STUDY OF MITIGATION OF SUPERHEATER TUBE FAILURE & MAINTENANCE OF AN INDUSTRIAL BOILER

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FACULTY OF MECHANICAL ENGINEERING
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ABSTRACT

As new industries and technologies emerges, the utilization of boilers never fades and it there all over the world. A boiler is a crux of most industries whereby it produces steam, hot water and etc for production purpose, steam turbine and etc. In this paper we concentrate on the water tube boiler due the relevance of the topic. Most industries relies on the steam turbine to generate electricity for production purposes and this requires usage of steam generated by boilers for their operation. Other than that, steam turbine requires dry steam and not saturated steam which most industries utilizes for production. The dry steam is produces by passing through one of a critical component of boiler which is the superheater. Superheater is required in order for the boiler to produce dry steam or also known as superheated steam. As a critical component, this superheater is prone to failure due exposure of high temperature constantly and to mitigate it, the paper studies method and ways to minimize and prevent the failure of superheater tube and also maintenance of an industrial boiler for better efficiency.

Keywords: Superheater: Boiler; Steam-turbine; Water-tube-boiler; Tube-failure

ABSTRAK

Apabila industri dan teknologi baru muncul, penggunaan dandang tidak pernah pudar dan di seluruh dunia. Dandang adalah industri paling banyak di mana ia menghasilkan stim, air panas dan lain-lain untuk tujuan pemprosesan, turbin stim dan lain-lain. Kebanyakan industri bergantung kepada turbin stim untuk menjana elektrik untuk tujuan pengeluaran dan ini memerlukan penggunaan stim yang dihasilkan oleh dandang untuk mereka beroperasi. Selain dari itu, turbin wap memerlukan stim kering dan bukan stim tepu yang kebanyakan industri menggunakan untuk pemprosesan. Wap kering menghasilkan dengan melewati salah satu komponen kritikal dandang yang merupakan superheater. Superheater diperlukan agar dandang menghasilkan wap kering atau juga dikenali sebagai stim panas. Sebagai komponen kritikal, superheater ini terdedah kepada kegagalan kerana pendedahan suhu tinggi dan untuk mengurangkannya, kaedah kajian kertas telah dibuat untuk mengetahui cara untuk meminimumkan dan mencegah kegagalan tiub superheater dan juga penyelenggaraan dandang industri untuk kecekapan yang lebih baik.

Keywords: Superheater: Dandang; Turbine-stim; Dandang-stim-air; Kegagalan-tube

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

SH	:	Superheater
OD	:	Outer Diameter
HRSG	:	Hear Recovery Steam Generator
FAC	:	Flow Accelerated Corrosion
ASLD	:	Acoustic Steam Leakage Detection
CAVT	:	Cold Air Velocity Testing

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Introduction

In the industries, boilers, which are a type of heat exchanger, are an essential part of the production or manufacturing cycle. The steam produced by the boiler can be both applied for heating things and to run the turbine to generate electricity. Boilers are most generally separated into two type of systems, which are fire tube boiler and water tube boiler. In the water tube boiler there are few more critical part compared to fire tube boiler. One of the critical part of the water tube boiler is superheater tube. Superheater is a part of the heat recovery steam generator (HRSG), which generally designed in two ways, one is coil type and the other is shell type. Superheater also designed according to the steam temperature requirement and commonly divided into two different parts which allows two different type of heat flow.

One of the type is radiant superheater and the other is convective superheater which designed for each zone of heat transfer for maximized heat transfer. Radiant superheater are used when the temperature difference is 100 C between the saturated steam and superheater steam and for the convective superheater it is used when the temperature difference not more than 50 C. This type of superheater always labelled as primary, secondary or tertiary superheater. The type of heat utilized by the boiler and the superheater are different even though both comes under a single system. Boiler uses both sensible heat and also latent heat in conversion of water into steam but as for the superheater tube it only utilizes sensible heat in order to superheat the steam supplied so the enthalpy can be increased.

As mentioned earlier superheaters are utilized when there are needs for dry steam or also known as superheated system, which mostly commonly needed for turbine because wet steam can easily corrode or degrade the turbine blades thus increasing maintenance cost which is why dry steam is needed. The advantages that can be gained using superheater is the reduction in the fuel consumption.

The major drawback of a boiler is when the superheater-tube fails. Superheater usually fail due to exposure of high temperature and pressure. There are also other reason which why the superheater fails but primarily most failure of superheater tube are caused by overheating and pressure. Superheater failure can be caused by various factors including mechanical stress, chemical reaction, thermodynamic and etc, Component failures on the pressure part have made high number of lost availability.

This research studies the nature of the superheater tube failure and also research the preventive method that can adapted which will be discussed on later chapters.

1.2 Overview

This section highlights the superheater backgrounds and together with possibilities of the superheater tube failure.

1.3 Project Abstract

The failure of superheater tubes been a major drawback to the industries since the cost and time needed to repair or replace this part expensive and time consuming. Therefore a proper mitigation strategies should be applied to prevent or minimize the occurrence together identifying the nature of defect.

1.4 Problem Statement

Superheaters are the most commonly damaged parts of a boiler, thus regular maintenance and preventative method are necessary to mitigate the tube failure. The damages can be due to mechanical, chemical (corrosion & erosion), thermodynamic means.

Improvement of materials and controlled operating system are moving in pace with advancement of boiler design. There are avenues to contribute on mitigation of superheater failure by systematic analysis of the process, design and preventive measures.

1.5 Research Objective

The nature of superheater failure often goes undetected, it crucial to know the nature of the failure so that steps to mitigate the failure can be minimized. Hence why, the objective of this research are as listed below:-

1. To investigate the nature of failure of superheater tubes from mechanical(pressure temperature, fabrication, welding and etc), chemical (corrosion & erosion), & thermodynamic
2. To identify and recommend the preventative method for superheater tube failure.
3. To analyze and recommend the efficient maintenance techniques of an industrial boiler.

1.6 Research Scope

1. Covers Superheater tube failure of an industrial water tube coal fired boiler.
2. Studies the nature of failure based on mechanical factors which covers pressure, fabrication and welding, Chemical factors and Thermodynamic factors only.
3. Focuses on preventive method that can be adapted to minimize the superheater tube failure.
4. Recommend maintenance technique that can be used to increase longevity of an industrial boiler.

CHAPTER 2: LITERATURE REVIEW

2.1 Industrial Boiler

According to Boiler book boiler defined as a closed pressure vessel in which fluid is hetead for use external to itself by the direct application of heating resulting from the combustion of fuel (sold, liquid, or gaseous) or by use of electricity or nuclear energy.

2.2 Superheater

The purpose of superheater is to enable the heat exchanger to produce dry steam to generate electricity by util izing the turbine according to Dehnavi et. al.

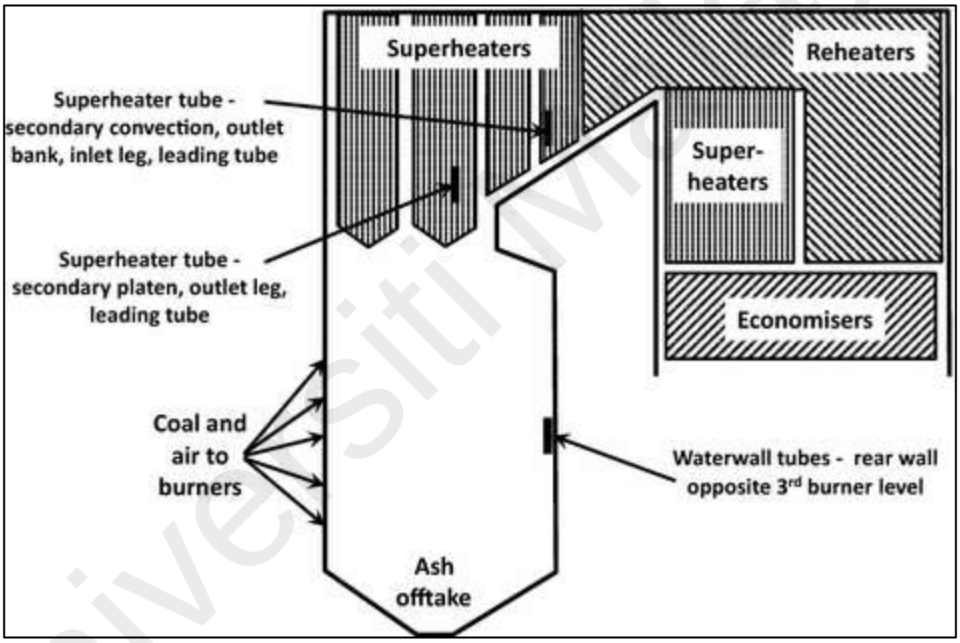


Figure 2.1: Superheater Tubes

According to Hennsey et. al Superheater component increase temperature above the saturation temperaturation.. Steam that enters the superheater are typically dry.

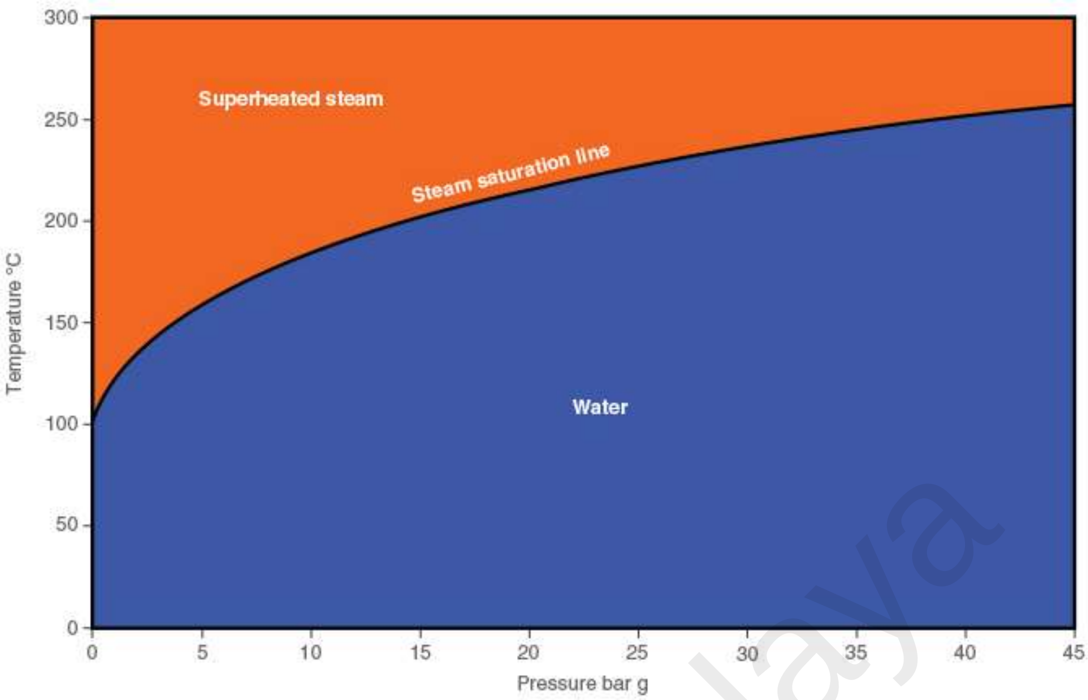


Figure 2.2: Steam Saturation Diagram

Numerous levels of pressure are used to superheat the steam so that it applicable for a particular process such as turbine operation or plant processing.

The purity of steam given by the superheater varies and mostly depends on the type of application it's needed. For example high purity is need when superheated steam is engaged with steam turbine because high purity steam protects the turbine from erosion and corrosion. As for lower purity of steam can be applied for processes whereby corrosion, erosion or fouling does not take part.

2.3 Superheater Failures

According to Drh Jones et al. One of the main reasons for the shutdown and removal of boilers from the circuit, and consequently, the removal of the unit from the network is the leakage occurrence as a result of the failure in boilers' tubes, particularly in superheater an the re-heater tubes. The reason behind rupturing of the superheater and reheater tubes in early stages are due to overheating. Overheating is defined when the tubes temperature rises above its design limit, let it be few hundred degrees above for short period of time or slight increase in temperature in long-term. Eventually both scenarios will lead to rupturing of tube.

According to Harry M, Spring Jr, generating tubes mostly fails due to overheating, this overheating can vary from scale or sludge build up, or obstructed circulation whether steam or water and concentration of heat which normal water or steam flowing cannot dissipate the heat fast enough. Rise of temperature in the superheater tubes usually because of development of scale internally and externally of the tube together with continuous exposure of high temperature according to Rajat K. Roy et al. According to Goutam das et. al the superheater tube comes in different materials for example it can be carbon steel to a low chrome ferrite or stainless steel. Futhermore, under operation superheater tube encounters many types of condition, one of which is oxides formation both inner and outer layers. This formation of oxides lead to corrosions.

Temperature rise is the most common nature if failure in boiler tubes. The reason behind is scales within inner and outer part of tube and or blocked tube which allows partially steam to flow which cause non-uniform flow. Internal scale formation reduces heat transfer rate across tube wall. Moreover, scale formation causes non-linear (non-uniform) heating, resulting in the retardation of heat transfer further and reduction of thermal efficiency. External oxide formation generally depends on type/quality of coal, which produces and develop flue gas. The mostly complex alkali sulfate scales. This effect raises the temperature of the tube locally and the long time exposure results in thicker oxide formation. The later phenomenon escalates wall thinning and rupture of the tube. A number of investigators has studied material de-generation and subsequent failure due to thermal fluctuation, in the recent past. Factors such as corrosion, pressure, stress and high temperature and etc are reason for damages.

Failures of superheater tubes brings not only economic losses but also people's live and property loss. It is an important research field for the domestic and overseas researchers. Boiler tubes are constantly exposed to high internal pressure, temperature and also increased amount of external environmental temperature.The most important reason for the destruction of the heater tubes is due to the temperature of pipe metal exceeding the defined strength limit. The metal temperature may gradually go up over the years with the growth of fouling (oxide, silica, salts etc) layer on the pipe, or it may even suddenly increase as a result of the decrease in gas flow or the cooling inside. Critical component which are mostly under high internal pressure is exposed to creep and after which destroyed give away increased amount of risk. Boiler tubes damages affects the power plant industry cost by billions of dollar yearly. Major power plants also witness such failures. In an work done by Mohapatra et al., In a gas-fire boiler, a prematurely failed tertiary superheater tube used in failure analysis. Boiler tubes of a coal fired plant faced harsh environment all the way from inside steam to outside flue gases.

According to Harry M, Spring Jr, scale formation that occurs in the boiler heating surface are due to present of certain impurities such Calcium (Ca), Magnesium (Mg), and silica(SiO_2). The combination of both calcium (Ca) or magnesium together with sulfates (SO_4) or the magnesium which results in scale forming. Scale forming water is referred to as "hard". Therefore this hardness is temporary, permanent or both. Scale formation increases as the evaporation rate increases. Mostly in superheater tubes there also chances of FAC (Flow-accelerated corrosion) to occur. According to Germaud, P.D (2017) FAC happens mostly in tubes, headers and risers where the operating range is between 200-500 °F. It happens when the velocity of water/mixture are high which happens at bends in tubes or risers. The reason to why FAC occurs is due to the fact the water treatment program is inappropriate and the flow consist of high velocities. Operational stress or also known as thermal fatigue happens mostly at the hot end of the Boiler according to

Germaud P.D (2017). Germaud P.D (2017) discussed that the thermal fatigue might be result of improper of insufficient drainage of superheater tubes during starting up. If water

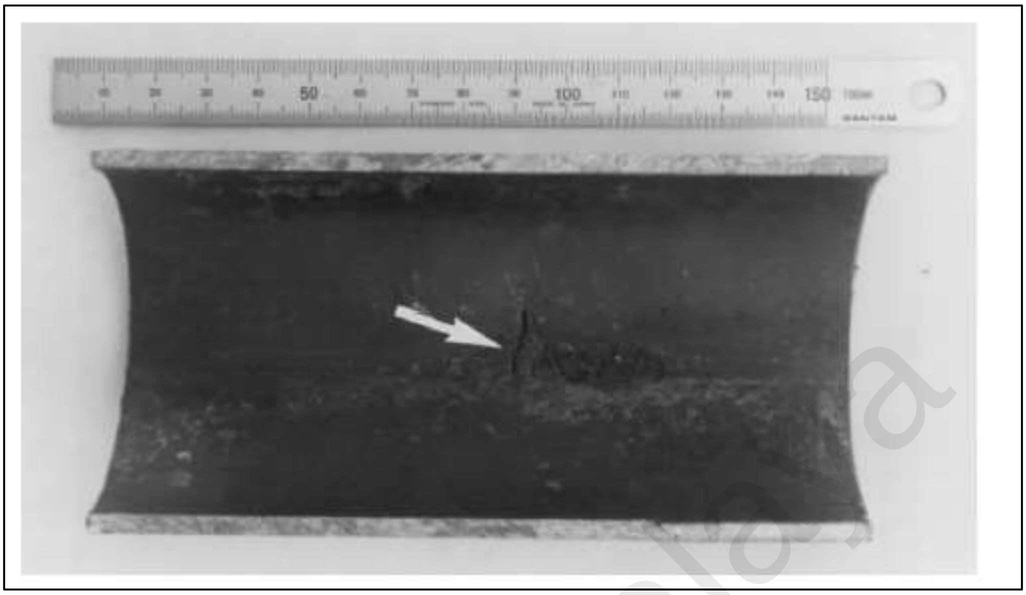


Figure 2.3: Internal Surface Pitting & Cracking

start getting into the coil it can damages. If the attemperator valves malfunctions it can result in improper disturbtion of spary into a superheater which will fatigue tubes fast. According to A.M Heyes (1999), main reason why oxygen pitting on tube occurs is due to lack of maintenance which was supposedly to done when the boiler is in the wet storage. A.M Heyes (1999) has proposed that failure due to oxygen pittings can be avoided with the boiler filled with water completely and also maintain the pH value at 11 pH.

According to Harry M, Spring Jr, Superheater tubes rarely fails due to corrosion unless the boiler has been in a long standby conditions. Superheater failure are mostly caused by overheating. There few ways that this overheating might occur, one is due insulating effect caused by deposited carried over by boiler water and the other is starvation. Starvation happens due to the fact that there’s insufficient steam within the superheater tube for heat transfer to happen. Also according to Harry M, Spring Jr deposit from the boiler water are carried over when foaming occurs within the steam drum which results in high concentration of dissolved solids or oil or other substances. Starvation of superheater tube is result of poor start-up practice or due operating boiler at low rating. During start-up of boiler, the furnace temperature is brought up too rapidly before the boiler reaches full pressure so there will be insufficient steam to cool the tubes.

CHAPTER 3: METHODOLOGY

3.1 Methodology

Basically to analyze the failure of superheater tube failure and maintenance technique for an industrial boiler. Recommend maintenance technique by analyzing previous work and research.

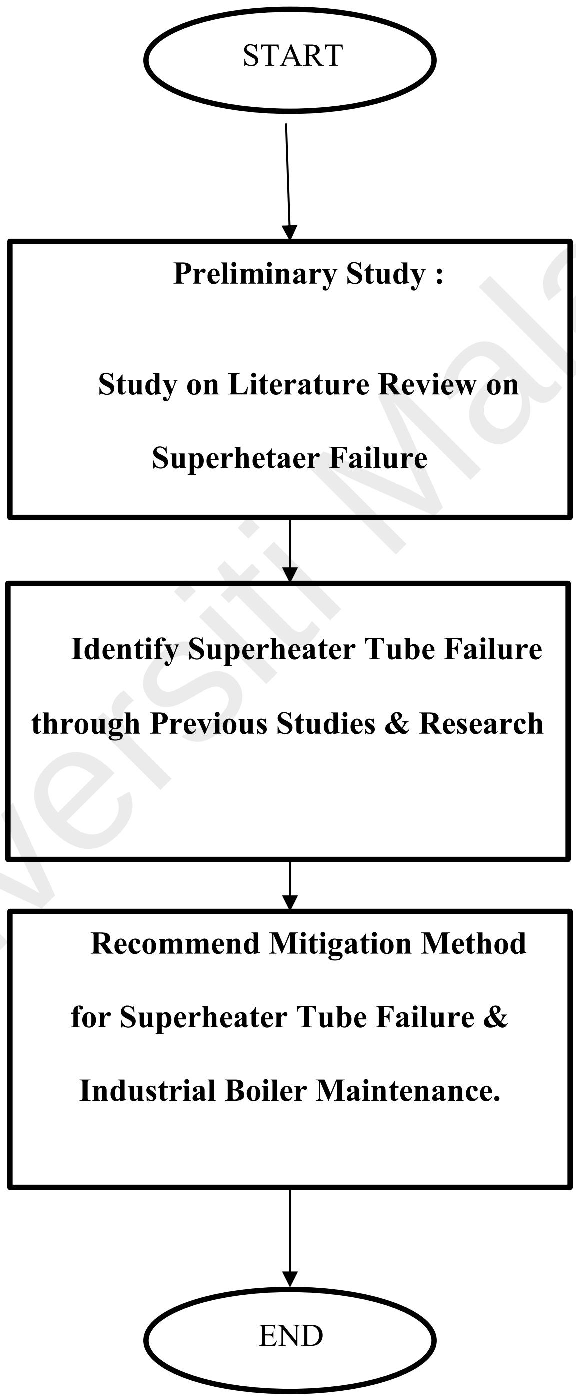


Figure 3.1: Study Flowchart

3.2 Milestone and Gantt Chart

These project covers for 2 semesters and the project's milestone can be viewed in the following table.

Table 3.1 Project Milestone

Project	Description	Period (Weeks)	Status
P1	Title & Supervisor Selection	1 - 3	Complete
	Literature Review	3 - 6	Complete
	Methodology	7 - 9	Complete
	Progess Report	10	Complete
P2	Project Wiriting	1 - 10	Complete
	Progress Report	10 - 14	Progessing
	Oral Presentation	15	Soon

CHAPTER 4: DISCUSSION

4.1 Overview

In this chapter, the nature of superheater tube failure and preventive method, which can be adapted, are discussed together with efficient maintenance technique for industrial boiler.

4.2 Preventative Method for Superheater Tube Failure

Preventative method used to increase the longevity of the superheater tubes itself.

4.2.1 Desuperheater

Desuperheater is a process by which superheated steam is converted to saturated state. There are two of type of desuperheater which can be used, one us indirect contact type and the other is direct contact type.

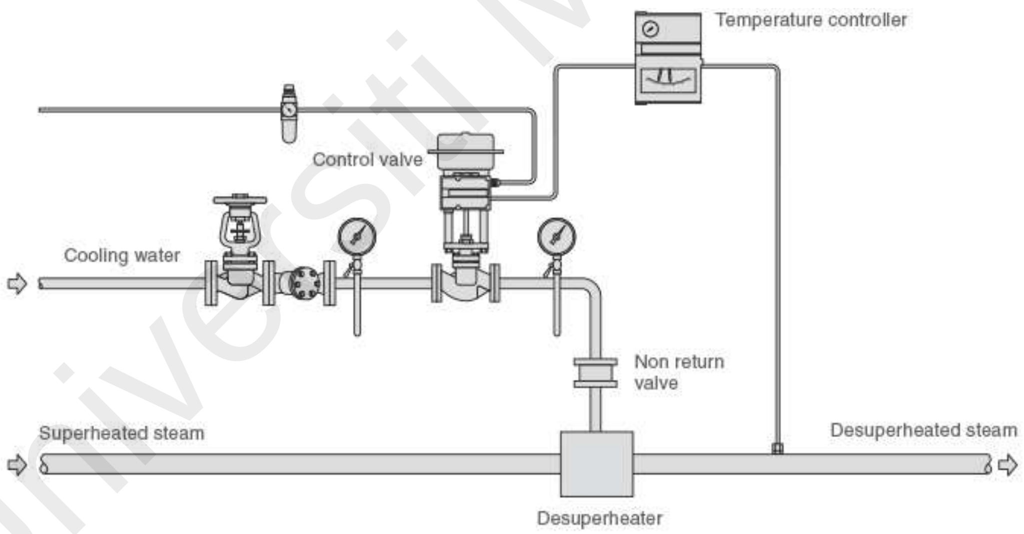


Figure 4.1: Desuperheater (Direct Contact)

Indirect contact type, used to lower the superheat steam temperature but does not come in contact with the steam. A cooler liquid is used as the cooling medium as for example the surrounding air, and this desuperheater can be found shell type of tube heat exchangers. In these process the superheated steam is supplied to one side of the heat exchanger and a cooler medium is supplied from the other side. Therefore when superheated steam passes through the heat exchanger, the steam losses the heat.

In the direct contact type superheated steam comes in contact with the medium used. Mostly the medium used for cooling is comes from the same fluid as the steam to be desuperheated. The amount of water to be added must be sufficient enough to cool down the steam to the appropriate temperature.

4.2.2 Blowdown/Anti foaming material

Increasing blowdown, allows deposit inside the boiler to be flushed outside, so that the deposit does not accumulate and result in foaming which can cause the deposit to enter the superheater tube and causing localized heating/overheat. Anti-foaming also does the same thing which removes the deposit but by using chemical reaction. We also need to know that the usage of too much anti-foaming can have reverse effect to the boiler water that can worsen the accu mulation of deposit.

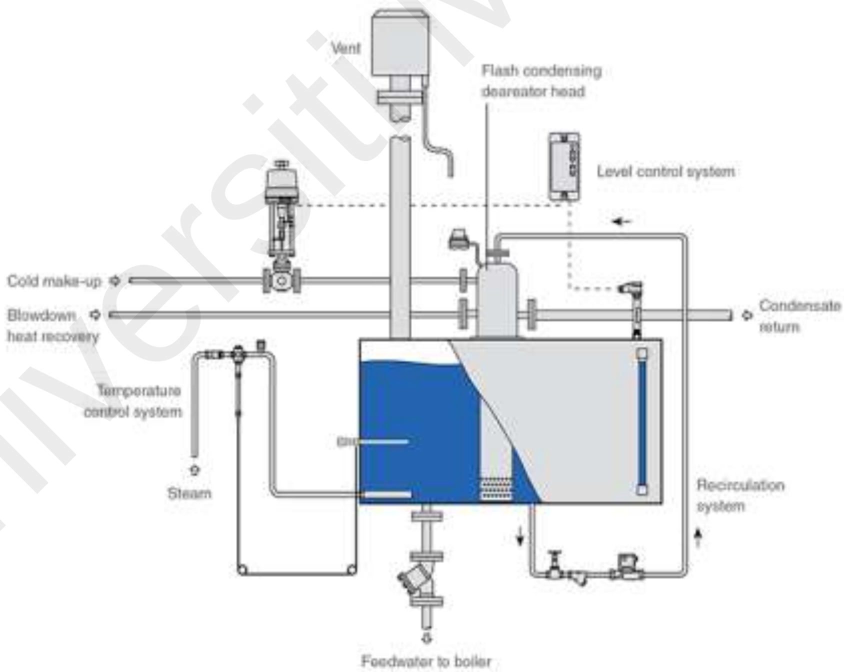


Figure 4.2: Blowdown Process

4.2.3 Safety Valve

According to FMA (Factory & Machinery ACT 1979) any separated superheater form the associated steam need to be provided with separate safety valve which shall comply to provision of regulation 12 which relates to steam boiler safety valves.

Safety Valve is needed so that any excessive steam can be blown out efficiently, also the steam drum safety valve will be set higher than of the superheater safety valve setting to avoid starvation.

4.2.4 Oil Separator/Water Level Controller

Providing oil separator in the feedwater line, with this we can eliminate the organic containments. Carryover is not because of pure hydrocarbon oils but additives in it. Carry over which is the form of slugs also one of problem faced by superheater. As by adding this oil separator this problem can be overcome.

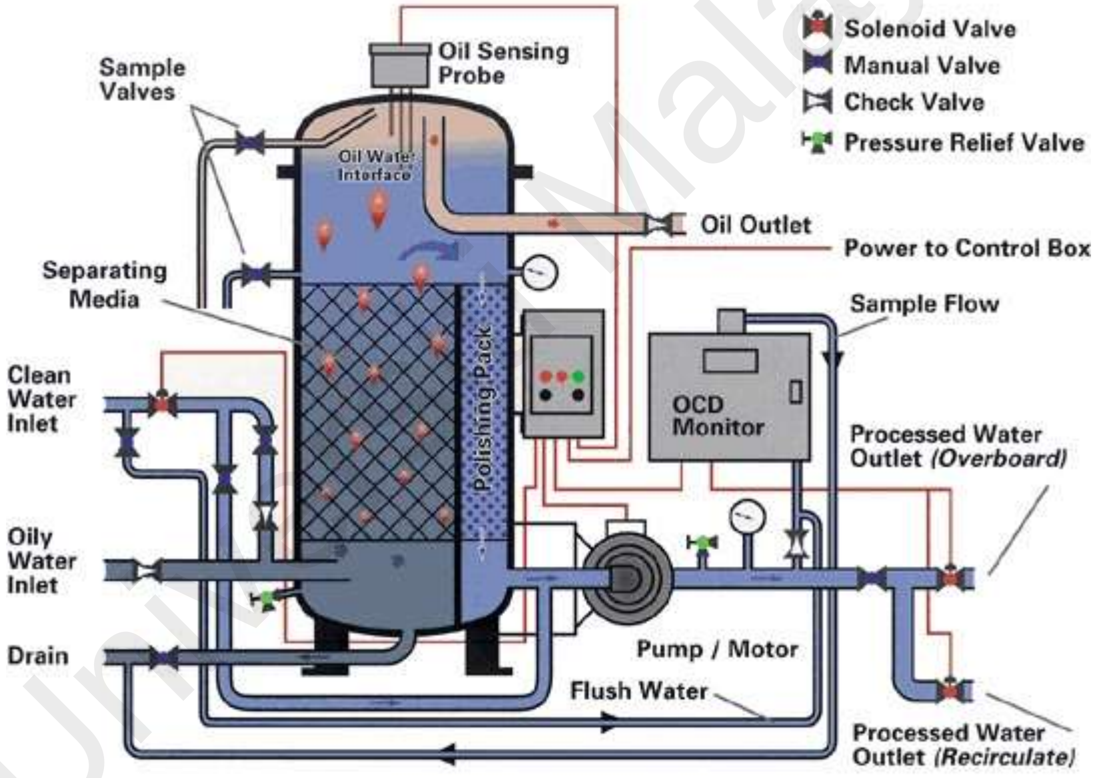


Figure 4.3: Oil Separator

4.2.5 Superheater Design

Superheater design requirements varies from the type of heat transfer it uses. It ultimialey important to take note on following requirement as listed in the table to get an optimum functioning superheater.

Table 4.1: Superheater Design

No.	Convection Superheater	Radian Superheater
1	Flue Gas Velocity	Temperature of Furnace
2	Steam Velocity	Temperature of steam
3	Temperature Difference between the flue gas and steam	Amount of heat absorbing surface exposed to radiant heat
4	Direction of gas flow - parallel or cross flow	Cleanliness of the tube surface
5	Clealiness of the tubes	

4.2.6 Material Selection

Superheater tube need to be made of the austenitic-class of steel, because this steel have high heat and corrosive resistance. The reason how such steel gets higher resistance to corrosion is due to presence of high content of chromium. Chromium metal makes strong, hard and imperative layer of Cr_2O_3 on the surface of tube which will be exposed to flue gas. This layer prevents penetration of oxygen and other gaseous, which are corrosive to metal base that hence resist corrosion of high temperature.

4.3 Maintenance Technique of Industrial Boiler

4.3.1 Reduction/Elimination Process

The appearance of failed boiler tubes if visualized and analyzed in a good manner, it will provide valuable information about the failure. The first step on which this failure reduction/elimination process begins are with determining the mechanism of failure.

Processes which are included are :

1. Determine Failure Mechanism
2. Find Root Cause of the Failures

3. Determine the extent of the damage
4. Find and implement short-term solutions
5. Find and implement long-term solutions to prevent re-occurrence

4.3.1.1 Determining the Failure Mechanism

Failure mechanism is what it is called as the process on which the failure occurred, for example it can be rupture by stress or fire/water side corrosion or erosion etc.

4.3.1.2 Find the Root Cause of Failures

To find the root cause of failure, first, the type of boiler need be specified and the location of tube failure should be specified as well. Root cause can be detected by undergoing several type of internal inspection such non-destructive testing etc.

4.3.1.3 Determine the Extent of Damage

This part tells to which extent the damage occurred, for example tube burst can cause other part of boiler component to fail or damaged as well, so identify the extent of damage enables us to know and focus on the damaged part.

4.3.1.4 Find and Implement Short-Term Solutions

Establishment of repair procedures, which clearly shows and elaborate on the method of repair but also quality control.

4.3.1.5 Find and Implement long-term solution

Long-term solution are needed so that any chances of re-occurrence of such failure or similar failure can be avoided or prevented. Furthermore, usage of inspection procedure for boiler tubes and other critical parts can be established so that it can be used as a baseline for method of verifying the problems and also check on the integrity of the tube repairs.

4.4 Methods of Maintenance

The maintenance method used to identify degrading parts or failed parts, which ensure downtime can reduced.

4.4.1 NDT Techniques

Non-destructive testing, relies upon the usage of electromagnetic radiation, sound and other conversion of signal to inspect or examine wide range of material and equipment.

4.4.1.1 Ultra thickness Measuring Gauge Method / D-metering

UTG (Ultra Thickness Gauge) used to measure local thickness of an element typically metal. This method uses ultrasound wave and calculate the time taken for the wave to return to the surface. This method can implemented on tube sheet, steam drum and etc to know their thickness and use it as reference to analysis the life expectancy of those material.

4.4.1.2 Dye Penetrate Testing

Liquid dye penetrant testing is the easiest and simplest form of technique/method to detcect cracks such as hairline cracks on tube sheets or tube surface etc. This method provides us with an immediate result by showing whether there is any form leakage. The indication is very simple because liquid dye penetrant test uses two type of liquid which is white and red. The cracks and flaws will be shown by the red liquid after the layering process finishes.

4.4.1.3 Oxide Scale Measurement

By identify the thickness of oxide scale, it can reveal the exposed temperature in which the tube has exposed to during operation period. By knowing the temperature , the life time which remains for the tube can be identified using LMP (Larson Miller Parameter).

4.4.2 RFET/LFET Magnetic Method

Another type of non-destructive testing is RFET/LFET which knows as Remote Filed Electromagnetic Technique and Low frequency Electromagnetic Technique.

4.4.3 CAVT Testing

CAVT Testing is knows as Cold Air Velocity Test which can be used to analysis and predict the flow of flue gas by measuring the cold air velocity manually within the boiler at a defined location.

This gives an added advantage since it gives the data of flue gas flowing which can be used to analysis which part of the vessel is exposed to increased amount of flue and which part exposed with less flue gas.

4.4.4 Time of Flight Diffraction Ultrasonic

This technique is a type of inspection which conducted to identify or detect flaws at the wall of components for example pipe joints or boiler header. This type of inspection uses ultrasonic method which can be easily utilized by the industries.

This technique enables user to detect cracks such hairline crack etc and also lack of fusion done by welder which would be less detectable if the radiography method is used.

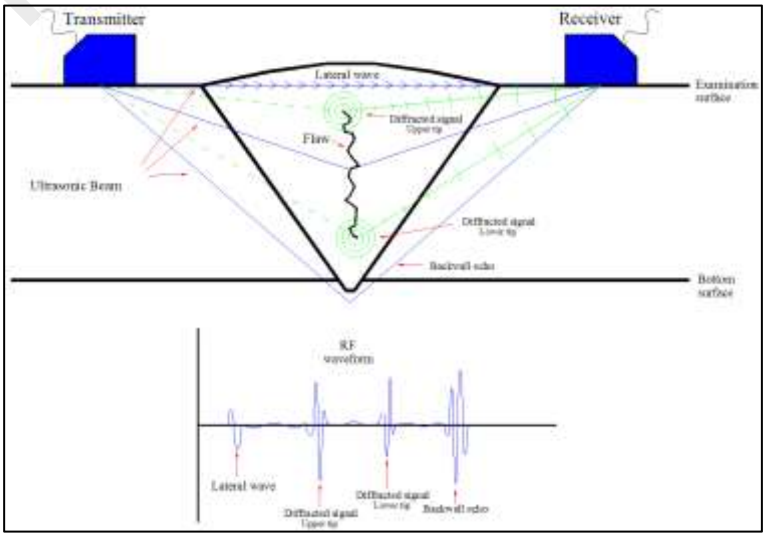


Figure 4.4: TFDU

4.4.5 Advance Inspection Techniques

Advance inspection technique allows more efficient of maintaining the boiler part which have restricted access.

4.4.5.1 Robotic Inspection by Magnetic Flux & Ultrasonic

This method is used to effectively test boiler tubes based on the magnetic flux leakage or ultrasonic. implementing this method enables outer diameter of the surface to be inspected for corrosion and also erosion.

4.4.5.2 Baroscopic Inspection or Fibroscopy Technique

As how the boiler manufactured, there are parts which are inaccessible by human to check or inspect, this parts which are normally headers and tubes can use this baroscope to actually access the internal surface of this parts. By using this inspection method one can identified if there are internal cracking which normally caused by the thermal fatigue. Furthermore, this technique is useful to identified internal scaling.

Figure 4.5: Baroscopic Inspection

Figure 4.6: Example of Baroscopic Inspection

4.4.6 Monitoring Techniques

Monitoring system feeds us with a critical data of a system. In the boiler there are quite number of critical part to monitor such as water level, economizer, superheater and reheater temperature etc as such part can be easily damaged or cause severe damages to surroundings if it fails. Futhermore, this monitoring method reduces boiler downtime and also expense that could occur if the parts fails.

4.4.6.1 Temperature Monitoring

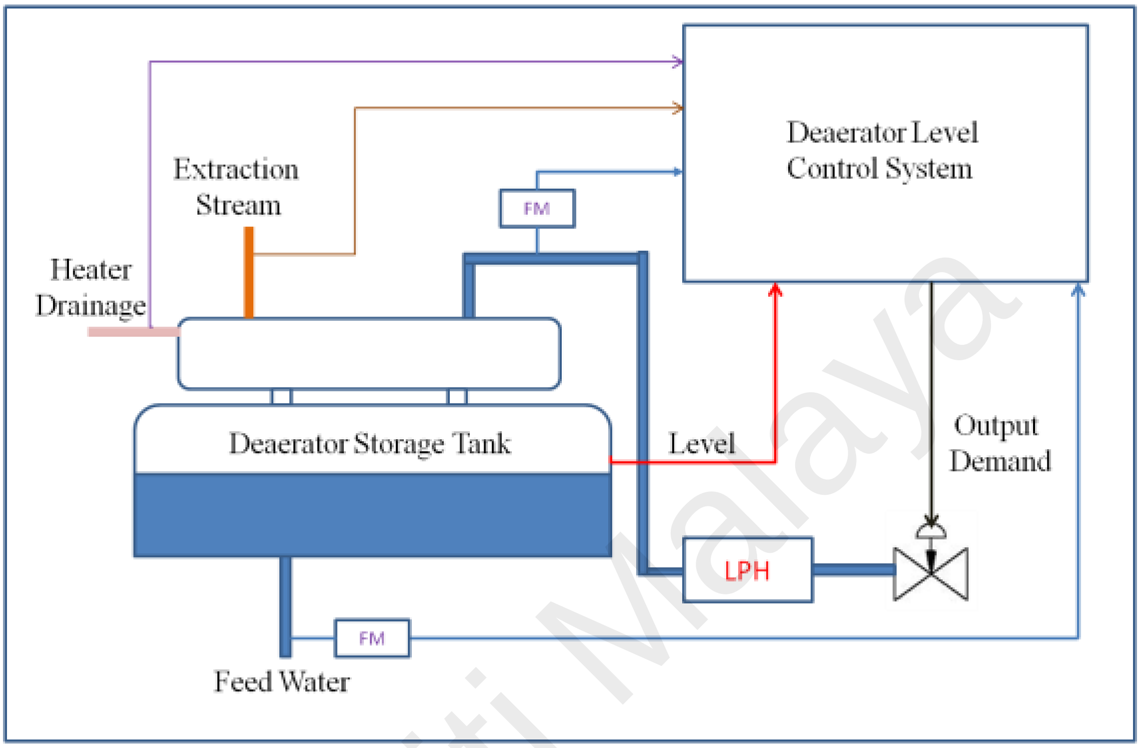
Temperature monitoring system is a must to detect temperature excursion. As such system enables us to know temperature reading which out of range. This data can be savior for boilers as such temperature can do great damage to the boiler and things or human around it.

4.4.6.2 Chemical Parameters Monitoring

Monitoring chemical parameter are very important because the water and steam pH need to be maintained for optimum function of the boiler. Example of chemicals are dissolved oxygen in deaerator , ammonia in water and phosphate in boiler drum.

4.4.6.3 Oxygen Dissolved In Condenser/Deaerator

Oxygen dissolved in the deaerator/condenser need to be regularly checked and maintain within limits as the reduction of oxygen level lower the corrosive action. Failures on



attachment or weld joint can be controlled or lowered by maintaining low oxygen in deaerator.

Figure 4.7: Deaerator System

4.4.6.4 Install ASLD (Acoustic Steam Leak Detection)

ASLD detects sound waves from steam leaks and processes indicating the leaks and together the location. The reason why implementing ASLD will be an efficient method for maintaining the boiler is because the conventional method for boiler tube leaks are through human ears and such method will increases the chances of secondary damages to boiler due to delayed action.

4.4.7 Boiler Storage Type

A good water treatment method might keep the boiler out of dissolved oxygen when in a normal operation, but when the boiler is put into idle offline and cool down for long period, oxygen can easily produce pitting in tube sheets and boiler tubes in a very short time and start corroding the tubes. This can cause costly tube replacement when starting it back after extended period.

There are primarily two types of storage methods to store the boiler when not in operation which are Dry Storage & Wet Storage. The important requirement in choosing the right storage depends: -

1. Boiler Capacity
2. Boiler Type
3. Period of offline
4. Temperature of boiler when not in operation
5. Resources needed to refill boiler with treated water and monitor the boiler.

4.4.7.1 Dry Storage / Dry lay-up

Dry storage can be used when the boiler is out of service for long period and situated in a place where temperature might hit freezing point.

4.4.7.2 Wet Storage / Wet lay-up

Wet storage can be used if there boiler is taken out of operation completely. Wet storage is necessary and useful when the standby boiler need go back in operation at short notice or dry storage is not possible to implement.

CHAPTER 5: CONCLUSION & FUTURE WORK

5.1 Overview

This chapter summarize the findings and technique, which can be implemented to increase the longevity of superheater together with industrial boiler.

5.2 Conclusion

The nature of superheater tube failure identification & prevention method are discussed. Type of maintenance of an industrial boiler which can increase the longevity of the boiler and its parts could be explored and implemented.

By knowing and together with understanding the nature of failure that might cause failure to certain critical part of the boiler, the maintenance team or engineering team can organize and utilized the maintenance program in extent where critical failures can be prevented.

Preventing superheater failure is not an easy task, but using the necessary method available, the longevity of the superheater tube can prolonged. By using the desuperheater we can control the steam temperature within the tube and this allows us to actual maintain the temperature of the tube in a uniform level so that it does not affect the tube. The usage of proper safety valve setting allows the superheater tube for undergoing starvation. Also increased blowdown and usage of anti-foaming material decrease the boiler deposit entering the superheater tube. Superheater design plays an important role as the specified heat transfer can only be fully optimized if the design requirement is taken into consideration.

The various kind of method and technique, which an organization can adapt to maintain their boiler system. Most inspection are based on ultrasonic technique because inside boiler mostly categorized under confined space and tube wall or tubes can’t be welded out for testing or analyzing, so ultrasonic method provide a brief and efficient way of providing necessary data to know the boiler condition.

Type of storage provided by an organization for their boiler when its not in the operating condition actually play a vital role in longevity of the boiler. Since difference type of storage, such dry or wet or nitrogen filled needed for different type of environment and conditions. If this storage type utilized properly can increase the life expectancy of boiler.

5.3 Future Work

Mitigation method for other critical parts of the boiler can be studied and failure mode effect analysis (FMEA) can be created of any defect or tube failure in the boiler, so that a better preventive method can be structured.

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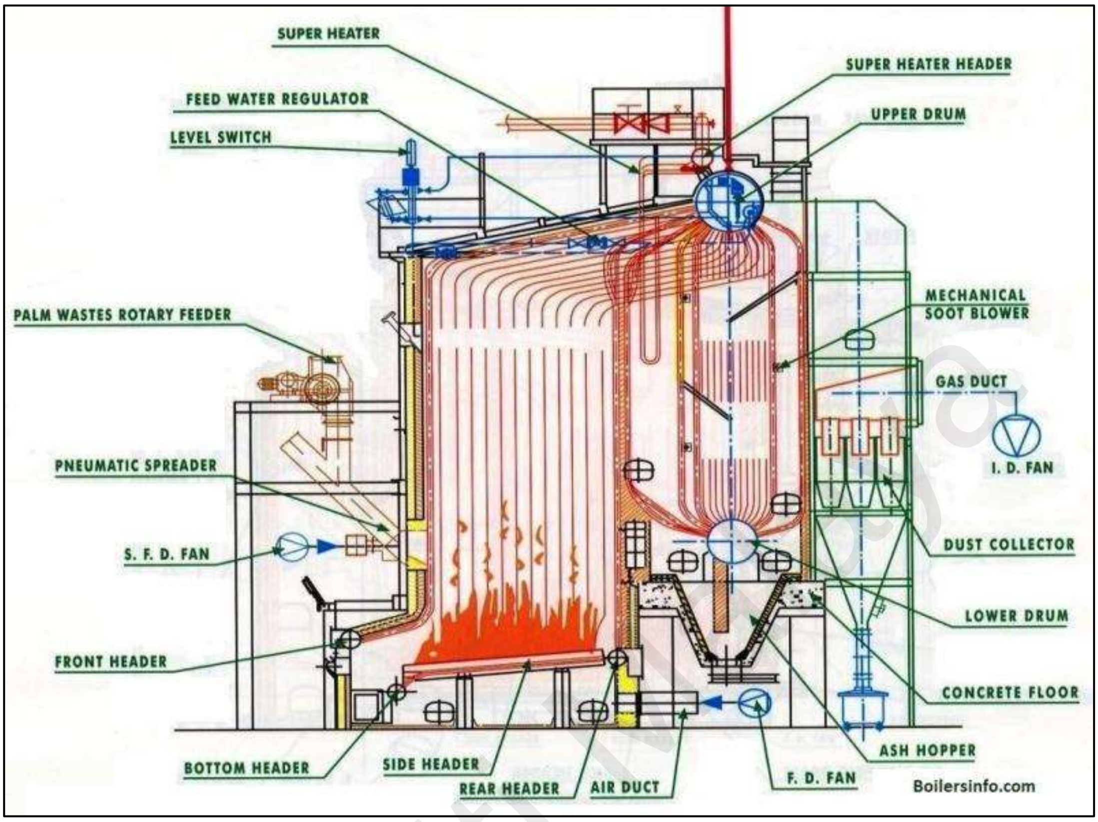
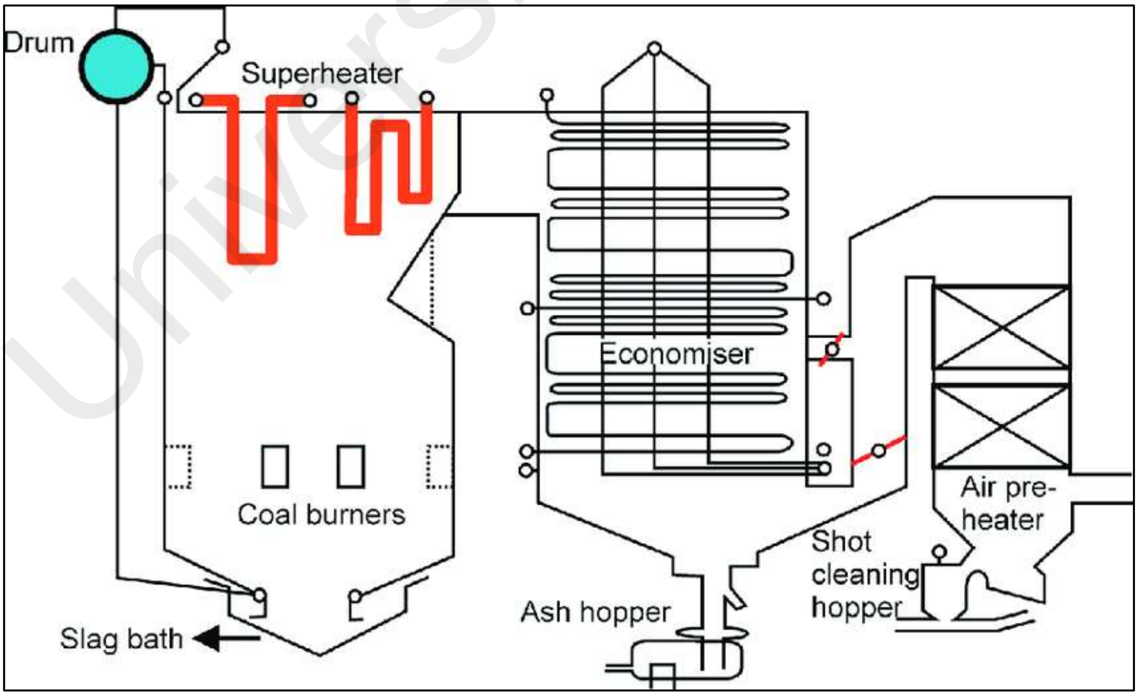
APPENDIX A



Appendix 1.1: Water-Tube-Boiler



Appendix 1.2: Superheater