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ON SELECTION OF EXPANSION JOINT FOR A TURBINE CONDENSER APPLICATION

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ABSTRACT:

The expansion joint decouples the steam surface condenser from the steam turbine. One of the principle functions of the expansion joint is to absorb the differential thermal expansion between the steam turbine and the condenser while imparting minimal forces and moments on the turbine exhaust flange. Steam turbines come in a variety of exhaust configurations such as down exhaust, axial exhaust and top exhaust. Each configuration has unique design and performance requirements for the expansion joint. The expansion joint must perform satisfactory under a wide range of operating conditions to ensure reliable operation of the turbine condenser system.

TYPES OF EXPANSION JOINTS:

The two main types of expansion joints used for the connection between the condenser and turbine are metallic or elastomeric (rubber). Stainless steel bellows expansion joints are used in large numbers in the power industry. In a bellows expansion joint, single or multiple stainless steel bellows absorb the axial compression between the condenser and turbine. The amount of axial compression and the resulting forces and moments are dependent on the height and thickness of the stainless steel bellows. On larger steam turbine condenser applications, the stainless steel bellows expansion joint is welded to the condenser and the turbine. In smaller turbine condenser applications the stainless steel bellows expansion joint can be bolted or welded to the steam turbine and the condenser. The stainless steel bellows expansion joint are equipped with a stainless steel liner that shields the bellows from the turbine exhaust steam. Figure 1 provides details on the construction of a stainless steel bellows expansion joint.

The elastomeric expansion joints can be the dog bone or rubber "U". In the dog bone expansion joint an endless belt in the shape of a "dog bone" is tightly held on both ends between machined clamps (keepers). The machined clamps and the bolting ensure leak tightness during operation. The clamps on either end are welded to a flange if the expansion joint is to be bolted to the condenser and the turbine. The clamps are welded to filler piece of a weld end if the expansion joint is to be welded to the turbine or the condenser. The rubber dog bone, if installed improperly, can leak air into the condenser and degrade its performance. A water seal is sometimes employed to eliminate air leakage into the condenser. In the event of an air leakage, water enters the steam space of the condenser instead of air thereby preserving the performance of the condenser. A drop in the water level indicates an air leakage. At the first available opportunity the operator would tighten the clamps holding the rubber dog bone (or flanged joint) and eliminate the air leakage. Water seals are usually installed in down exhaust applications. Installing a water seal in an axial turbine application is very tedious and cumbersome. A dog bone expansion joint absorbs the axial as well as lateral movements between the turbine and the condenser. The elastomer type expansion joint offers a lesser resistance to axial and lateral movements hence the forces and moments imposed on the turbine exhaust are minimal. Figure 2 provides details on the construction of a dog bone expansion joint.

The rubber "U" expansion joint is an endless belt in the shape of "U". The rubber "U" expansion joint is always bolted to the turbine exhaust and the condenser. The vertical sections of the "U" act as the flange and are bolted to the turbine exhaust flange and the condenser steam inlet flange. A stainless steel liner is included to protect the rubber from the turbine exhaust steam. The forces and moments required to compress the rubber "U" expansion joint are substantially less than that for a stainless steel bellows expansion joint. As a result, the forces and moments imparted on the turbine exhaust flange are minimal. Rubber "U" expansion joint can only be flanged as a result they cannot be used in applications where the expansion joint has to be welded to the condenser steam inlet and the turbine exhaust. Rubber "U" expansion joints are ideally suited for smaller turbine condenser applications, especially axial exhaust steam turbines where a possible misalignment between the turbine exhaust and the condenser centerlines can occur. In large welded expansion joints, the misalignment between the steam turbine and condenser is accounted for by adjusting the expansion joint on the landing bar on the condenser steam inlet. Such a luxury is not available with flanged joints. Figure 3 provides details on the construction of a rubber "U" type expansion joint.

Elastomeric expansion joints can be made of neoprene (Poly-Chorprene) or EPDM (Ethylene Propylene Polymer). Neoprene can withstand continuous operating temperature of 220°F. EPDM can withstand a continuous operating temperature of 300°F. Neoprene is resistant to oils in steam whereas EPDM is not.

EXPANSION JOINTS FOR DOWN EXHAUST TURBINES:

Stainless steel bellows, rubber dog bone, and rubber "U" expansion joints are all suitable for down exhaust turbines. Rubber dog bone expansion joints and stainless steel bellows are suitable when the expansion joint is to be welded to the turbine exhaust and the condenser steam inlet.

Rubber dog bone is an ideal candidate when excessive lateral movement or minimal forces and moments are specified by the turbine supplier. The dog bone belt can be replaced in its entirety from a manway access in the steam dome of the condenser. In a bellows expansion joint, damage to the bellows is hard to access and repair.

EXPANSION JOINTS FOR AXIAL EXHAUST STEAM TURBINES:

Steam turbines with axial exhausts can be flanged or welded. For large steam turbines with welded connections, stainless steel bellows or dog bone expansions are suitable. The stainless steel or dog bone expansions joints can be centered on the landing bar on the condenser steam inlet and then welded on both ends. Lower forces and moments on the turbine exhaust and higher lateral movements would dictate the use of a dog bone expansion joint. As it is tedious to install a water seal on the dog bone expansion joint careful attention must be paid to the design and fabrication of the clamps that hold down the dog bone elastomer. The clamps must be tightened on a routine basis to ensure leak tightness.

In smaller turbine applications a rubber "U" expansion joint can be installed between the turbine exhaust flange and the condenser steam inlet flange. The rubber "U" can accommodate relative large axial compression and lateral movement. Any unforeseen misalignment between the centerline of the steam turbine and the condenser or elevation differences due to uneven settling of foundation can be easily accommodated.

EXPANSION JOINTS FOR TOP EXHAUST TURBINES:

When the turbine exhaust faces upwards a cross over duct is used to divert the steam from the turbine to the condenser. The expansion joint in such an application has to accommodate both axial and lateral movements. Cross over duct expansion joints can be designed in a number of ways. Typical design includes a cross over duct with a pressure balanced stainless steel bellows expansion joint as shown in Figure 4. The cross over duct with pressure balanced stainless steel expansion joint is bolted or welded to the turbine exhaust and the cross over ducting. The pressure balanced expansion joint accommodates the axial and lateral movements as well as the vacuum forces. An alternate design, shown in Figure 5, involves installing a pedestal for the crossover duct. The cross over duct is welded to the condenser steam inlet on one end and rests on the pedestal at the other end. An elastomer expansion joint connects the cross over duct to the turbine exhaust flange. In such an application the elastomer expansion joint absorbs the axial and lateral movements. The elastomer expansion joint can be rubber "U" or dog bone. The bolting on the pedestal withstands the vacuum forces.

In certain instances two separate pedestals can be installed to support the cross over duct as shown in Figure 6. The bolting on the pedestal supporting the cross over duct withstands the vacuum forces. An elastomer expansion joint connects the cross over duct to the steam inlet on one end and a second expansion joint connects the cross over duct to the turbine exhaust at the other end. In this design the cross over duct is totally decoupled from the turbine and the condenser during the erection stages. This design is preferred when the distance between the

turbine and condenser centerlines are relatively large and higher lateral movements are to be absorbed.

EXPANSION JOINTS FOR CONDENSERS WITH BYPASS OPERATION:

Steam surface condensers in combined cycle plants are designed to operate in bypass mode. When the steam turbine is not in operation the high pressure high temperature steam from the HRSG is attemperated in a pressure reducing and desuperheating valve. Bypass steam, typically at 100 psig and 360°F, is admitted into the steam surface condenser through a bypass header equipped with orifices. The bypass steam expands from the inlet pressure to the condenser equilibrium pressure in the steam dome of the condenser. In bypass operation the expansion joint will come into contact with the bypass steam as it migrates toward the steam turbine. Stainless steel expansion joints can with stand higher temperatures when compared to elastomer expansion joints. If a stainless steel expansion joint is used then it must be designed to withstand the maximum operating temperature in bypass operation. Elastomer expansion joints can be used is a spray curtain is deployed. The spray curtain should be installed downstream of the elastomer expansion joint. The spray curtain should be designed such that the spray is initiated before the bypass steam enters the condenser. In addition, the amount of spray water is adequate to cool the bypass steam migrating towards the expansion joint to a temperature below the limit for continuous operating temperature for the selected expansion joint.

CONCLUSION:

The orientation of the turbine exhaust and the requirements for the turbine exhaust flange must be carefully evaluated prior to the selection of the expansion joint. Allowances must be made for misalignment between the centerlines of the turbine exhaust and the condenser steam inlet. The axial and lateral movements must be carefully addressed. The forces and moments on the turbine exhaust flange must be within the specified limits. Flanged or welded connections to the turbine exhaust or the condenser steam inlet must be carefully configured to ensure proper and leak tight closure.

REFERENCES:

1. Heat Exchange Institute Standards for Steam Surface Condensers, 10th Edition

2. Recommended Guidelines for the Admission of High Energy Fluids to Steam Surface, Condensers, EPRI Report CS-2551, February 1982.

3. Expansion Joint Manufacturers Association Standards, 9th Edition

4. Fluid Sealing Association Standard, FSA-PSJ-706-06

5. Maarky Thermal Systems, Importance Of Temperature Of Bypass Steam Admitted Into A Steam Surface Condenser In A Combined Cycle Plant, EPRI Condenser Conference, 2011.

FIGURES:

Figure 1: Stainless steel bellows expansion joint configurations

Figure 2: Rubber Dog bone expansion joint configurations

Figure 3: Rubber "U" expansion joint detail

Figure 4: Expansion joint for top exhaust turbines: Cross over duct with pressure balanced expansion joint.

Figure 5: Expansion joint for top exhaust turbines: Cross over duct with one pedestal and rubber "U' expansion joint

Figure 6: Expansion Joint for top exhaust turbines: Cross over duct with two pedestal and two rubber "U' expansion joint

FIGURE 1: STAINLESS STEEL EXPANSION JOINTS

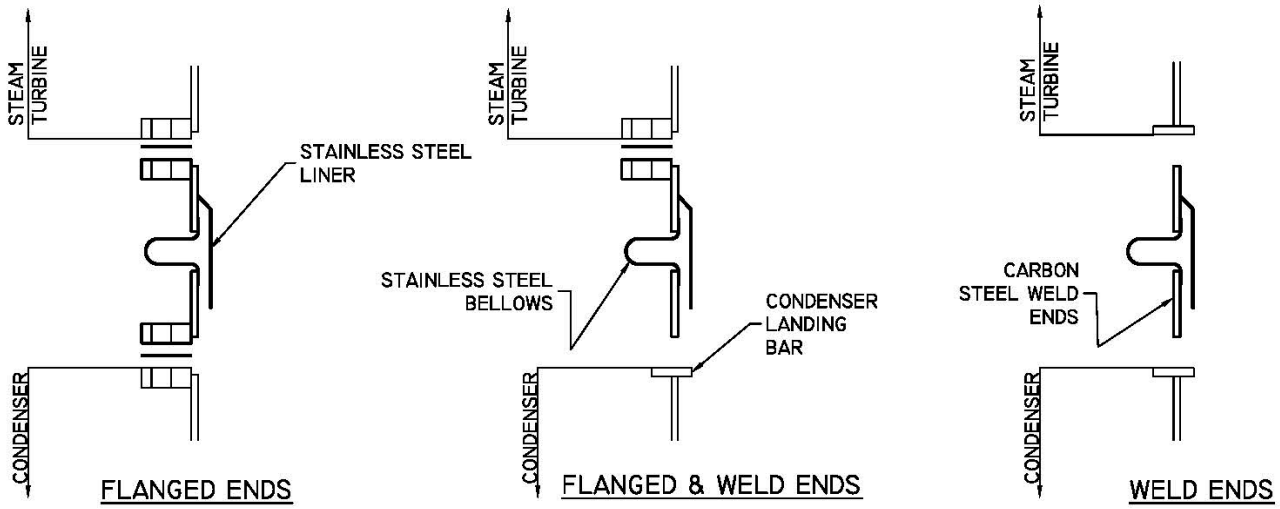

FIGURE 2: DOG BONE EXPANSION JOINTS

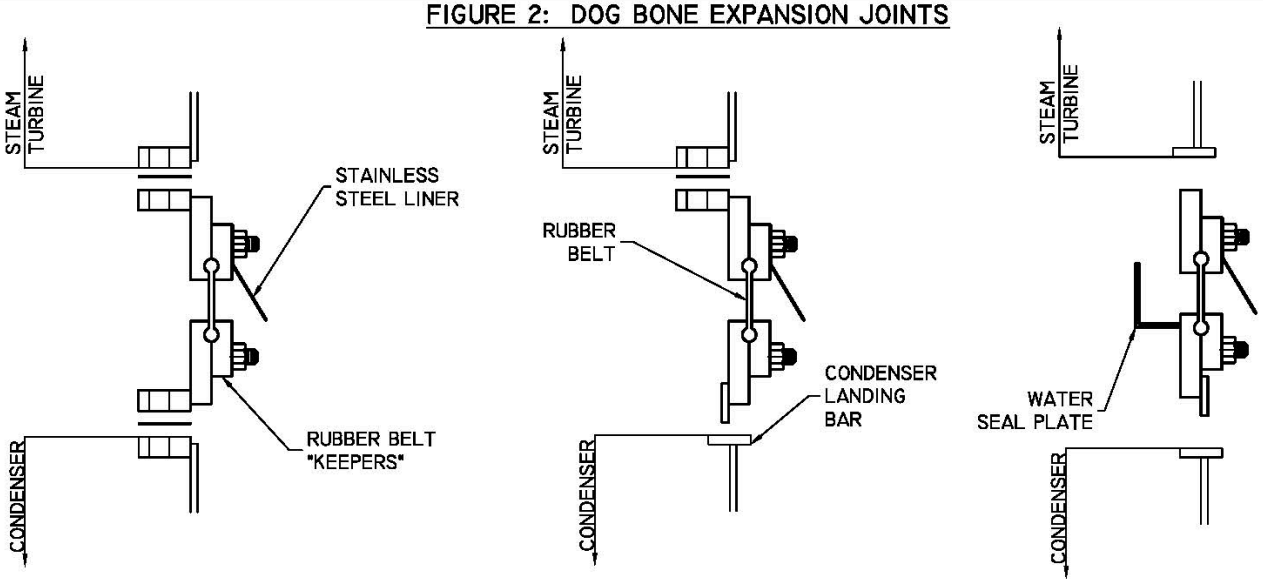

FIGURE 3: RUBBER "U" EXPANSION JOINT

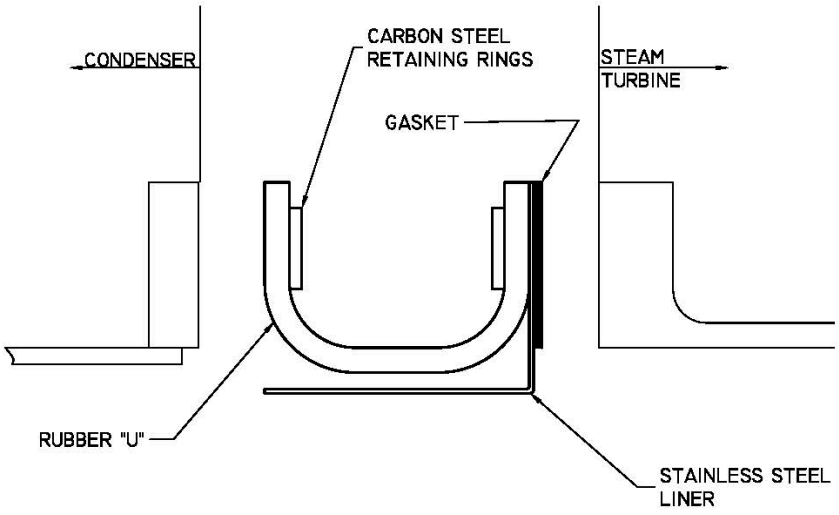

FIGURE 4: CROSS-OVER DUCT WITH PRESSURE BALANCED EXPANSION JOINT

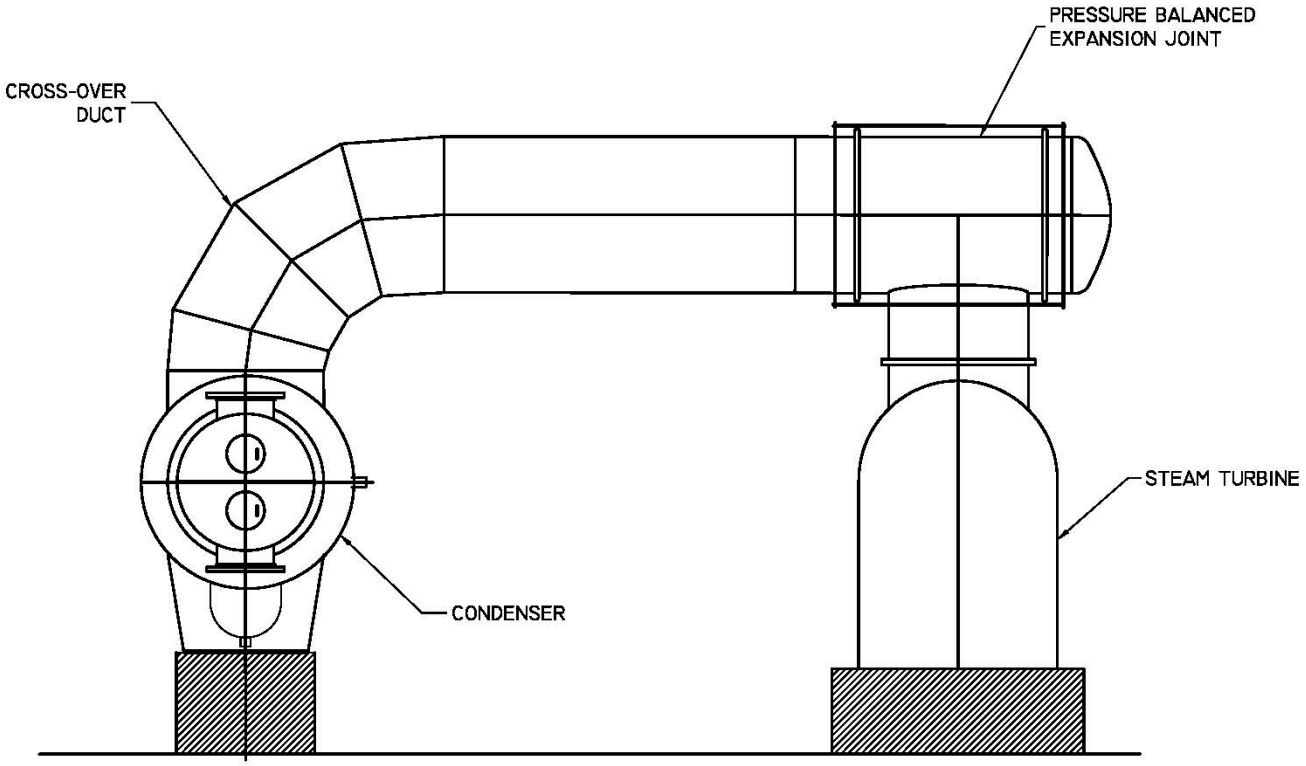

FIGURE 4: CROSS-OVER DUCT WITH RUBBER "U" EXPANSION JOINT & SUPPORT

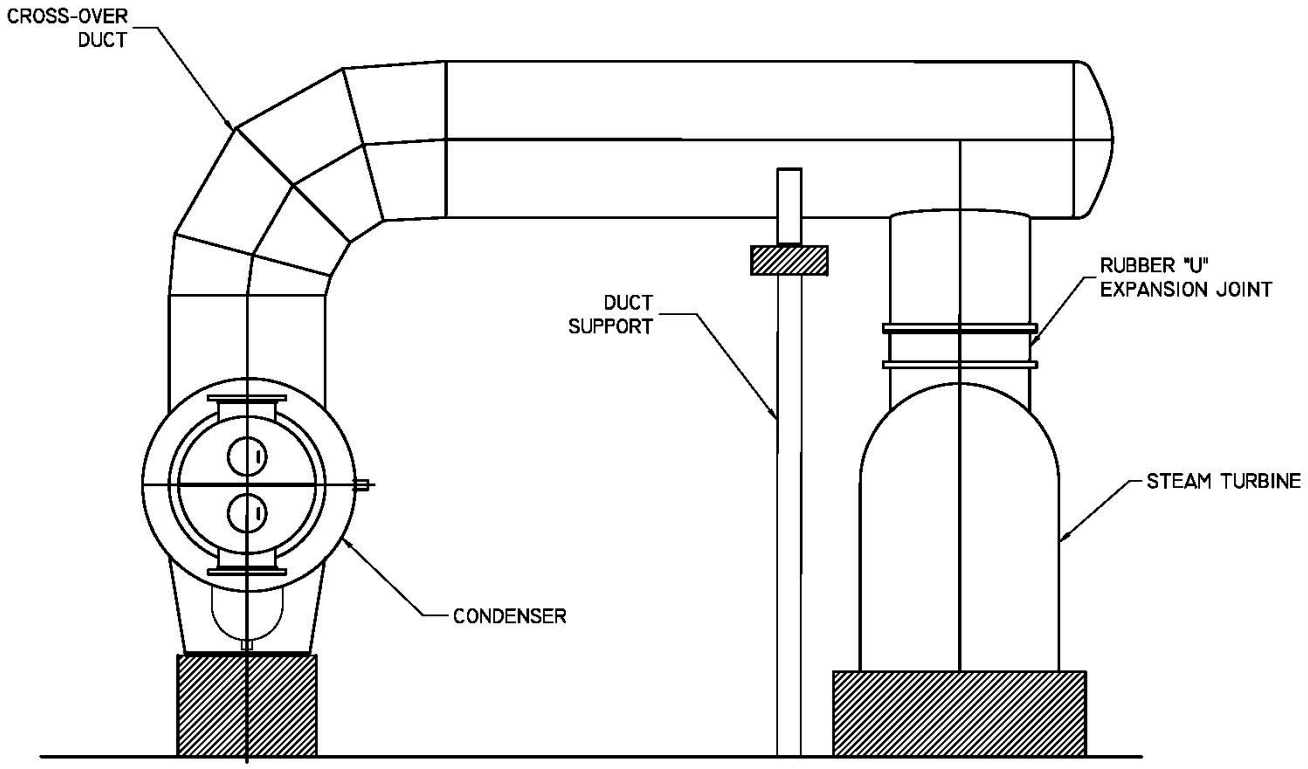

FIGURE 6: CROSS-OVER DUCT WITH TWO (2) RUBBER "U" EXPANSION JOINTS & SUPPORTS