode and effect analysis (FMEA) is an engineering technique used to eliminate potential failures, problems and errors in the system and determine their effects on the operation of the product. It could be a design, manufacturing process and services of products before it reaches to the customers. The analysis of the evolution may take two courses of action. First

using historical data, there may be analysis of similar data for similar products and/or services, warranty data, customer complaints and any other appropriate information available to define failure. Secondly inferential statistics, mathematical modeling and simulations, concurrent engineering and reliability engineering may be used to identify and define the failure. Using the FMEA does not mean that one approach is better than the other or that one is more accurate than the other. Both can be efficient, accurate and correct if used properly and appropriately.

Any FMEA conducted properly and appropriately will provide the practitioner with useful information that can reduce risk (work) load in the lad system, design, process and service. This is because it is logical and a progressive potential failure analysis method (technique) that allows the task to be performed more effectively. FMEA is one of the most important early preventive actions is system, design, process or service, which will prevent failure and errors occurring and reaching to the customer.

Conducting FMEA is a team approach. To conduct FMEA, it is recommended to cross functional team of knowledgeable individual with expertise and design, manufacturing, assembly, service and quality. The responsible team of product or manufacturing/ assembly engineer leads the FMEA tool. The responsible design or

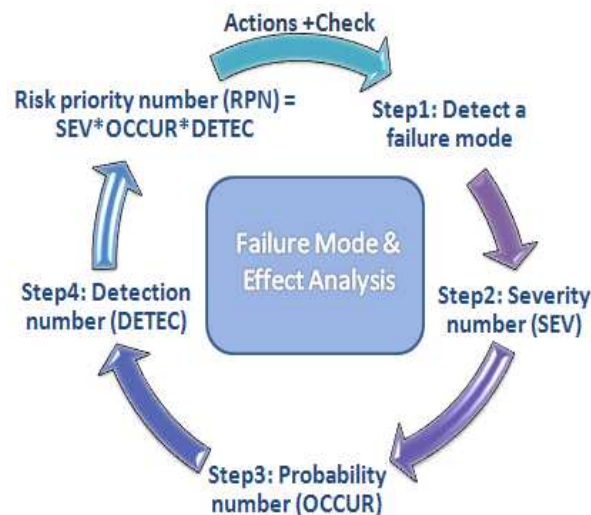
process engineer is expected as a representative from all the affected activities. Team members will various the concept, product and process design matures. For proprietary designs suppliers are responsible. FMEA stimulates the interchange of ideas between the function affected and thus promote a team approach.

Types of FMEAs based on nature of application, and can be classified into three basic types of FMEA:

- a) Process FMEA
- b) Design FMEA
- c) Concept FMEA

FMEA conduct as the steps given below:

- a) Detect a failure mode.
- b) Find the severity number for the failure mode.
- c) Find the probability of occurrence for the failure mode.
- d) Detection for the failure mode.
- e) Calculate the risk priority number for the different failure modes.
- f) Recommended action for the failure modes.



**Figure 1: Risk Priority Number**

In Fig. 1 Risk Priority Number (RPN) shows the risk associated with potential problems identified during a Failure Mode and Effects Analysis (FMEA). The basic RPN method and then examines some additional and alternative ways to use RPN ratings to evaluate the risk associated with a product or process design and to prioritize problems for corrective action. RPNs calculated at the level of the potential causes of failure (Severity x Occurrence x Detection). RPN do not play an

important part in the choice of an action against failure modes. They are more threshold values in the evaluation of these actions. The failure modes that have the highest RPN should be given the highest priority for corrective action.  $RPN = Severity (S) * Occurrences (O) * Detection (D)$ . We apply process FMEA on water tubes, because process FMEA used to assess any processes and mostly involves manufacturing area process. For effective process FMEA, a team of expertise is

necessary. A team is organized in Suratgarh Super Thermal Power Plant to understand the process, test, operation and maintenance and to identify numbers of failure modes and calculate Risk Priority Numbers and take corrective recommended action to minimize RPN.

### 3. Failure Mode and Effects Analysis in Thermal Power Plant

Suratgarh super Thermal Power Plant (SSTPS) is the First Super Thermal Power Station of Rajasthan with a total planned installed capacity of 1500 MW. SSTPS is running under the state government and Rajasthan Rajya Vidhut Utpadan Nigam. The installed capacity of Rajasthan state as on 04-05-2010 is 8315.48 MW out of which the capacity of RVUNL is 4097.35 MW. In this plant all six units are 250 mw of each. Plant Load Factor (%) in 2009-10 is 95.33. Aux. Power Consumption (%) of this plant 9.19 and Sp. Oil Consumption (ml/kwh) is 0.77.

#### A. Boiler:

In a simple a boiler may be defined as a closed vessel in which steam is produced from water by combustion of fuel. In the thermal power plant the water tube (Babcock and wilcox) boiler to be used. In the plant the pressure of boiler is about 150 kg/cm<sup>2</sup> and temperature 5500 c.

#### B. Boiler Description:

Boiler: Water tube boiler (Babcock and Wilcox) Fuel: Bituminous coal

#### Specification:

Weight: 123 tons  
 Internal diameter of drum: 1676 mm  
 Outside diameter of drum: 1942 mm  
 Length of boiler: 15700 mm  
 Diameter of water tube: 75 mm  
 Working pressur: 150 kg/cm<sup>2</sup>  
 Steaming capacity: 780 ton/hour  
 Material: Carbon steel  
 Efficiency of boiler: 86 %  
 Coal per/used in boiler: 3500 ton/day

#### C. Boiler Tube:

In the power plant the boiler is the big part of the plant. In the there are many component of the boiler. Water tube is the main mounting of the boiler. In the water tube there are many of the failure occurs in it, which is big issues that reason unit had shut down. There are many failures occur (unit 5) in the tube these are followings:

- a) Caustic attack
- b) Oxygen attack
- c) Hydrogen damage
- d) Acid attack
- e) Stress corrosion cracking (SSC)
- f) Waterside corrosion fatigue
- g) Super heater fireside ash corrosion
- h) Short term heat
- i) Long term heat
- j) Erosion

The total no. of failures are occurs in the tubes from 2005-2009 is shown in the figure 2 and the occurrence of the boiler tube failures is shown in figure 3

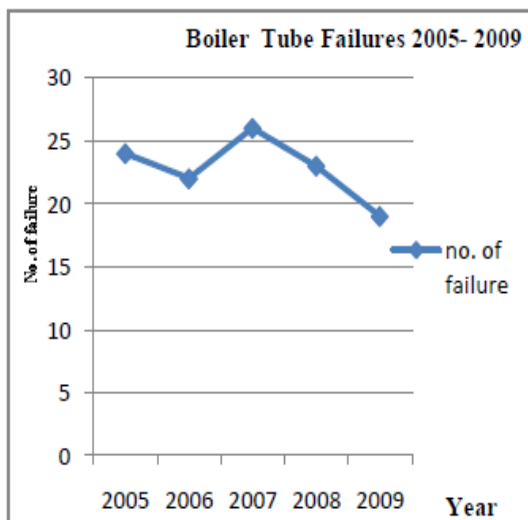


Figure 2: Boiler tube failures 2005-09

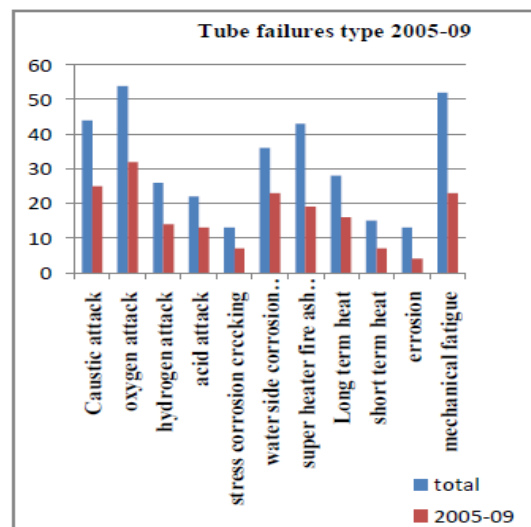


Figure 3: Tube failure types 2005-09

**D. Starting of FMEA:**

The start of the FMEA is the hardest part. It can be very hard to build up the dedication to complete what can be a long task. Any attempt to reduce the detail at any stage, especially the start, is likely to continue. Therefore, it is worth putting that little bit more effort in initially. Whether it is a design or process FMEA, it is best to rough it out on the draft document. When the various stages are taken out of order, many of the potential benefits are lost. Although it is tempting to rush, never attempt this, otherwise the process will become a paper exercise and you end up by matching the document to the design or process you expect. On the analysis of last three years boiler failure records, find the many causes of boiler tripping, then classify the most probable causes of boiler failure according to team

member suggestions and give appropriate RPN to that cause of failure.

**E. Observation:**

RPN of each cause of the failure is calculated ( $S * O * D$ ) from these rankings. For example consider the problem of Boiler tube failure the team member agree on severity ranking as 9, occurrence rating 7, and detection 5 rating as. Thus Severity = 9, Occurrence = 7 & Detection = 5  $RPN = S * O * D = 9 * 7 * 5 = 315$  As this one, RPN of all the causes of the problems are calculated. On the basis of RPN calculation it is observed that cause of tripping with high RPN of Boiler tube having the more failures in the boiler. Now here we considered the four month failure data due to boiler tube these are shown in the table 1

**Table 1 Different causes of boiler tube failure**

Date	Causes of boiler tube failure
07/10 /09	High Temperature
22/10 /09	High impurities in feed water and poor water circulation
16/11 /09	Water tube leakage and water corrosion
04/12 /09	Misalignment of tubes
17/12 /09	Flow of welded material
03/01 /10	Super heater fireside ash corrosion

**F. Cause and area of tube failure:**

- a. Due to producing of wrong or excess quantity of air fuel mixture the temperature of tube suddenly increase.
- b. Due to failure of feed water pump and presences of impurities in the circulating water in tubes occurs the corrosion and other problems in water tubes.
- c. Due to effect of corrosion tubes have leakages the water and due to this leakage affected the other sub components.
- d. Misalignment and setting of the water tubes is the major problem due to this vibration and sound effect of generated.

**G. Recommended Action:**

**(i)Boiler Operation:** The boiler under consideration here is of the water tube natural circulation type. The feed water enters the boiler steam drum from the economizer or from the feed water heater. For reducing the tube failure there are following recommended action to be taken.

- a. At the time of working condition alignment of the tube, excess steam temperature and pressure to be check in routine maintenance.
- b. Controlling the flow velocity in the riser tube is to be sufficient; due to some abnormality excess steam build up in the risers occurs the tubes may over heat and the excess stress in the tube.
- c. During the operation if the corrosion effect in tube

to be small area, take the concern action by boiler maintenance department.

- d. If the any doubt in leakage of water tube and setting of the tubes to be disturbed by the vibration to be examined.
- e. If the temperature of the tubes excessively high to inform quickly control room.

**(ii)Improve Routine Maintenance of Water Tube:**

In water tube there is several type of failure to be generated by the different problems. Water tube is major component of the boiler. It is a mounting of the boiler. With the tube failure or any of the mounting have been failed boiler cannot work safely. So in the small type of failure cannot ignore, in routine maintenance to be necessary work effectively. If a major failure occurs unit had been shut down for 3 to 4 days it will very affected the power generation. During the routine maintenance, maintenance engineering should take the action in following areas:

- a. In the water tubes innovative preventive technique to be used to reducing the failures.
- b. Extensive inspection of pressure load to be measure where the pressure rises.
- c. Shielding tube at critical at critical zone to reducing the erosion and corrosion.
- d. Improve maintenance of flue gas part.
- e. Expert analysis of tube failure.

**5. Results**

**a) Results after implementation of FMEA**

After implement the FMEA on water tube between “FEB 2010 to MAY 2010” compare the cause of failure and tripping due to water tube in boiler.

**For Water Tube**

Tripping in last three year = 32  
 One month tripping is =  $32/36 = 0.89$   
 One year tripping =  $0.89*12 = 10.67 \approx 11$   
 During implementation period tripping = 2

**b) Resulting RPN**

Table 2 Comparison of RPN before and after implementation of FMEA

	Occurrence	Severity	Detection	RPN
Old RPN	7	9	5	315
New RPN	6	9	4	216

From the above table, after implemented FMEA on water tube, calculated RPN is to be reduced and recommended action are to be taken referred the reducing the occurrence the of failure modes and severity in water tube. In the part of reliability analysis of the water tube, major failure of the water tube to be taken from last three years, after calculated MTTF by the weibull least square method is the 4519 hours or 188 days.

**6. Conclusions**

This Study concentrates on the failure analysis of the water tubes. Reducing the risk priority number (RPN) for different failure of tubes by eliminating the cause of failures and reliability analysis of the boiler tubes. We have seen the there are many critical failure modes in the boiler but we have considered only failure on the water tubes. From the last three years number of maximum failures occurs in water tubes. These failures affected the boiler performance and power generation but here our aim is to be eliminating the failure mode of water tubes and find the mean time to failure of water tubes by the regular and routine maintenance of the tubes. In this paper, failure of the water tubes by reducing the risk priority number and using the reliability analysis find the mean time to failure (MTTF). By taking the recommended action for the failures and reducing the occurrence of failure modes. In water tubes RPN is to be reduced by the Controlling the flow velocity in the riser tube is to be sufficient, improve maintenance of flue gas part, extensive inspection of pressure load to be measure where the pressure rises.

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