

Design and Analysis of Start-up System in Supercritical Boiler

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ABSTRACT: In this work, flexibility analysis of Start-up system is done by CAESAR II to prevent premature failure of piping and piping components and ensure that piping stresses are kept within allowable limits. Stress analysis is a critical component of piping design through which important parameters such as piping safety, the safety of related components and connected equipment, and piping deflection can be checked and rectified timely. During the boiler startup and lower load processes, the recirculating pump of the boiler start up system can guarantee the safety of the boiler before the flow rate reaches the Benson point. After this point, the boiler assumes its normal operation, and the startup system is shut down. The piping system in the startup undergoes various stresses due to external force factors, temperature stresses, its self-weight and numerous other factors. Through the flexibility analysis of the piping, the integrity of the piping system and its individual parts can be guaranteed against breakdown.. System operability can be maintained. The piping is well supported and is prevented from sagging and deflecting under its own weight. Deflection under thermal and other loads can be controlled. The loads and moments imposed on the machinery and vessels by the thermal growth of the attached piping are not excessive.

KEYWORDS-CAESAR, Start-up system, Supercritical Boiler

I. INTRODUCTION

The start-up system in super critical boilers is used to protect super-heaters from water carry-over by separating water from steam and re-circulating it through the evaporator surfaces during start-up, low load operation and shutdown of the boiler. The required water flow rate through the evaporator tubes is therefore maintained greater than the evaporation rate to protect them against overheating. The entire system but the furnace connecting sphere and the recirculation mixing sphere, used as intersection points of the piping in the system, can be sized based on the guidelines mentioned in the ASME codes [1]. CAESAR II is a complete pipe stress analysis software program that allows quick and accurate analysis of piping systems subjected to weight, pressure, thermal, seismic and other static and dynamic loads. It can analyze piping systems of any size or complexity. Pipe Design mainly depends upon stress analysis. Process piping and power piping are typically checked by pipe stress engineers to verify that the routing, nozzle loads, hangers, and supports are properly placed and selected such that allowable pipe stress is not exceeded under different loads such as sustained loads, operating loads, pressure testing loads, etc., as stipulated by the ASME B31, EN 13480 or any other applicable codes and standards. Piping System is a network of Pipes by using Pipe Fittings and other special components to perform the required mode of transferring fluids (Liquids/ Gas/ Slurry) from one location to another location. It is the effective method for transferring fluids without considerable or about zero losses in properties and quality of fluid. CAESAR II has unique, incorporating calculation methods and analysis options not found in any other program. It provides for the static and dynamic analysis of piping systems. Calculation capabilities include:

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(An ISO 3297: 2007 Certified Organization)

Vol. 6, Issue 1, January 2017

- i. Fiber reinforced plastic
- ii. Buried piping
- iii. Wind, wave and earthquake loading
- iv. Expansion joints
- v. Valves, flanges and vessel nozzles
- vi. Piping components
- vii. Nozzle flexibilities

II. START-UP SYSTEM

The schematic of the start-up system is shown in the Fig.1 starting from separators extending to the economizer inlet link. Water from the economizer enters the system through risers. It flows through the separators where the hot water is separated from steam and is collected in the collecting vessel. From there water flows through the down comer connecting links, furnace connecting sphere where the outlets from the collecting vessels unite, water down comer to recirculation mixing sphere where the temperature of water is reduced before it enters the recirculation pump, and joins the feed line after the globe check valve.

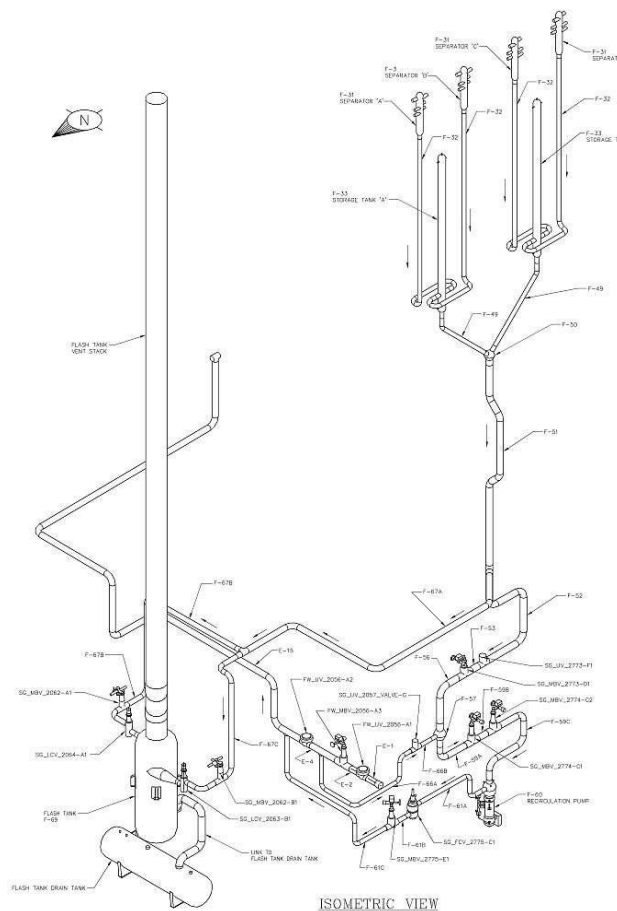


Fig. 1 Start-up system isometric view

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III. FLEXIBILITY ANALYSIS OF THE STARTUP SYSTEM

IV. A. Introduction

Flexibility analysis of the system is performed to obtain the exact displacement, restraint forces, reaction forces and moments acting on to the nozzle of the mixing sphere using the CAESAR [2] pipeline flexibility analysis software. Piping stress analysis is a term applied to calculations, which address the static and dynamic loading resulting from the effects of gravity, temperature changes, internal and external pressures. The purpose of stress analysis is to ensure safety of piping and piping components as well as the safety of connected equipment's and supporting structure. Flexibility as well as stress analysis for this piping system is done through CAESAR II software. Operating loads are calculated using self-weight, operating pressure and temperature for the piping system, Sustained loads are by using self-weight and operating pressure and Expansion loads are due to temperature differences.

B. Modelling

The piping system along with furnace connecting sphere, recirculation mixing sphere, recirculation pump, valves and fittings were modeled in CEASER as shown in Fig. 1. The pipes were modeled as elements with end nodes by specifying the co- ordinates and the direction. The geometric details of the pipes namely diameter and thickness were also given as input. The bends and fittings namely elbow's and Tee's were defined using necessary tools available in CEASER. The spheres, pump and valves were modeled as rigid bodies.

C. Materials

The material properties [3] and the operating conditions, i.e., the internal fluid pressure and the temperature, of each component specified for the supercritical boiler considered are given in Table 1.

Table 1. Material Properties

Item Description	1	2	3
Material	SA106 C	SA335 P12	SA335 P91
Size (D x t) (mm)	508.0x74.6	355.6x52.3	558.8x63.5
Pipe Density (Kg/m ³)	7833.439	7639.624	7693.654
Poisson ratio	0.3	0.31	0.31
Elastic Modulus (MPa)	20339.56	20477.58	21304.99

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(An ISO 3297: 2007 Certified Organization)

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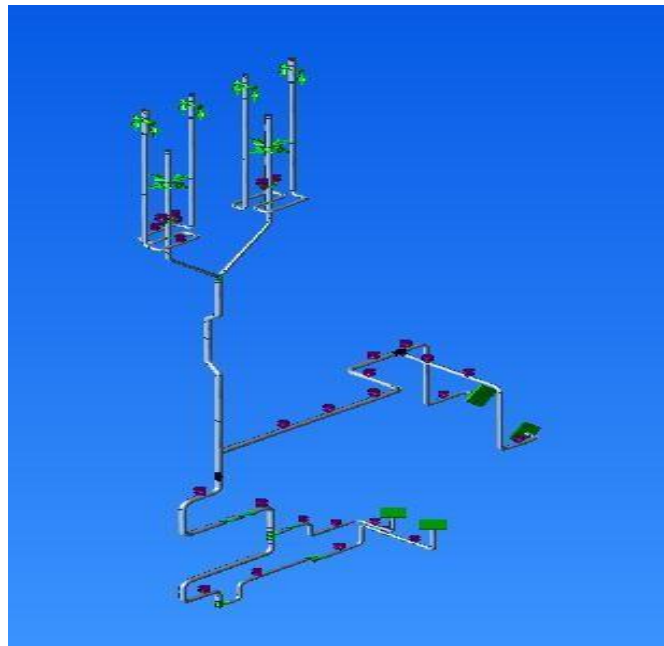


Fig.2 Start-up system CAESAR Model

1: Code compliance for Sustained load case

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1+H

Piping Code: B31.1 -2017, January 16, 2017

*** CODE COMPLIANCE EVALUATION PASSED ***

Highest Stresses: (lb./sq.in.)

CodeStress Ratio is 95.3	at Node 130	LOADCASE: 4 (SUS) W+P1+H
Code Stress: 13576.4	Allowable: 14240.2	
Axial Stress: 6257.6	@Node 470	LOADCASE: 4 (SUS) W+P1+H
Bending Stress: 8549.5	@Node 100	LOADCASE: 4 (SUS) W+P1+H
Torsion Stress: 4012.0	@Node 540	LOADCASE: 4 (SUS) W+P1+H
Hoop Stress: 13772.6	@Node 20	LOADCASE: 4 (SUS) W+P1+H
3D Max Intensity: 20108.4	@Node 20	LOADCASE: 4 (SUS) W+P1+H

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Issue 1, January 2017

2: Code compliance for Expansion load case

LOAD CASE DEFINITION

KEY CASE 5 (EXP) L5=L3-L4

Piping Code: B31.1 -2017, January 16, 2017

*** CODE COMPLIANCE EVALUATION PASSED ***

Highest Stresses: (lb./sq.in.)

CodeStress Ratio is 50.2		at Node 548	LOADCASE: 5 (EXP) L5=L3-L4
Code Stress:	12276.6	Allowable: 24477.3	
Axial Stress:	180.6	@Node 580	LOADCASE: 5 (EXP) L5=L3-L4
Bending Stress:	12532.4	@Node 1670	LOADCASE: 5 (EXP) L5=L3-L4
Torsion Stress:	5944.5	@Node 540	LOADCASE: 5 (EXP) L5=L3-L4
Hoop Stress:	0.0	@Node 20	LOADCASE: 5 (EXP) L5=L3-L4
3D Max Intensity:	12810.6	@Node 1670	LOADCASE: 5 (EXP) L5=L3-L4

D. Loads and Boundary Conditions

Various types of loads act on the start-up system both internally as well as externally. Internal loads include the internal pressure of the fluid (Table I) and the self-weight of the piping and the components. External loads include forces and moments from the economizer. Displacement boundary conditions for pumps, valves.

E. Analysis and Results

As per Expansion load the allowable stress value is 168.76 MPa and the code stress developed is 84.65 MPa. The code stress ratio is 50.2 for expansion load case. Sustained load the allowable stress value is 98.18 MPa and the code stress developed is 93.61 MPa. The code stress ratio is 95.3 for expansion load case.

V. CONCLUSION

The flexibility analysis and code compliance analysis on connecting equipment's are observed. The stresses developed are within allowable limits so that the system will not fail prematurely.

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