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Efficient Energy Transfer and Importance of Jacketed Piping in Sulfur Transportation

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Abstract: *In natural gas, sulfur is present mainly as hydrogen sulfide (H2 S), while in crude oil it is present in sulfur-containing organic compounds which are converted into hydrocarbons and H2 S during the removal process (hydrodesulphurization). In both cases, corrosive, highly-toxic H2 S gas must be converted into elemental sulfur. This elemental sulfur is received from the sulfur recovery process in a liquid or molten form .Heating and maintaining temperature in process piping is very important to the operation of sulfur in oil & gas industry. Hence, several different technologies are used to transport the sulfur. In this several technologies, jacketed piping is one of the common types which maintain a process temperature or it may be considered as a system of single tube heat exchangers. This application is to prevent heat loss from a fluid which it gets cooled by even a couple of degrees below its freezing point. This paper will discuss about the types of jacketed piping, efficiency of heat transfer in jacketed piping, limits of calculated stresses due to sustained loads and displacement strain for core as well as jacket pipe and limits of calculated stresses due to occasional loads as per ASME B31.3. It also explains external pressure applying on the inner pipe wall, checking of buckling stress and distance of spacer calculated for each size, checking of welding strength between jacket and core pipe. Finally this paper deals with prevention and quality control during fabrication, erection and installation of jacketed piping.*

Keywords: *Sulfur, Claus Process, Jacketed Piping, Stress analysis*

1. INTRODUCTION

Sulfur is one of the most important element in oil & gas industry. The vast majority of sulfur is recovered from natural gas and oil, which contain hydrogen sulfide and a wide variety of organic compounds that contains sulfur. It has to be removed before the natural gas and oil can be used as feed stock for the chemical industry as they poison the catalyst that are used in the various process to make chemicals.H2S is a flammable gas with a wide limit of flammability and unlike elemental sulfur it is extremely toxic. In fact 5min exposure to only 800 ppm results in death and a single breath of 1000 -2000 ppm may cause coma [1]. For environmental and safety reasons, venting or flaring H2S to the surroundings is unacceptable. Therefore, its conversion to the harmless elemental sulfur is necessary. Elemental sulfur can be stored, handled and transported in bulk. The primary use of sulfur is for the production of sulfuric acid and the minor uses include manufacturer of pesticide, fertilizer, bactericide in food preservation and other fine chemicals.

2. SULFUR RECOVERY

Sulfur is recovered through various types of processes. One of the type is Straight through Claus process. This process is used when the acid gas containing more than 50% of H2S. This process consist of a thermal stage(Combustion chamber, waste heat boiler) and two or three catalytic reaction stages (reheater, reactor and condenser).In thermal stage, Acid gas combines with air passes through the reaction furnace, where the amount of heat generated in the reaction furnace depends on the amount of H2S available in the burner.

The furnace normally operates at combustion chamber, temperatures ranging from 980 degC to 1300 degC with pressure higher than 70 Kg/cm2.[2]. Before entering a sulfur condenser, hot gas from the reaction furnace is cooled in a waste heat boiler that generated high to medium pressure steam. About 80 % of heat released could be recovered as useful energy. Liquid sulfur is removed in a separator section of the condenser and flows by gravity to a sulfur storage tank. The cooled gas exiting the condenser is sent to the catalyst beds. The catalytic reactor operate at lower temperatures, ranging from 200 to 315 deg C . Alumina or bauxite is sometimes used as a catalyst. Because this reaction represents an equilibrium chemical reaction, it is not possible for a Claus plant to convert all the incoming sulfur compounds to elemental sulfur [2]. Therefore two or more stages are used in series to recover the sulfur. Almost 95 to 98% overall recovery of sulfur can be achieved depending in the number of catalytic reaction stages and the type of reheating method used.

For lean acid gases that contain 5-30% H2S, the straight through Claus process is not workable without additional equipment. The alternative is to replace the thermal section of the modified Claus process by a direct oxygen process. However, straight through Claus process is commonly used in oil & gas industry since sulfur recovery will be higher.

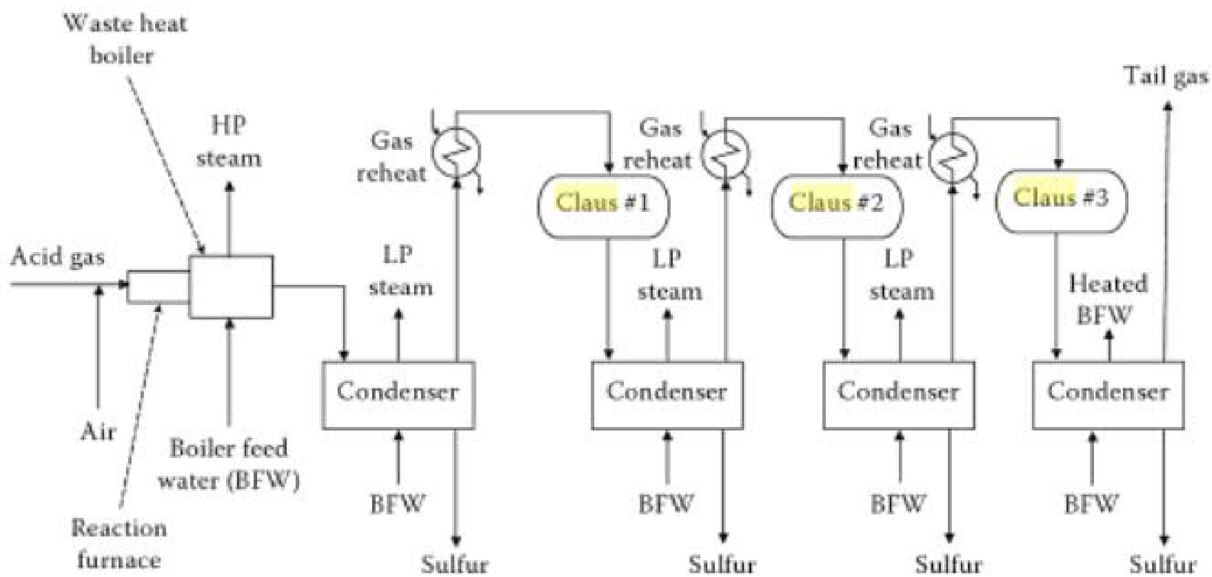

Fig. 1. (Straight Through Claus Process) [1]

3. TRANSPORTATION OF SULFUR

The elemental sulfur is received from the recovery process in a liquid or molten form. Melting point is between 112 degC and 121 degC depending on the crystalline form. The flash point of liquid sulfur –the temperature at which it vaporizes to form an ignitable mixture in the air. The ignition temperature of liquid sulfur is the point at which it will auto ignite without an external spark is between 248 deg C and 261degC.[2].These properties mean it is vital that liquid sulfur can be stored and transported at carefully maintained temperatures, typically above 130 degC. Sulfur undergoes a sudden increase in viscosity that makes it impossible to pump. Thus the challenge is to maintain the temperature of sulfur within the acceptable temperature range in all equipments and pipe lines. The challenge is even greater when sulfur is transported long distance in pipe lines.

This is achieved by transferring liquid sulfur through pipe lines heated in one of the three ways.

1. Electrical Tracing Piping System
2. Contro tracing Piping
3. Jacketed Piping System

3.1 ELECTRICAL TRACING PIPING

Electrical heat tracing is used to maintain or raise temperature of pipes and vessels. It is based on the principle that heat will be generated along a conductor according to the losses in the conducting element.

$$Q = f(I^2 R)$$

'I' is the current applied to the conductor and it is constant along its entire length. 'R' is the resistance of the conductor and varies with the average temperature along the conductor. Thus the heat is generated uniformly along the entire length of the conductor. A problem occurs when a line is not uniformly insulated. In areas where insulation is less, heat losses will be greater but there will not be a corresponding increase in heat generated in this area to compensate. This is the major problem with traditional electric heat tracing systems. [3].

3.2 CONTRO TRACING

Contro tracing element is a rectangular tube with one surface curved to match the outside diameter of the pipe to be heated. It is strapped onto the outside of the pipe with a layer of heat transfer cement between the pipe and the trace. Heating fluid typically steam, runs through the tube. The number of elements used on a pipe is adjusted to match the thermal requirements.

3.3 JACKETED PIPING

Steam jacketed piping is the traditional method for conveying the molten sulfur throughout the plant. Jacketed piping is basically a pipe within a pipe. Inner pipe is commonly referred to as core pipe whereas outer pipe is known as jacketed pipe. Molten sulfur flows in the central or core pipe which is heated by a fluid, typically steam, flowing in the annular space formed between the core and jacketed pipe. It maintains a very uniform temperature on the process pipe wall. Jacketed piping is of two types. Continuous Jacketed and Discontinuous Jacketed piping. All straight lengths, flanges, fittings, valves and branch connection are fully jacketed. In discontinuous jacketed piping, only straight length of pipes is jacketed. Other fittings are not jacketed.

3.3.1 CORE AND STEAM JACKETED SYSTEM

Key successful for jacketed piping system installation is the location of steam supplies and condensate removal points. The steam supply to each jacketed circuit shall be taken from the main header or sub headers and condensate from the steam trap shall be returned to a condensate sub header/ main header. In principle, the steam inlet pipe must be connected to the uppermost point of the circuit. The steam supply line to jacketing system and steam/ condensate line from jacketing system shall have block valve located near nozzle of jacketing pipe.

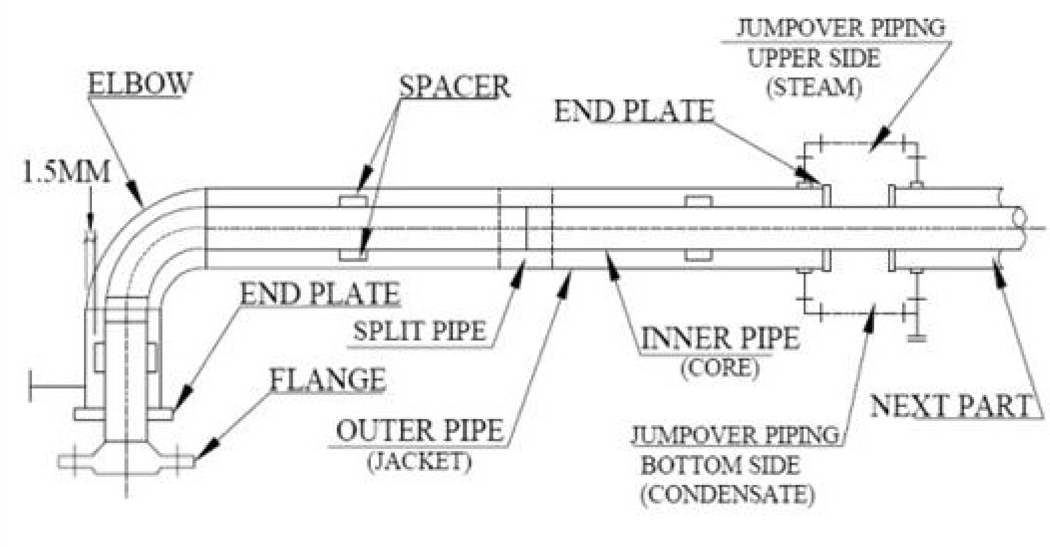

Fig. 2. Discontinuous Jacketed Piping [5].

3.3.2 CENTERING GUIDES

Centering guide is used to support the core pipe for long span. Centering guide shall be place for 3m between the core pipes(Spacing is depends upon the project guide lines). Guides are similar to the plates which will be welded in the core pipe. A gap of 1.5mm to be provided between the guide plates and Jacketed pipe.

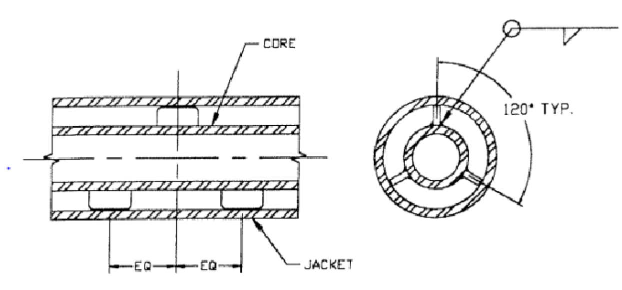

Fig. 3. Centering Guide [5].

3.3.2 TEES AND CROSS TEES

It is desirable to use a tee or cross tee instead of 90 deg elbow due to change in direction. Tees and crosses can be fabricated to provide a fully concentric core pipe and even annular space. For molten sulfur lines, crosses with open ends with blind flange at direction changes are used to allow roding out of each run of pipe from two directions.

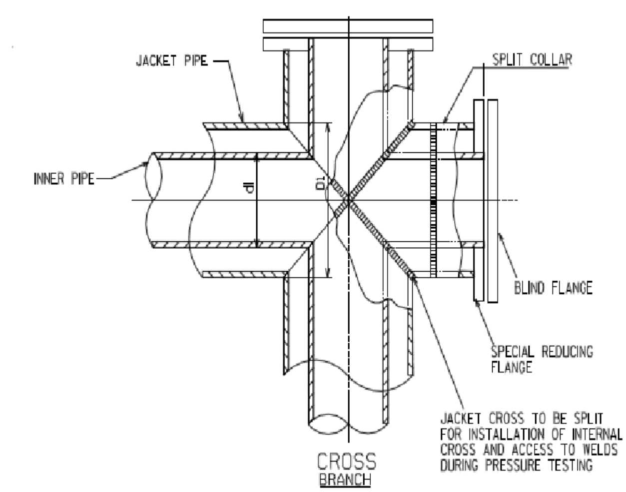

Fig. 4. Cross Tee [5].

4. PREVENTIONS FOR JACKETED PIPING

During fabrication of a jacketed piping system, close monitoring and quality control to be taken to prevent problems. Failure of a core pipe will lead to mixing of molten sulfur and steam. Failure can be the results of poor welding, faulty fabrication and incorrect design. The core pipe can develop a crack in the heat affected zone of a butt weld. When the sulfur pressure is higher than the steam pressure, sulfur will enter the steam / condensate system. The sulfur in the core pipe will be freeze and process will be stopped. Hence proper care to be taken while fabrication and erection of the core and jacketed pipe. When the core fabrication is completed, it should be hydraulically tested. Any defect should be repaired prior to the fabrication of the jacket. When the jacket piping is completed it should be hydraulically tested as well [4].

5. STRESS ANALYSIS FOR JACKETED PIPING

A pipe system is jacketed to ensure that flow medium inside the core pipe is maintained at a certain temperature, by using a low pressure steam between core and jacketed pipe. This results in temperature differential between the core and jacket pipe.

Modeling the core and jacketed pipe in analysis software is little complicated for jacketed piping. Initially core pipe to be modeled along with spacer as per the design guidelines, then the jacketed piping to be modeled above the core pipe. Normally jacketed pipe is one size higher than core pipe. As per process requirement, parameters to be updated and supports shall be provided on jacketed pipe as per pipe span.

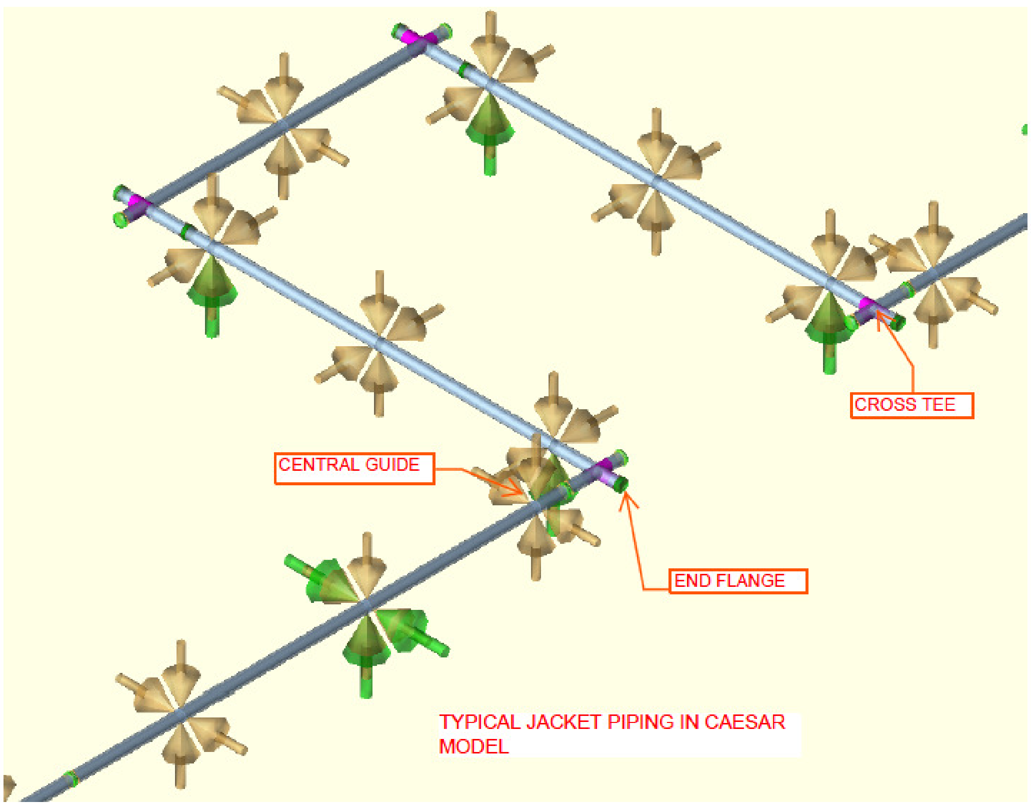

Fig. 5. Modeling of Jacketed Piping in Caesar Model

5.1 MAJOR STRESS CHECK FOR PERFORMING STRESS ANALYSIS

Limits of calculated stress due to sustained loads and displacement strain due to expansion stress to be evaluated separately for core and jacket piping as per clause 302.3.5 of ASME B31.3 and Limits of calculated stress due to occasional loads to be evaluated as per clause 302.3.6 of ASME B31.3 [6]. Other than computer analysis manual stress checks to be performed for jacketed piping. i.e. Buckling load and weld strength between core and jacket to be checked.

5.2 CHECKING OF BUCKLING LOAD

Computer program does not check compliance for the buckling load. Hence manual calculation to be made for the same. Computer program gives the value of ‘P’ calculated at the junction point between core and jacket. This calculated value is to be less than critical force (Pcr).[4]

$Pcr= (4\pi^2 \times E \times I_C) / L^2$ for Core pipe
$Pcr= (4\pi^2 \times E \times Ij) / L^2$ for Jacketed pipe
Where,
P is calculated by computer program

Pcr = critical force
E= Modulus of elasticity
I_c = Moment of inertia for core
I_j = Moment of inertia for jacket
L= Length of pipe between the junction of core/ jacket.
If P ≤ Pcr, then no buckling failure.

5.3 CHECKING OF WELDING STRENGTH BETWEEN JACKET AND CORE PIPE

'P' calculated at the junction point between core & jacket is compared with allowable load at weld point.
Pall – Area of weld x 60% of allowable stress
Area of weld = π x D x root of weld
D = diameter of core pipe
Root of weld = 0.707 x weld size
Load calculated at the junction point,P ≤ Pall. [4].

6. CONCLUSIONS

Our discussion shows that the how Sulfur plays an important role in oil and gas industry with straight through Claus process and transferring the liquid or molten sulfur from recovery process through jacketing piping. Holistic piping design for in the jacketed piping, transfer heat more efficient than other process with their double barrier between the heating medium and the process, this is one of the best methods for transferring the high viscous fluid. Additional care to be taken for piping stress analysis, fabrication and erection of jacketed piping, since leakage may take place due to improper welding and faulty fabrication. This will allow refinery to maximize SRU capability, improve emission performance to meet the latest stringent environmental standards.

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