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Design and Analysis of Material for the Pipeline between Power Plant Accessories

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ABSTRACT: Generally power plant consists of various parts such as boiler, super heater, economiser, turbine etc. and there is a pipeline to connect these parts. For example the working temperature and pressure of economiser is less, but for the superheater it is extremely high. So the pipeline between these parts plays a vital role for the power generation i.e. it should carry the pressure difference otherwise it will explode. Our project focus on the design of this pipeline. This pipeline consists of elbow, endcap and stub. In our project as per the need of the customer requirement we are going to design these parameters by using two materials such as carbon steel and stainless steel with their corresponding grades. The design is based on ASME B 31.1, power piping 2012 Edition.

I. INTRODUCTION

A **power plant** or a **power generating station**, is basically an industrial location that is utilized for the generation and distribution of electric power in mass scale, usually in the order of several 1000 Watts. These are generally located at the sub-urban regions or several kilometres away from the cities or the load centres, because of its requisites like huge land and water demand, along with several operating constraints like the waste disposal etc. The all power generating stations has an A.C. generator or an alternator, which is basically a rotating machine that is equipped to convert energy from the mechanical domain (rotating turbine) into electrical domain by creating relative motion between a magnetic field and the conductors.

1.1 TYPES OF POWER STATION

The types of power station are ,

- 1 . Thermal power station
2. Nuclear power station
3. Hydro-electric power station

1.1.1 THERMAL POWER STATION

A thermal power station or a coal fired thermal power plant is by far, the most conventional method of generating electric power with reasonably high efficiency. It uses coal as the primary fuel to boil the water available to superheated steam for driving the steam turbine. The steam turbine is then mechanically coupled to an alternator rotor, the rotation of which results in the generation of electric power. Generally in India, bituminous coal or brown coal are used as fuel of boiler which has volatile content ranging from 8 to 33 % and ash content 5 to 16 %.

1.1.2 NUCLEAR POWER STATION

For the process of nuclear power generation, the radioactive fuels are made to undergo fission reaction within the nuclear reactors. The fission reaction, propagates like a controlled chain reaction and is accompanied by unprecedented amount of energy produced, which is manifested in the form of heat. This heat is then transferred to the water present in the heat exchanger tubes. As a result, super-heated steam at very high temperature is produced. **HYDRO-ELECTRIC POWER STATION**

In Hydro-electric plants the energy of the falling water is utilized to drive the turbine which in turn runs the generator to produce electricity. Rain falling upon the earth's surface has potential energy relative to the oceans towards which it flows.

$$P = \rho g Q H$$

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Where g = acceleration due to gravity = 9.81 m/sec^2
 ρ = density of water = 1000 kg/m^3
 H = height of fall of water.

THERMAL POWER PLANT

The coal which you use in your backyard for barbeque performs much more important functions such as generating electricity for us in thermal power plants. Learn about the layout of these plants in this article.

LAYOUT OF THERMAL POWER PLANT

There are four main circuits in any thermal power plant and these are ,

1. Air & Gas Circuit – we know that air is one of the main components of the fire triangle and hence necessary for combustion. Since lots of coal is burnt
2. inside the boiler it needs a sufficient quantity of air which is supplied using either forced draught or induced draught fans. The exhaust gases from the combustion are in turn used to heat the ingoing air through a heat exchanger before being let off in the atmosphere.
3. The equipment which handles all these processes fall under this circuit.
4. Feed Water & Steam Circuit – this section deals with supplying of steam generated from the boiler to the turbines and to handle the outgoing steam from the turbine by cooling it to form water in the condenser so that it can be reused in the boiler plus making good any losses due to evaporation etc.
5. Cooling Water Circuit – this part of the thermal power plant deals with handling of the cooling water required in the system. Since the amount of water required to cool the outgoing steam from the boiler is substantial, it is either taken from a nearby water source such as a river, or it is done through evaporation if the quantity of cooling water available is limited.

GENERATOR

An alternator is an electromechanical device that converts mechanical energy to alternating current electrical energy. Most alternators use a rotating magnetic field. Different geometries - such as a linear alternator for use with stirring engines - are also occasionally used. In principle, any AC generator can be called an alternator, but usually the word refers to small rotating machines driven by automotive and other internal combustion engines.

TRANSFORMER

It is a device that transfers electric energy from one alternating-current circuit to one or more other circuits, either increasing (stepping up) or reducing (stepping down) the voltage.

Uses for transformers include reducing the line voltage to operate low-voltage devices (doorbells or toy electric trains) and raising the voltage from electric generators so that electric power can be transmitted over long distances. Transformers act through electromagnetic induction; current in the primary coil induces current in the secondary coil. The secondary voltage is calculated by multiplying the primary voltage by the ratio of the number of turns in the secondary coil to that in the primary. A turbine is supplied with superheated steam at 90 bar a/450°C. The exhaust is at 0.06 bar a (partial vacuum) and 10% wet. Saturated temperature = 36.2°C.

II. LITERATURE REVIEW

X. Ying-Bai ; W. Shao-Hung ; L. Bing ; L. Yun Pipelines for the main steam, hot sections of the reheat steam, cold sections of the reheat steam and the high pressure feed water are main constitutes of the power plant boiler. Material selection of the four main pipelines will have significant impact on the security and economy of the power plant operation. The pressure of the main steam of the 1000MW ultra supercritical unit in Tianjin SDIC Jinneng Electric Power CO.LTD is 27.56 MPa, and the temperature of the main steam is 605°C. It brings forward the high requirement of the mechanical characteristic and high temperature performance of the four main pipelines. Demonstration is processed considering the thermal stress, coefficient of the heat expansion, operation reliability and the economy, and the compositions of the four main pipeline material are selected. **CHI Chengyu, YU Hongyao, XIE**

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Xishan 700°C level Advanced Ultra-Super Critical (A-USC) technology with high thermal efficiency is a focus on clean coal-fired power generation technology, it will be developed in the future to reduce coal consumption and pollution emissions. Several countries including China have started 700°C A-USC relative research projects. This paper introduces current development status of 700°C A-USC power plants and materials for high temperature components in units in the world. The research development of nine candidate superalloys including Inconel 740/740H, Inconel 617, Nimonic 263, HR6W, GH2984 etc. For high temperature components superheater/reheater and main pipes in 700°C A-USC boilers are analyzed in terms of chemical compositions, microstructures after long term aging, mechanical properties and process performance. The results show that Inconel 740H which developed from Inconel 740 alloy by chemical composition adjustment characterizes with the best comprehensive properties can be considered as the first choice material for high temperature components superheater/reheater tubes in units. **H. Fujikawa, H. Makiura** Austenitic stainless steel tubes of AISI 304, 316, 321, and 347 types are sometimes exposed to severe hot corrosion environments in superheaters and reheaters of utility boilers. Hot corrosion depends on the existence of V₂O₅ and Na₂SO₄ in the oil-fired boilers, and of Na₂SO₄ and K₂SO₄ in the coal-fired boilers. Among various kinds of ash corrosions, the alkali sulphate side corrosion has been mainly studied. Type 347 steel showed better resistance to the alkali sulphate side corrosion than three other conventional 18Cr-10Ni stainless steels (304, 316, and 321 steels). Alloying with Nb was more effective than with Mo or Ti. It was detected that a (Cr, Fe, Ni)-spinel oxide layer with little ash content formed at the scale-metal interface in 347 steel, while such an oxide layer did not form on the other steels. In field tests, 347 steel tubes have maintained good resistance to both the fire-side and the steam-side corrosions for five years. However, 321 steel tubes were removed after three years of service, because of severe fire-side corrosion. **I. G. Wright and A. J. Minchener** The application of advanced coal-fired heaters to heat the working fluid for a closed-cycle gas turbine provides some challenging problems for the selection of metallic heat exchanger materials. The requirements of a working fluid temperature of 1550°F (1116 K) at a pressure of 300–600 psig (2.07–4.14 MPa/m²) necessitate that the alloys used for the hottest part of the heat exchanger possess high-temperature strength in excess of that available in widely used alloys like alloy 800. The maximum-duty alloys must therefore be selected from a group of essentially nickel-base alloys for which there is scant information on long-term strength or corrosion resistance properties. The susceptibility to corrosion of a series of candidate heat exchanger alloys has been examined in a pilot plant size fluidized-bed combustor. The observed corrosion behavior confirmed that at certain locations in a fluidized-bed combustor nickel-base alloys are susceptible in varying degrees to rapid sulfidation attack, and must be protected by coating or cladding. **Paul Wilhelm, Paul Steinmann and Jürgen Rudolph** A statistical model for austenitic stainless steels (SSs) for predicting the effect of boiling water reactor (BWR) environments on fatigue life for a range of temperatures and strain rates is developed based on the analysis of available material data from Europe, U.S., and Japan. Only fatigue data from polished specimens of wrought material tested under strain control were considered. Hollow specimens were not treated in the final calculations. The fatigue-life correction factors were defined as the ratio of life in water at 240 °C (464 °F) (reference conditions) to that in water at service conditions. The model is recommended for predicting fatigue lives that are 102–104 cycles. **E. C. Chapman and R. E. Lorentz, Jr.** The Eddystone supercritical boiler, designed to operate at a maximum pressure of 5000 psig and 1200-F temperature, required the use of new high-temperature materials in tubes and stop valves in order to avoid excessive wall thicknesses. None of the materials approved by the ASME Boiler and Pressure Vessel Code for superheater service had the required properties. The present paper describes the high-temperature tests carried out and the welding development which led to the selection of the new materials. The properties of these new materials are discussed. Design features and fabricating procedures for the tubes and valves are presented.

PROBLEM IDENTIFICATION

The determination of optimal cutting condition for specified surface roughness and accuracy of product are the key factors in the selection of machining process. In drilling operations, and especially boring operations, are associated with serious vibration-related problems. To reduce the problem of vibration and ensure that the desired shape and tolerance are achieved, extra care must be taken with production planning and in the preparations for the machining of a work-piece.

Through this investigation of the vibrations involved is therefore an important step toward solving the problem. Researches have been done to improve cutting tool material, tool geometry and cutting parameter to optimize

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the machining process. The diameter and length of boring bar are the most important factor has to be considering in boring operation, following the other cutting parameter such as spindle speed, feed rate and peck increment.

III. METHODOLOGY

MATERIAL SELECTION - STAINLESS STEEL AND CARBON STEEL

The stainless steel does not corrode, rust or stain with water as ordinary steel do. It is not fully stain proof of low oxygen in high environment. They are different grades and surface finish of stainless steel is suit to both properties of corrosion resistance are required.

The carbon steel in which carbon range is 0.12 – 2.0 %.The specified minimum copper does not exceed 0.40 %. In carbon steel may include alloy steel. The carbon percentage rises they become harder and stronger through heat treating.

3.2 COMPOSITION OF STANLESS AND CARBON STEEL

Table 3.1 Chemical composition

Specification	Chemicals	Composition in percentage
SA 672 Gr. B 60 CL 32	Carbon	0.24 %
	Silicon	0.13 – 0.45 %
	Manganese	0.98 %
	Phosporous	0.035 %
	Sulfur	-

3.3 MECHANICAL PROPERTIES OF STAINLESS AND CARBON STEEL

Table 3.2 Mechanical properties

Product	Properties	Specification
SA 672 Gr. B 60 CL 32	Yield strength	220N/mm ²
	Tensile strength	415 – 550 N/mm ²
	Elongation	0.25 %

3.4COMPOSITION OF STANLESS AND CARBON STEEL

Table 3.3 Chemical composition

Specification	Chemicals	Composition in percentage
	Carbon	0.30 %
	Silicon	0.10 %

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SA 106 Gr . B	Manganese	0.29 – 1.06 %
	Phosphorous	0.035 %
	Sulfur	0.035 %

3.5 MECHANICAL PROPERTIES OF STAINLESS AND CARBON STEEL

Table 3.4 Mechanical properties

Product	Properties	Specification
SA 106 Gr . B	Yield strength	240N/mm ²
	Tensile strength	415 N/mm ²

3.6 COMPOSITION OF STANLESS AND CARBON STEEL

Table 3.5 Chemical composition

Specification	Chemicals	Composition in percentage
SA 234 WPB	Carbon	0.30 %
	Silicon	0.10 %
	Manganese	0.29 – 1.06 %
	Phosphorous	0.05 %
	Sulfur	0.058 %

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3.7 MECHANICAL PROPERTIES OF STAINLESS AND CARBON STEEL

Table 3.6 Mechanical properties

Product	Properties	Specification
SA 234 WPB	Yield strength	240N/mm ²
	Tensile strength	415 - 585N/mm ²

IV. DESIGN PROCEDURE AND CALCULATION

4.1 SELECTION OF VARIOUS DATA OF STRESS CALCULATION

Table 4.1 List of Drawings Prepared

S.no	Description	Drawing Number
1	PIPE LINES	Identification number as per customer requirements.
2	ELBOW	
3	END CAP	

List of standard / codes

1. ASME B 31.1, power piping 2012 Edition
2. ASME B 36.10 M, power piping 2004 Edition
3. ASME B 16.9, power piping 2007 Edition
4. ASME B 16.11, power piping 2011 Edition
5. ASME B 16.5, power piping 2009 Edition
6. ASME SECTION II, PART A, 2013 Edition
7. ASME SECTION II, PART D, 2013 Edition

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8. ASME SECTION I, 2013 Edition

Table 4.2 DESIGN DATA

Design & Construction code	:	ASME B31.1 ,Power piping 2012 Edition.
Piping Ref.	:	PIPE
Drawing No.	:	IDENTIFICATION NO AS PER CUSTOMER REQUIREMENTS
Fluid Handled	:	Saturated Steam
Design parameters		
Maximum allowable working Pressure	:	-0.023 MPa(g) = -0.230 kg/cm ² (g)
	:	0.0794 MPa(a) = 0.810 kg/cm ² (a)
Design Pressure	:	-0.023 MPa(g) = -0.230kg/cm ² (g)
	:	0.0794 MPa(a) = 0.810 kg/cm ² (a)
Design Temperature	:	93.28 °C / 200°F
Corrosion Allowance	:	1.6 mm
Radiography	:	NIL
Post Weld Heat Treatment	:	As per code

Table 4.3 HYDRO STATIC TEST PRESSURE

Design pressure – P	:	-0.023	0.0794 Mpa(a)
Hydro test pressure = 1.5 P	:	0.0345 Mpa (g)	0.1191 Mpa(a)

**Table 4.4 PIPES/FITTING SIZES & MATERIAL
PECIFICATION**

A.PIPES

Sl. No.	Description	Design Parameters		Temp. °F	Material Specification	Matl P.No	Size	
		Internal Pressure Mpa (a)	External Pressure Mpa				DN x Sch No.	OD X Thk mm x mm
1	Pipe	-	0.023	200	SA 672 Gr.B60 CL32	1	711.2 x 6.35 THK	711.2 X 6.35
2	Pipe	-	0.023	200	SA 106 Gr.B	1	400 x SCH.10	406.4 x 6.35
3	Stub	-	0.023	200	SA 106 Gr.B	1	100 x Sch.40	114.3x 6.02

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B .BUTT WELDED FITTING

Sl. No.	Description	Design Parameters		Temp. °F	Material Specification	Matl P.No	Size	
		Internal Pressure Mpa (a)	External Pressure Mpa				DN x Sch No.	OD X Thk mm x mm
1	Elbow (90° LR)	-	0.023	200	SA 672 Gr.B60 CL32	1	711.2 x 6.35 THK	711.2 X 6.35
2	End Cap	-	0.023	200	SA 234 WPB	1	100 x SCH.40	114.3 x 6.02
3	End Cap	-	0.023	200	SA 234 WPB	1	700 x SCH.10	711.2 x 7.92

Table 4.5 ALLOWABLE STRESS

Material Specification	Design Temp. °F	Yield strength at Room Temp		Allowable stresses at design Temp.	
		Psi	MPa	psi	MPa
SA 672 Gr.B60 CL32	200	32000	220.60	15400	106.18
SA 106 Gr.B	200	35000	241.32	17100	117.90
SA 234 WPB	200	35000	241.32	17100	117.90

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Table 4.6 RADIOGRAPHIC OR ULTRASONIC EXAMINATION OF WELD

		Applicability	Requirement
	Piping design conditions fall under "All Others Category"		
1	<u>For Butt welds</u>		
a)	RT or UT for over NPS 2 with thickness over 3/4" (19 mm)	Not Applicable	Not Required
b)	VT for all sizes with thickness 3/4" (19 mm) or less	Applicable	Required
02)	For welded branch connection		
a)	RT or UT for Branches over NPS 4 and thickness of branch over 3/4" (19 mm)	Not Applicable	Not Required
b)	MT or PT for Branches NPS 4 and less with thickness of branch over 3/4" (19 mm)	Not Applicable	Not Required
c)	VT for all sizes with branch thickness 3/4" (19 mm) or less	Applicable	Required
03)	Fillet, socket, attachment and seal welds		
a)	VT for all sizes and thicknesses	Applicable	Required

Table 4.7 HEAT TREATMENT

8A. Post weld heat treatment			
	Description	Applicability	Requirement
	PWHT is not mandatory when all the following conditions are met.		
i)	Nominal thickness < 3/4" (19 mm).	Not Applicable	PWHT Not Required.
ii)	Minimum preheat of 200°F is applied when the thickness of base metal exceeds 1" (25 mm)	Not Applicable	
8B. Preheating			
i)	Preheat temp of 175 °F applicable if carbon content > 0.3 % and thickness at the joint > 1" (25.0 mm).	Not Applicable	PWHT Not Reqd
ii)	Min. preheat for all other materials shall be 50° F.	Applicable	Required

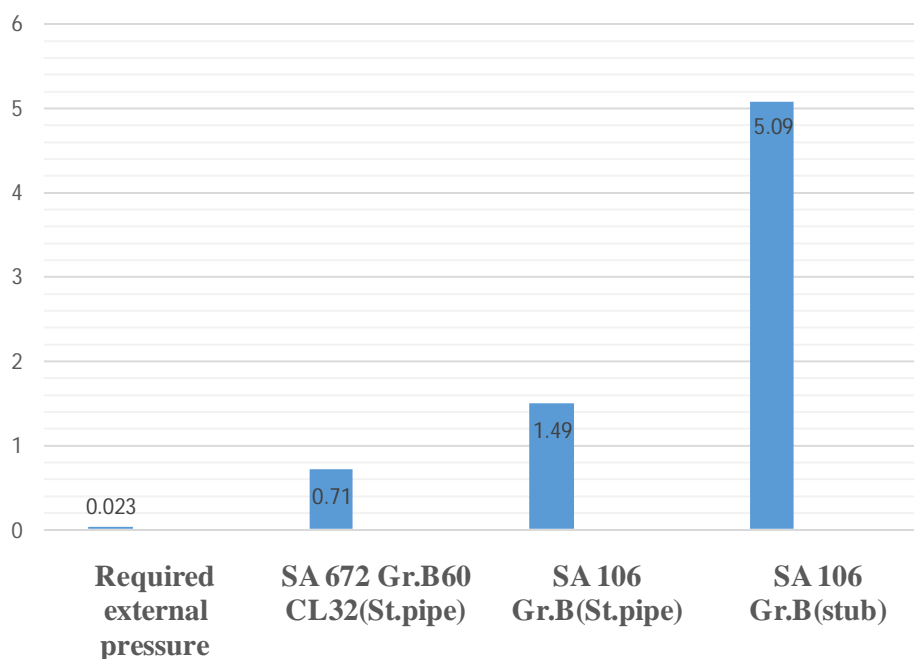
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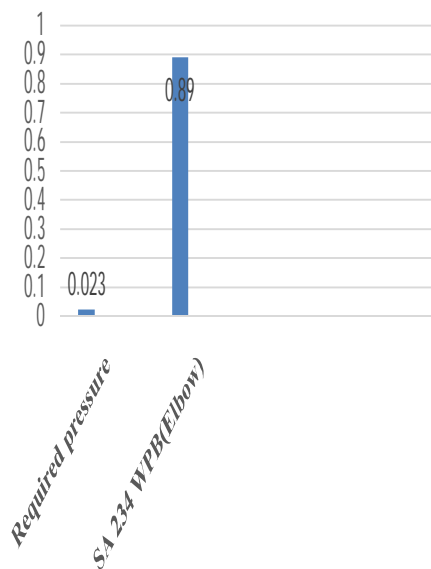
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V. RESULT AND DISCUSSION

1 COMPARISON OF REQUIRED PRESSURE AND CALCULATED PRESSURE FOR PIPES AND STUB



5.2 COMPARISON OF REQUIRED PRESSURE AND CALCULATED PRESSURE FOR ELBOW



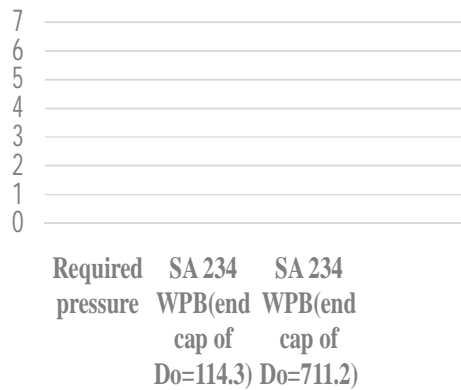
Graph 5.2 Required pressure vs calculated pressure of elbow

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COMPARISON OF REQUIRED PRESSURE AND CALCULATED PRESSURE FOR ENDCAPS



Graph 5.3 Required pressure vs calculated pressure of end caps

The above graphs shows that the comparison of required pressure and calculated design pressure. The calculated pressure should be greater or similar to the required pressure for the better effective piping design. In our project, all the pipe fitting's are calculated pressure value is higher than the required pressure. So the piping design is safe and satisfactory one to the customer.

VI. CONCLUSION

Now a days , Boiler pipe lines are essentially monitoring due to the explosion . ASME/IBR regulation are used to avoid that problems. So economically and efficiently obtained the output without any harm . It is majorly consider as a safety. By using these two materials finally we made the design which is enough to withstand the pressure and temperature differences to avoid explosion during the power generation.

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