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# OPTIMIZATION OF STEAM SYSTEM

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***Abstract*** — *With the shortage of conventional energy sources, efforts have been sought to use energy in a rational manner. Whereas the biggest energy consumption is in the industrial sector, various techniques to reduce energy have been searched. . In industry where steam is utilized, the steam production and distribution system consumes a significant portion of energy. Optimization of steam system is the biggest energy saving potential in industry. The steam system should be year after year to identify more energy wastes and to improve efficiency of steam system and reducing the energy cost. At same time this will also help save the environment.*

***Keywords- Design of steam pipes, steam nozzles, desuperheater, steam silencer, flow nozzles***

## I. INTRODUCTION

This project is about designing various equipments that are necessary for proper functioning of the steam system. A steam system should have a desuperheater to increase the degree of desuperheat of the steam required at the low pressure side of the gland sealing, a safety valve that can release the steam if working pressure increases than the set pressure and a flow nozzle at appropriate position to measure the mass flow of the steam.

## II. MAIN WORK

### 2.1 Design of steam piping

The basic concept of a piping design is to safely and economically transport steam, brine, or two- phase flow to the destination with acceptable pressure loss. The piping associated with plant can be divided in piping inside the plant and the piping in the steam field. Factors needed to be considered for water pipe design are scrubbing the water, velocity of water, corrosion allowances, pressure drop, pressure and temperature.

**2.1.1. Structural Analysis.** Circumferential stress or Hoop stress due to pressure and vacuum is considered for sizing and selecting the pipe with suitable wall thickness.

Equations for pipe stress analysis are given in the design code. The first step is the determination of wall thickness required by ASME B31.1 (Power Piping):

$$T_m = \frac{PD_o}{2(\sigma + Py)} + A$$

Where, Tm = Wall thickness in millimeters;

P = Design pressure in kilopascals;

$D_o$ = Pipe outside diameter in millimeters;

σ = Allowable stress in kilopascals;

y = 0.4, for most geothermal application it based on temperature range and steel type;

A = 1 mm corrosion and erosion allowance.

Stress analysis should be carried out for the following load cases for compliance with the code requirement and support load calculation. ASME B31.1 POWER PIPING requires that a pipeline shall be analyzed between anchors for the effects of:

1. Sustained loads, Gravity + Pressure;
2. Operation loads, thermal expansion stress alone or thermal expansion stress + sustained loads;
3. Occasional loads, sustained loads + seismic load or wind load perpendicular to the general alignment of the pipe;
4. Occasional loads, sustained loads + seismic loads along the general direction of the pipe;
5. Reverse the direction of seismic or wind loads;
6. Modes of thermal operation need to be considered in the analysis.

**2.1.2. PROPOSED MATERIAL.** ASTM A335 P91

| Compositions | Data |
|---|---|
| UNS Designation | K91560 |
| Carbon(max.) | 0.08-0.12 |
| Manganese | 0.30-0.60 |
| Phosphorus(max.) | 0.025 |
| Silicon(max.) | 0.50 |
| Chromium | 4.00-6.00 |
| Molybdenum | 0.45-0.65 |

| Properties | Data |
|---|---|
| Tensile strength, min, (MPa) | 415 Mpa |
| Yield strength, min, (MPa) | 205 Mpa |
| Elongation, min, (%), L/T | 30/20 |

***Table 1. Mechanical properties of ASTM A335 P91 and chemical composition.***

## 2.2 Safety valve

According to ASME standards Safety valves are defined as the pressure relief valves actuated by inlet static pressure and characterized by rapid opening or pop action. The essential first function of a safety valve is to protect life and property. In steam systems, safety valves are typically used for boiler overpressure protection and other applications such as downstream of pressure reducing controls. The essential role for safety valves are also used in process operations to prevent product damage due to excess pressure.

### 2.2.1. Design of safety valves.

Area, A= $\frac{100*E}{C*(P+1.013)}*F$

Actual relief capacity E = $\frac{C*(P+1.013)}{100*F}*A'$

Where, F=force on nozzle
P= pressure of steam
C= velocity of steam

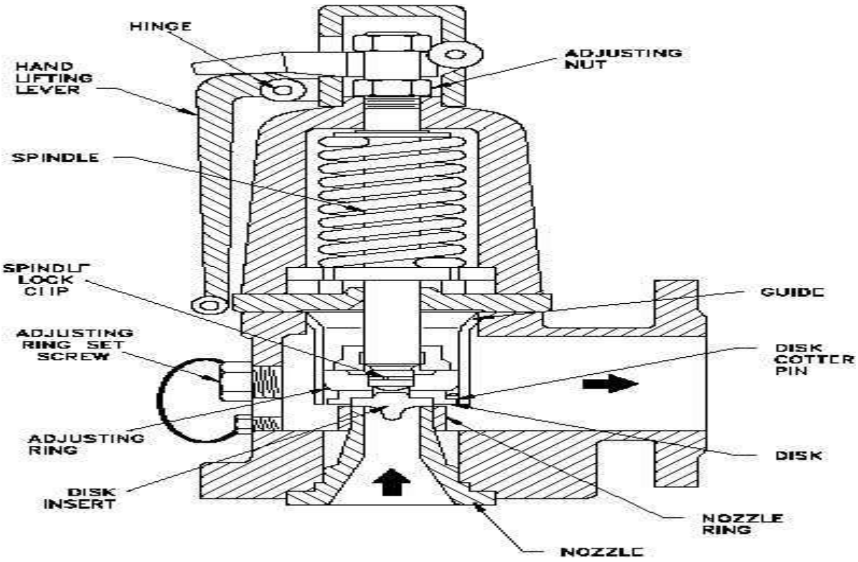


*Fig.1. safety relief valve*

**2.2.2. Design material for safety relief valve.**

| COMPONENT | MATERIAL |
|---|---|
| **SPRING** | 302 STAINLESS STEEL |
| **NOZZLE** | AISI 316 |
| **BODY** | SA216GrWCC |
| **LEVER** | CARBON STEEL |

*Table.2.Proposed material for safety valve*

| COMPONENT | MATERIAL |
|---|---|
| **SPRING** | ALLOY STEEL |
| **NOZZLE** | AISI 304 |
| **BODY** | SA216GrWBC |
| **LEVER** | CS |

*Table.3.Existing material for safety valve*

**2.3 Steam silencer**

A silencer is a device used to reduce unwanted noise created by gas or steam flow in a pipeline discharging directly into the atmosphere. The silencer is installed either within the stack or at the stack outlet to intercept this noise before it escapes into the environment.

*Fig.2. steam silencer*

**2.3.1.Design of steam silencer.**

Calculate the critical velocity i.e. sonic velocity, $V_s = \sqrt{kRT}$

Calculate velocity of steam in pipe, $V = \frac{m}{\rho A}$

Calculate the Reynolds number, Re in the pipe, $Re = \frac{\rho V D}{\mu}$

Calculate Darcy coefficient, $f = \frac{0.316}{Re^{0.25}}$

Calculate the pressure drop due to friction, $h = \frac{f l V^2}{2gD}$

Calculate $K_{required}$ that is the sum of all pressure drops including $\Delta P$.
$K_{required} = h + \Delta P$

Calculate K of the orifice, $K_{orifice} = \frac{1-\beta^2}{C^2 \beta^4}$

Calculate the speed in the orifices to determine if sonic speed is reached.
Velocity through each orifice, $V_o = q/A_o$

**2.3.2. Design material for steam silencer.**

| Component | Materials |
|---|---|
| **Main steam pipe** | ASTM A335 P91 |
| **Silencer pipe** | SA216GrWCC |
| **Pipe elbow** | SA 403 M |
| **Orifice plate** | *JIS G4304 SUS316J1L* |
| **Expansion pipe** | SA216GrWCC |
| **Operating valve** | A182Gr F5a 1500# |

*Table.4.proposed material for steam silencer*

| Component | Materials |
|---|---|
| Main steam pipe | 150NB SA335Grp22 Sch40 |
| Silencer pipe | SA515Gr70 |
| Pipe elbow | SA234WP304H |
| Orifice plate | SA240Gr304 |
| Expansion pipe | SA515Gr70 |
| Operating valve | SA182Gr22 1500# |

***Table.5. existing material for steam silencer***

### 2.4. Desuperheater

Desuperheating is the process of reduction of temperature in steam line through the direct contact and evaporating of water within the steam flow stream. The principle function of Desuperheater is to accelerate the phenomenon of absorption of the spray water by the steam so that steady conditions of steam temperature are reached within a short distance from the outlet.

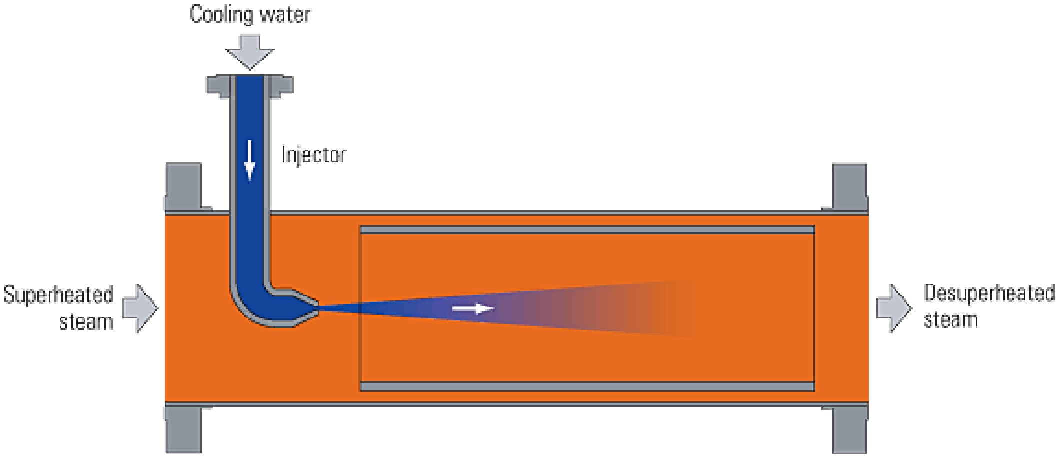


***Fig.3. desuperheater***

#### 2.4.1. Design Material for Desuperheater.

| Components | Material |
|---|---|
| **Cooling water pipe** | ASTM A335 P11 |
| **Flange** | ASTM A105N |
| **Spray nozzle** | ASTM 316 |
| **Nozzle holder** | ASTM A182 F11 |
| **Thermal sleeve** | ASTM 312TP304 |

***Table.6. proposed material for desuperheater***

| Components | Material |
|---|---|
| **Cooling water pipe** | 106GrB |
| **Flange** | SA105 |
| **Spray nozzle** | 304STELLITED |
| **Nozzle holder** | SA106GrB |
| **Thermal sleeve** | SA312TP304 |

***Table.7. existing material for desuperheater***

### 2.5. Flow nozzles

Flow nozzle is used to measure the flow rate of the steam system. The flow nozzles create an intentional pressure drop, ΔP for calculating the flow rate. The flow of any compressible fluid neglecting the velocity approach factor is given by the following equation.

$$Q = YC_d A\sqrt{\frac{2\Delta P}{\rho}}$$

#### 2.5.1. Design material for flow nozzle.

| Component | Material |
|---|---|
| **Nozzle** | ASTM 316 |
| **Nozzle ring** | SS312 |

***Table.8. Proposed material for flow nozzle***

| Component | Material |
|---|---|
| **Nozzle** | SS304STELLITED |
| **Nozzle ring** | SS312 |

***Table.9. Existing material for flow nozzle***

## III. CONCLUSION

**Hence from the above experiment and by changing the various grades of materials in various steam system equipments we found the steam system to be more efficient by using the proposed grades of materials. And also there is minor cost difference between the both grade of materials, as the materials proposed are having minor cost reduction also. Therefore from the whole experiment and related calculations, it can be concluded that by using the following proposals in steam systems there would be a lot savings in steam loss, heat losses can be minimized and a new far more efficiently optimized steam system can be proposed.**

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