

THERMAL EXPANSION OF BOILERS

INTRODUCTION

Boiler is made up of plates, tubes, pipes and simple steel of various grades depending upon the duty conditions. Depending on the service such as cold air / hot air / cold flue gas / hot flue gas / cold water / hot water / saturated steam / superheated steam, thermal expansion movement of steel materials take place to different extent in Boiler. Ignorance of thermal expansion movement of boiler components in design / installation may lead to failure of boiler components. The damage to boiler components can be costly affecting human life in some cases. This article is aimed at imparting awareness among boiler users.

ABSOLUTE EXPANSION & DIFFERENTIAL EXPANSION

The boiler has an absolute expansion movement as a total mass. There are places where there is a relative expansion movement, which can cause stress in those parts. A packaged boiler expanding as a total can be regarded as a single mass movement.

THE PACKAGED BOILER

Boiler shell

Shell type packaged boilers are generally mounted on two saddles. The boiler is to be mounted on base plates on the RCC footing. One of the saddles will be a fixed support and the other is a sliding support. At the fixed support the boiler will be fastened to the foundation bolt or held in place by means of stoppers. At the sliding support, slippery medium is required between the saddle and the base plate. The locknut is loosened by half a turn to facilitate expansion. The guide blocks are provided to make the boiler move in the desired direction. One may observe breakages of RCC pedestals where this aspect is ignored.

Ducting

In packaged boilers, flue gas ducting to chimney would need an expansion joint to accommodate the duct expansion due to heat. The expansion joint is generally metallic and pre-expanded. The expansion joint would be compressed when the duct expands due to heat. An expansion joint may be with a single or multiple bellows as illustrated in figure 1.

Water & steam piping

In packaged boilers, the feed piping is generally small and flexible and thus may not call for spring hangers / supports. The steam piping is generally managed with fixed and guiding supports and expansion loops. Expansion loops accommodate the displacement due to thermal expansion. See the typical illustration in figure 2.

LARGER CAPACITY BOILERS

Larger capacity boilers are mostly designed for high pressure & high steam temperature. The thermal expansion phenomenon is more seen in many parts of the boiler. When the design pressures are higher the strain on the boiler components is not tolerable. In several components the design should address the differential expansion aspect.

PRESSURE PARTS - STEAM DRUM

A steam drum may be either top supported or bottom supported or floating. Top supported steam drum can be saddle supported or hanger supported. The steam drum may be floating free through support from downcomer or from bank tubes

Case 1. Saddle support from base.

When supported from base the steam drum will stretch in length due to heat. The drum movement must be generally arrested at the centre and allowed to expand linearly towards the ends. This is taken care of stopper blocks. The drum base plates must be provided with Teflon sheet so that it freely slips over the fixed supporting surface. Positioning fasteners when provided, must be made loose by ½ a turn and nuts must be tack welded with bolts. Machined base plates help in free movement. Instead of Teflon sheet, graphite lubrication or dry lubricant may also form a slippery surface for the drum to freely expand as shown in figure.3 (A)

Case 2. Hanger supports.

The steam drum may be supported through hangers from top structure. In such a case the hangers are provided with rocker plates to facilitate from rotational freedom for the hangers. The rocker directions are important and shall be as shown in figure 3 (B)

Case 3. Bottom supported through downcomers

The downcomer supports are critical supports and vulnerable for buckling, if the drum is not guided for vertical expansion. In some cases the steam drum may be physically attached to waterwall and thus the expansion may be guided. Otherwise it is necessary to provide guides, which will make the drum to go up vertically without any lateral movement in the direction perpendicular to the drum axis. When supported on downcomers, the support base of downcomer should be free for movement along drum axis. There will have to be guides, which ensure the movement is free in the desired direction. Teflon base / graphite lubricated base plates are required to allow for the slip.

In some cases the downcomer may be rigidly attached to waterwall giving a complete lateral support along the height.

LOWER DRUM

The lower drum may be bottom supported or hanging from top drum through the bank tubes.

Case 1. Lower drum bottom supported

The lower drum may be base supported with three saddles or two saddles. In the case of three saddles supported design the centre one will be the zero point of expansion. In the case of two-saddle support design an external stopper or guide is required to guide the boiler expansion. A restraint is required to ensure the drum center point is anchored to the structure.

Case 2. Lower drum hanging from top through bank tubes

When the lower drum is supported through bank tubes, the mud drum should be free from any restraint.

ASH HOPPERS

The ash hoppers are generally attached to pressure parts such as waterwall second pass, Lower drum of boiler bank, Economiser casing, Airheater base frame, Bag filter / ESP fields. In all the cases, the ash hoppers move along with the equipment or part to which they are attached. Suitable metallic expansion joints are added. It is a good practice to hang the ash feeders from the flange of ash hopper. External supported ash feeders act as restraints for expansion and hence care is to be taken here. Flexible metallic bellows are used to care of downward expansion or linear movement of ash hopper.

DOWNCOMERS

Downcomers start from steam drum in case of single drum design. In case of bidrum design, downcomers start from steam drum or lower drum depending on the designer's choice.

Downcomers should preferably be attached to waterwall. If unavoidable, then external supports are provided. Flexibility is a very important factor to avoid development of thermal stresses. Most of the time the stresses can be made below allowable limits only by providing spring supports. Spring supports support the piping allowing some deflection of the pipe. Only when there is a constraint for expansion movement, the stresses are high.

In some cases, it may not be necessary to provide spring supports, as the piping itself may be flexible to accommodate the thermal expansion by elastic deflection.

RISERS

Riser tubes are usually quite a good number of them. It is more sensible to support these pipes from the water wall top headers. By this way there will not be any differential expansion between waterwall & risers. External supported risers are susceptible for undue stresses.

WATERWALL

There are basically two types of waterwall, namely fin-welded waterwall & loose tube waterwall.

Top supported waterwall is free to expand downwards. Ensuring the free expansion by suitable clearances to the combustors is very important.

Bottom supported waterwall is to be supported at same level. Differences at supporting level can lead to tearing of waterwall fin weldment.

In the case of loose tube waterwall, the boiler should necessarily be supported from top. This will ensure the tubes do not buckle or distort laterally. Improper supporting system leads to leakages in roof refractory work and ash leakage outside. See in figure 4.

BUCKSTAYS

Membrane waterwall panels are stiffened with buckstays to withstand furnace pressure fluctuation. The buckstays being unheated are not going to expand as the way waterwall expands. The corner pins should allow the expansion movement of waterwall. Improper erection of buckstays can lead to failure or distortion of waterwall. The buckstays have anchor points, which would generally coincide the zero axis of boiler expansion.

SATURATED STEAM LINKS

The link piping between drum and superheater can be very well supported from the top waterwall header. This is practical for top supported Superheater headers. For horizontal Superheaters the links should be supported properly allowing expansion movement. Constant load hangers or variable spring hangers are required to support the piping.

SUPERHEATER COIL ASSEMBLY

Superheater assemblies, which are hung from waterwall top headers, the downward movement of coils should be restricted. The nose panel to Superheater coils clearance should be adequate. Otherwise the coils become distorted.

In horizontal superheater, the waterwall to Superheater clearances are important. Otherwise the superheater coils get distorted.

SUPERHEATER HEADERS

Superheater intermediate headers & Final steam headers expand differentially as compared to waterwall panels. When headers are supported from waterwall headers through saddles, differential expansion must be considered. Where SH tubes pass through the space between waterwall tubes, the

SH tube / Water wall tube space is sealed by plates. There should be flexibility in Superheater stubs for differential expansion of Superheater. See in figure 5

REFRACTORY

Refractory walls expand. The coefficient of linear expansion of refractory is different as compared to any steel material to which they are attached or resting on.

The hot wall expansion length is more as compared to cold wall expansion across the thickness of the wall.

For this reason expansion joints are given along the hot face during construction. Similarly as the refractory walls are expanding, at the end they have a total movement resulting in pushing them each other. This is taken care of by leaving gaps before as shown in figure 6. Where castable refractory is used in the boiler, to take care of differential expansion, expansion joints are given. Even the anchors have linear expansion. To take care of this, plastic anchor covers are used over steel anchors. Wax is applied over anchors so that there is gap over the steel anchors, once the refractory is heated up while in service.

TUBULAR AIRPREHEATER

In most of the tubular airpreheater, the hot flue gas passes through the tubes and relatively cold air passes around the tubes. There will be relative expansion between the tubes and the casing. To take care of this a metallic expansion joint is provided as shown in the figure 7.

PIPING

The expansion movement of piping is the greatest in the boiler. The piping is always between equipment, which are usually stationary. At the terminal point the piping is usually supported rigidly. The piping in between stretches as the heating takes place. The piping needs some kind of flexible support. This is provided by means of spring hangers. The spring hangers support the piping and at the same time allow movement of piping so that the piping is not strained.

Piping can be carrying fuel oil, gas, hot water, LP steam, HP steam, Condensate. Depending on the service, the expansion of piping will be to a different extent.

In case of piping terminating at turbine or feed pumps, the forces exerted by piping on the flanges should be zero as otherwise it would cause damage to the connected equipment. The design of the piping is to be done carefully. Constant load hangers are to be used for this purpose.

EXPANSION POINTER

Expansion pointers are used for verifying the expansion movement of the boiler. These are attached to the drum ends / bottom or top header ends. When the boiler is under commissioning stage the expansion must be monitored. Depending on the anchor points in X-axis and Y-axis, the expansion is predicted by designers. The same is counter checked at site. Deviations in the form of non-uniform expansion should be checked.

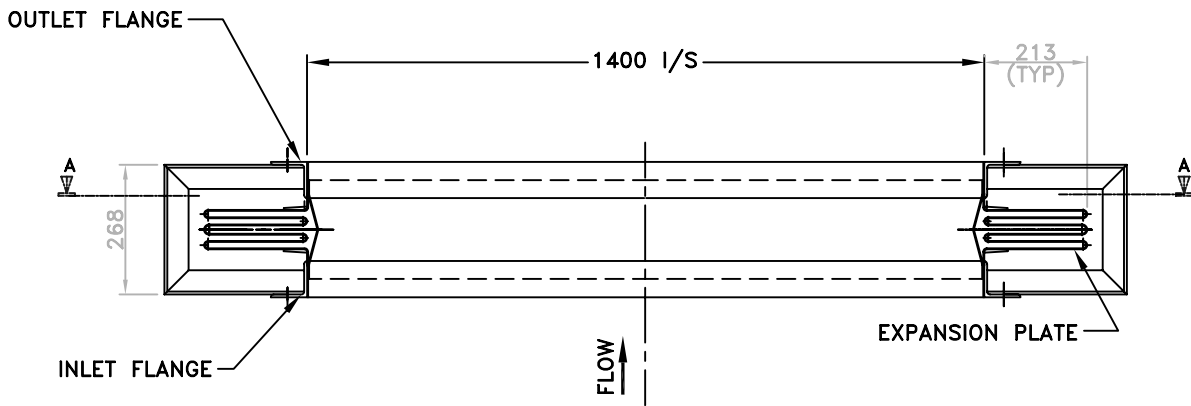
DUCTS

Ducts expand in length. Ducts expand in other two dimensions also. The thermal expansion along the length may push the connecting equipment. For example a hot air duct from an airheater will push the windbox. This is taken care of by expansion joints. See in figure 8. Flexible fabric expansion joints easily take care of expansion in all three directions. Metallic expansion joints of single bellow design would accommodate linear expansion. These expansion joints are pre-pulled and locked at boiler vendor's place. Only after erection of complete ducting, the transportation clamps or the locks are released. The thermal expansion movement now compresses the expansion joint. Expansion joints are

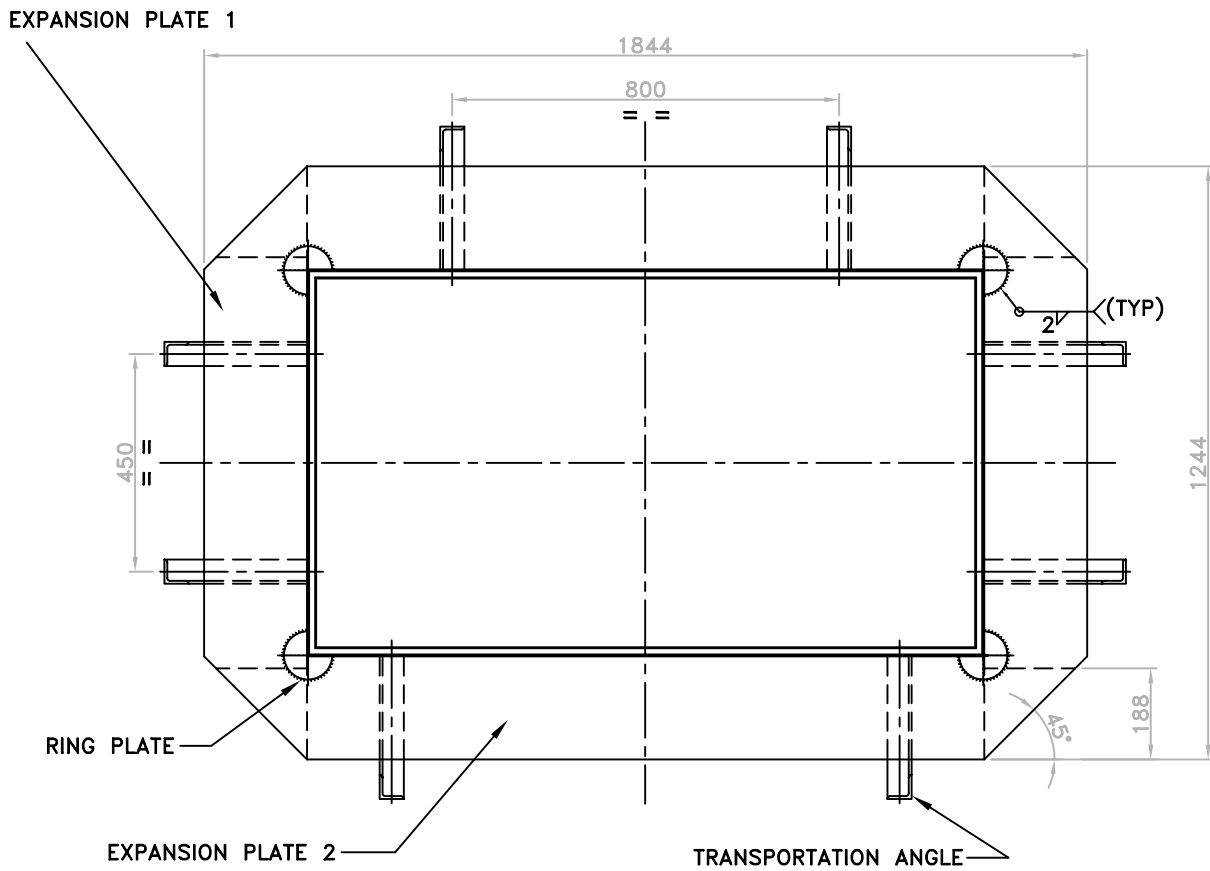
required practically wherever the duct takes a turn. Further at all equipment terminal points with fans / windbox, fuel feeding equipment, chimney, Fans, isolation guillotine gates, the expansion joints are to be provided.

FEEDBACK FROM BOILER INSTALLATIONS

Failures to account thermal expansion in design or erection can lead to several types of failures. Author had diagnosed some boiler problems such as piping distortions, boiler membrane waterwall failures, seal plates failures, ash leakages, and repeated flange leakages. The cause had been thermal expansion. It may be true that some of the readers may have any of the above-referred problems in their installations. Care at design or aptly at erection stage would help to prevent failures due to thermal expansion.



SECTIONAL ELEVATION



SECTION - AA

FIGURE NO.1 MULTIPLE BELLOW EXPANSION JOINT

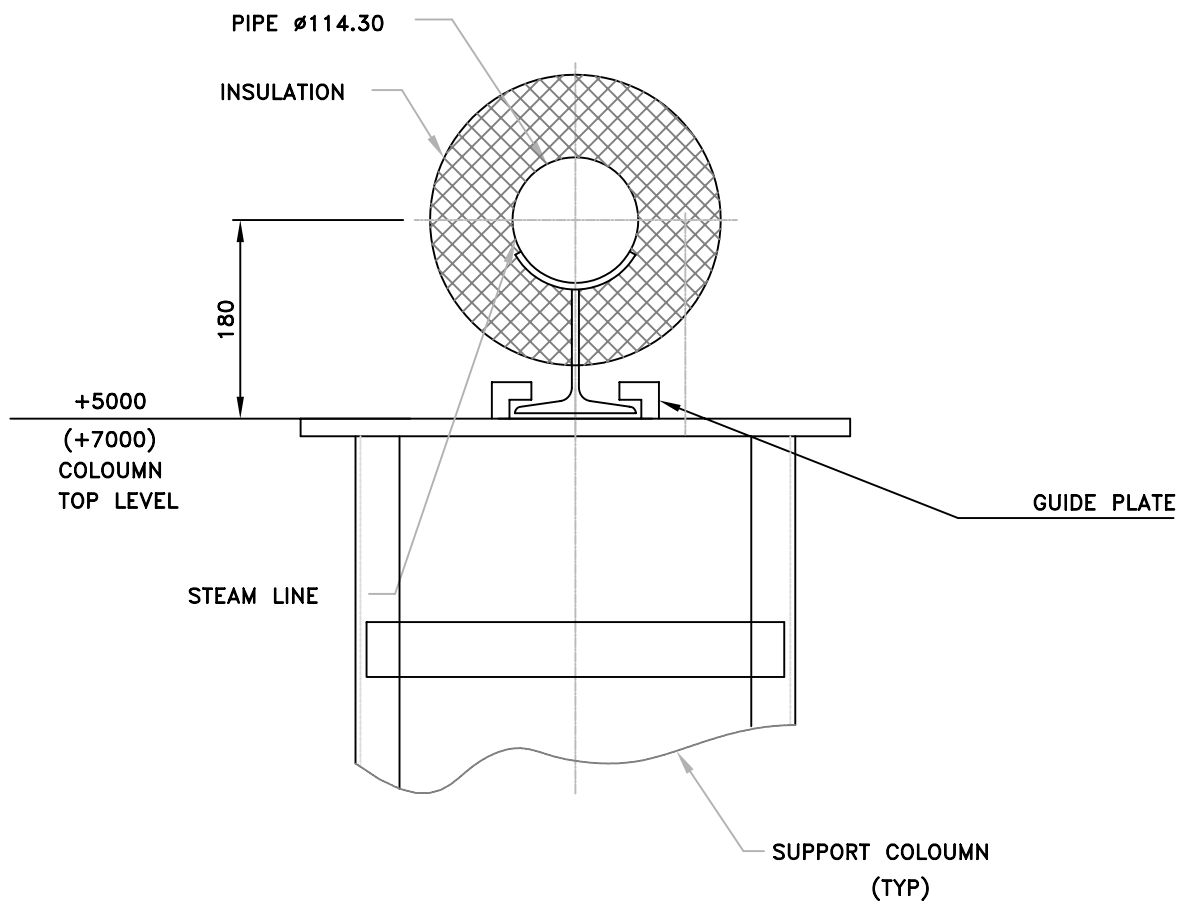
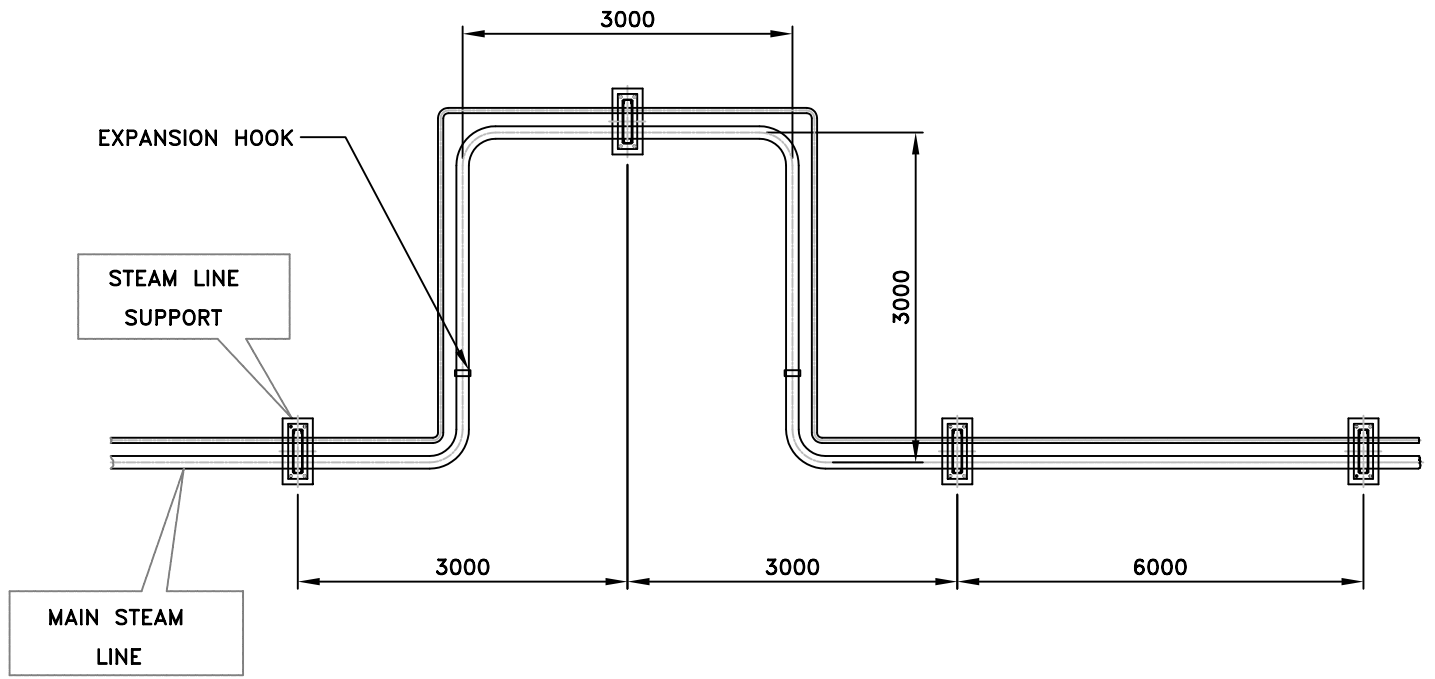
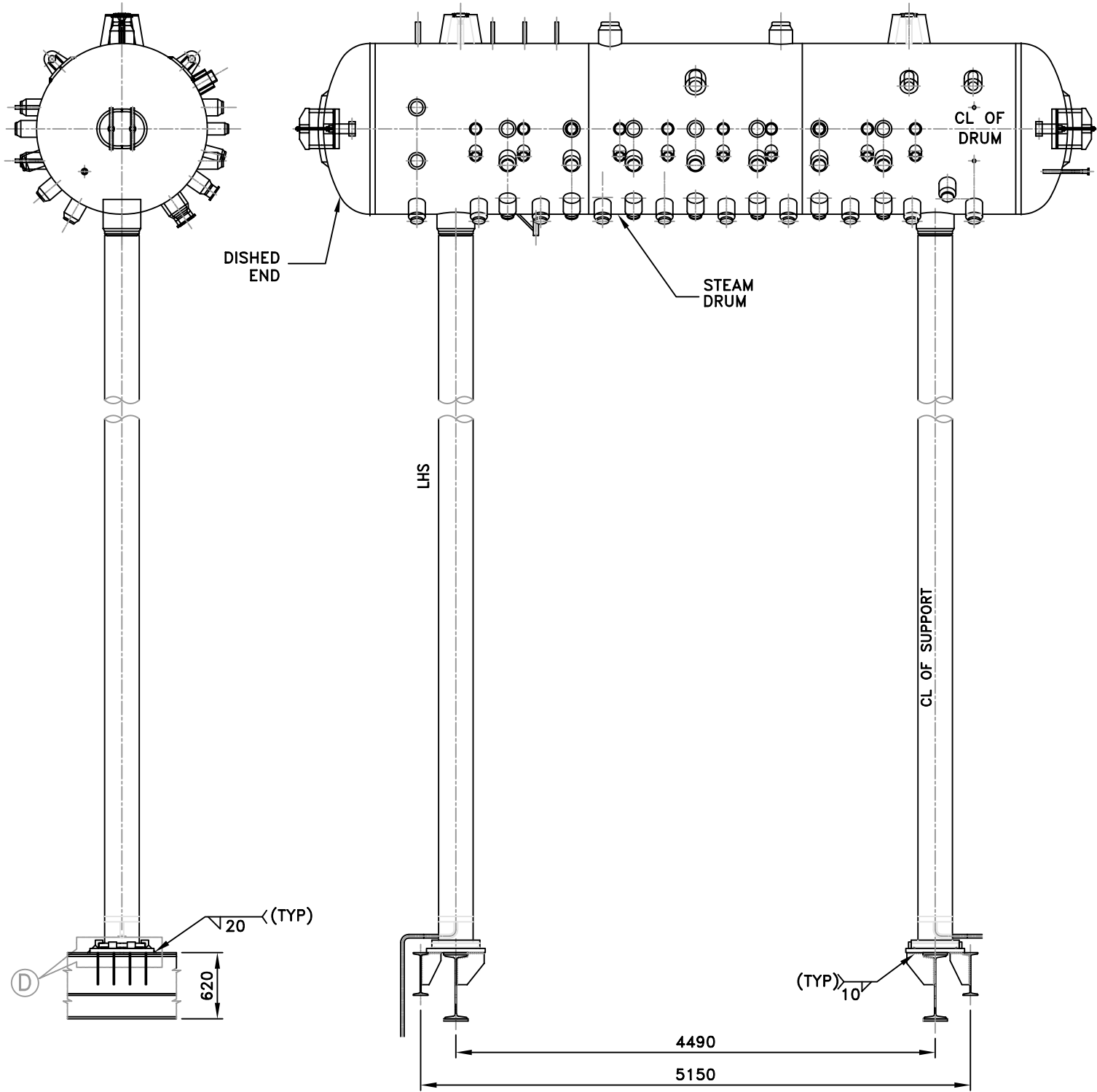
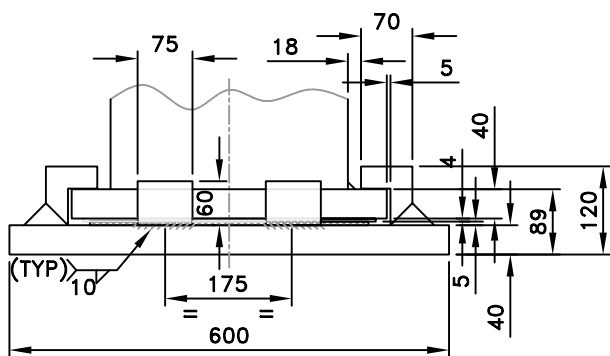


FIGURE NO.2 TYPICAL STEAM PIPING LAYOUT



SIDE VIEW

FRONT VIEW



DETAIL-D

FIGURE 3 (A) DOWNCOMER SUPPORTS FOR STEAM DRUM

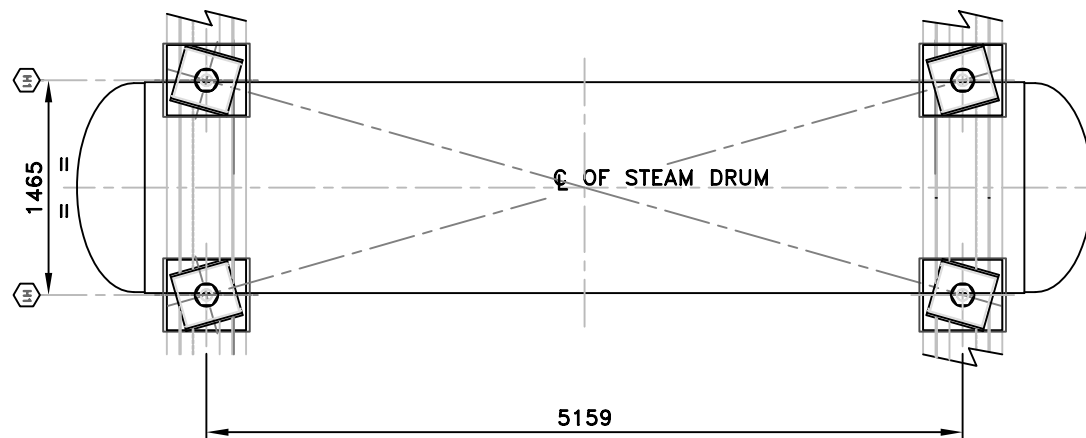
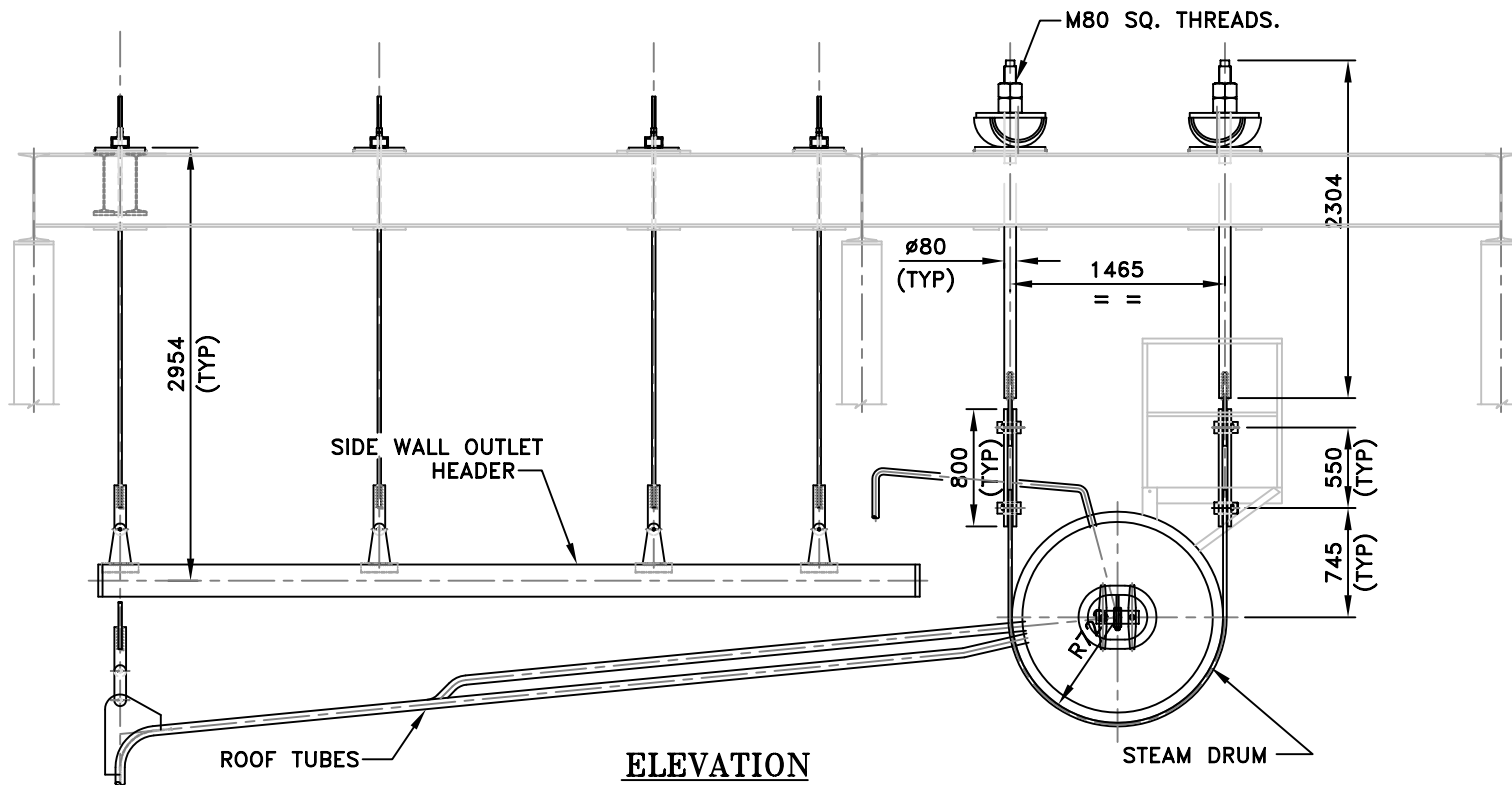


FIGURE NO.3 (B) PLAN VIEW SHOWING THE ROCKERS OF DRUM HANGERS

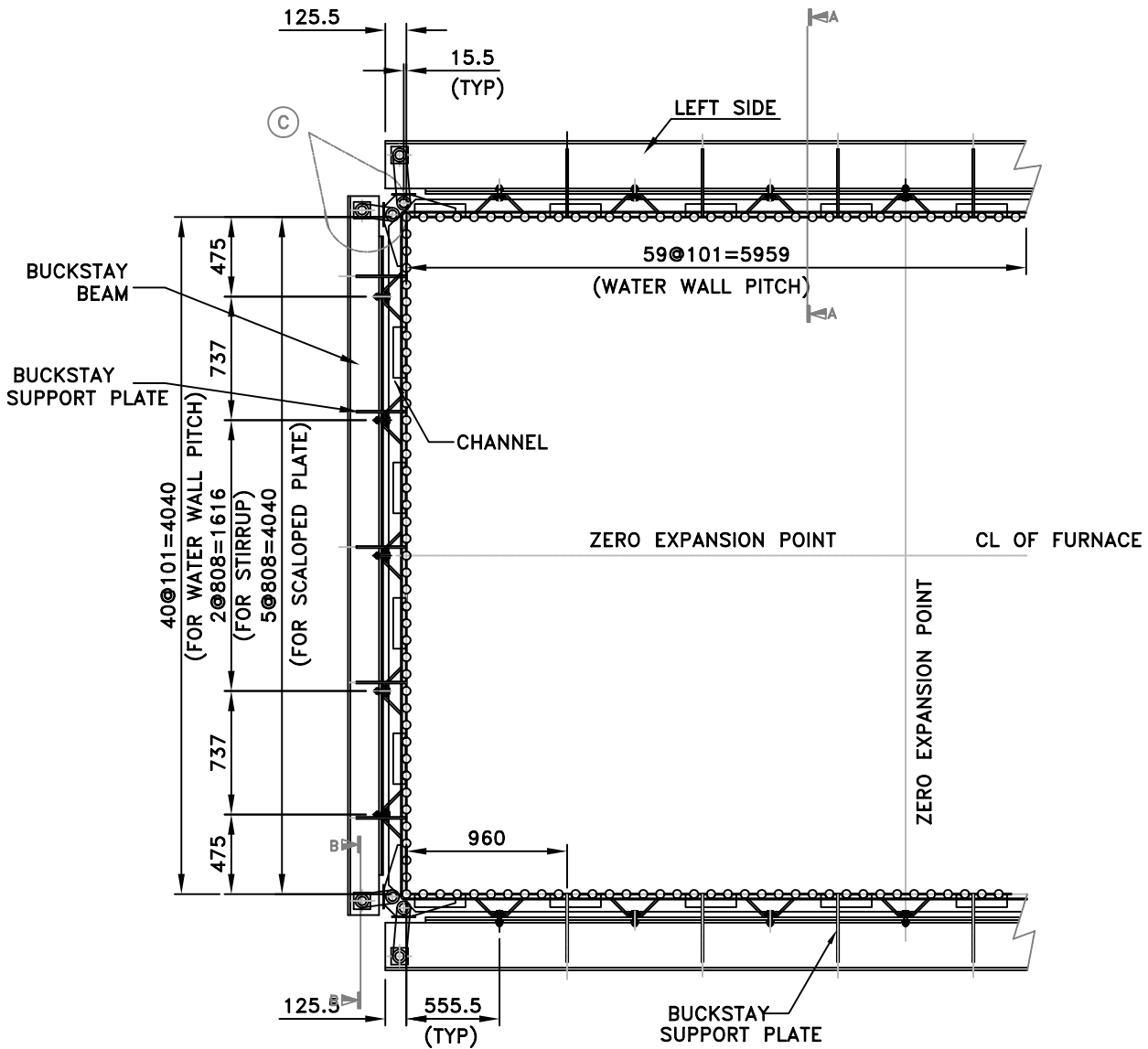
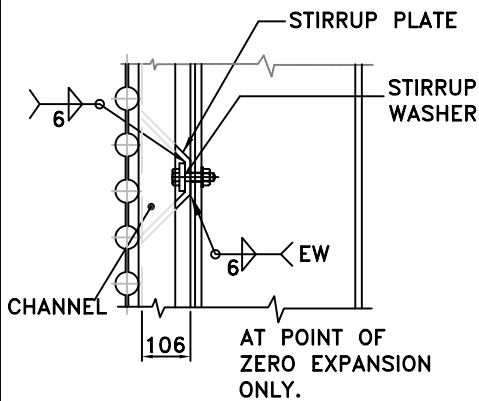
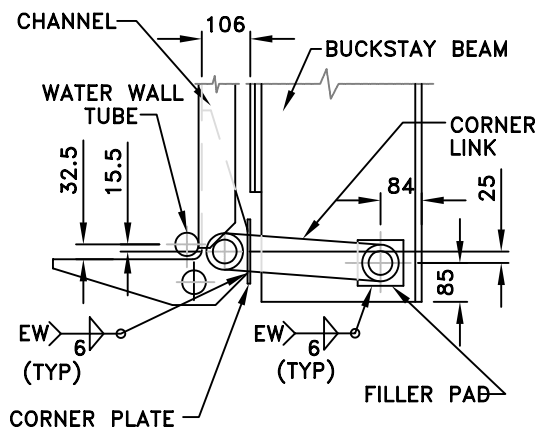


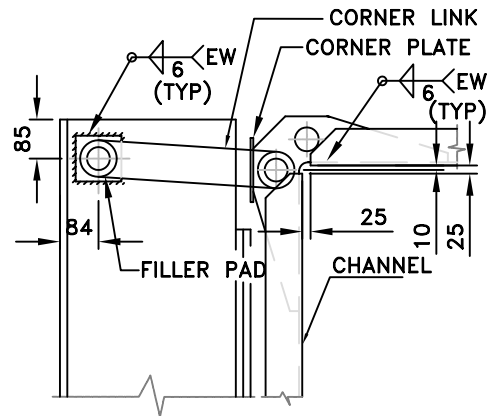
FIGURE NO.4 BUCKSTAY ARRANGEMENT FOR WATER WALL TUBES



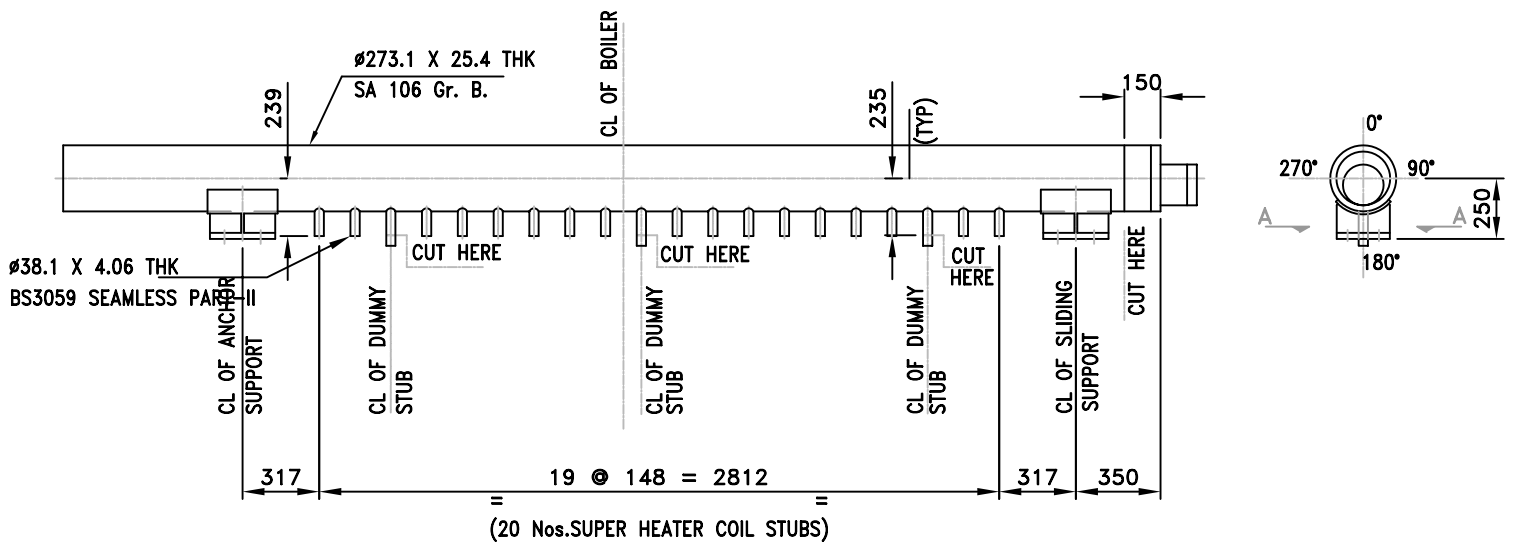
SECTION - AA



SECTION - BB

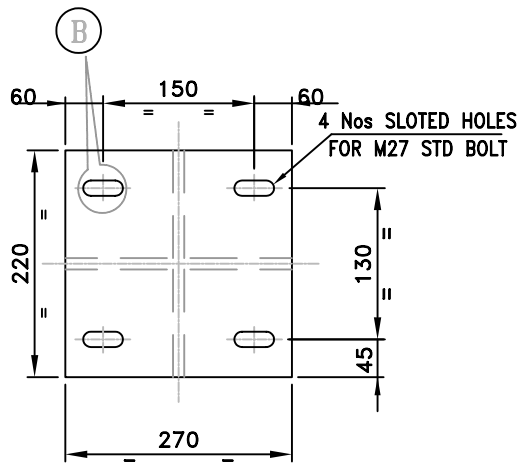


DETAIL - C

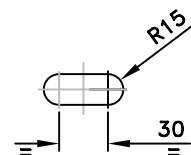


ELEVATION

SIDE VIEW

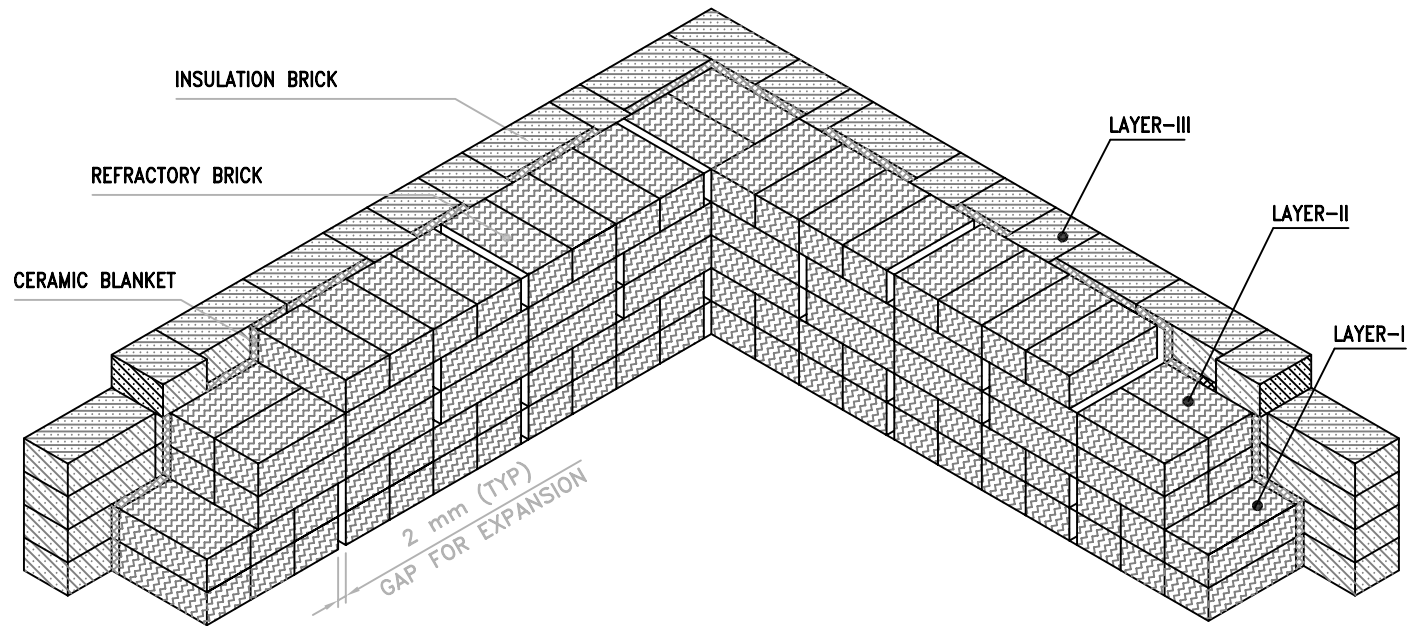


VIEW-AA



DETAIL - B

FIGURE NO.5 SUPERHEATER EXPANSION ARRANGEMENT AT SUPPORT LOCATIONS OVER SIDE WALL OUTLET HEADERS



FURNACE WALL CONSTRUCTION ARRANGEMENT

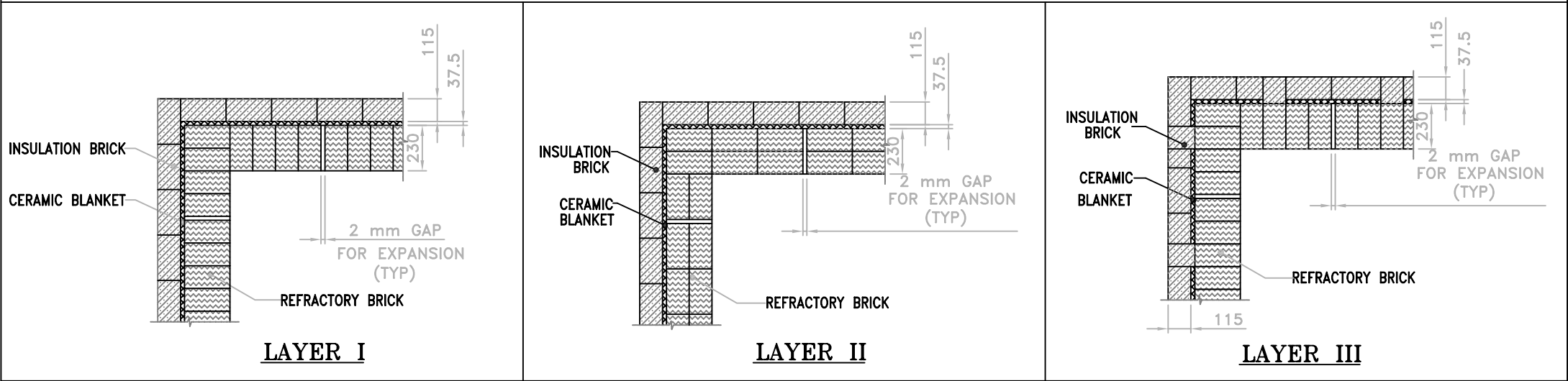


FIGURE NO.6 TYPICAL FURNACE REFRACTORY ARRANGEMENT

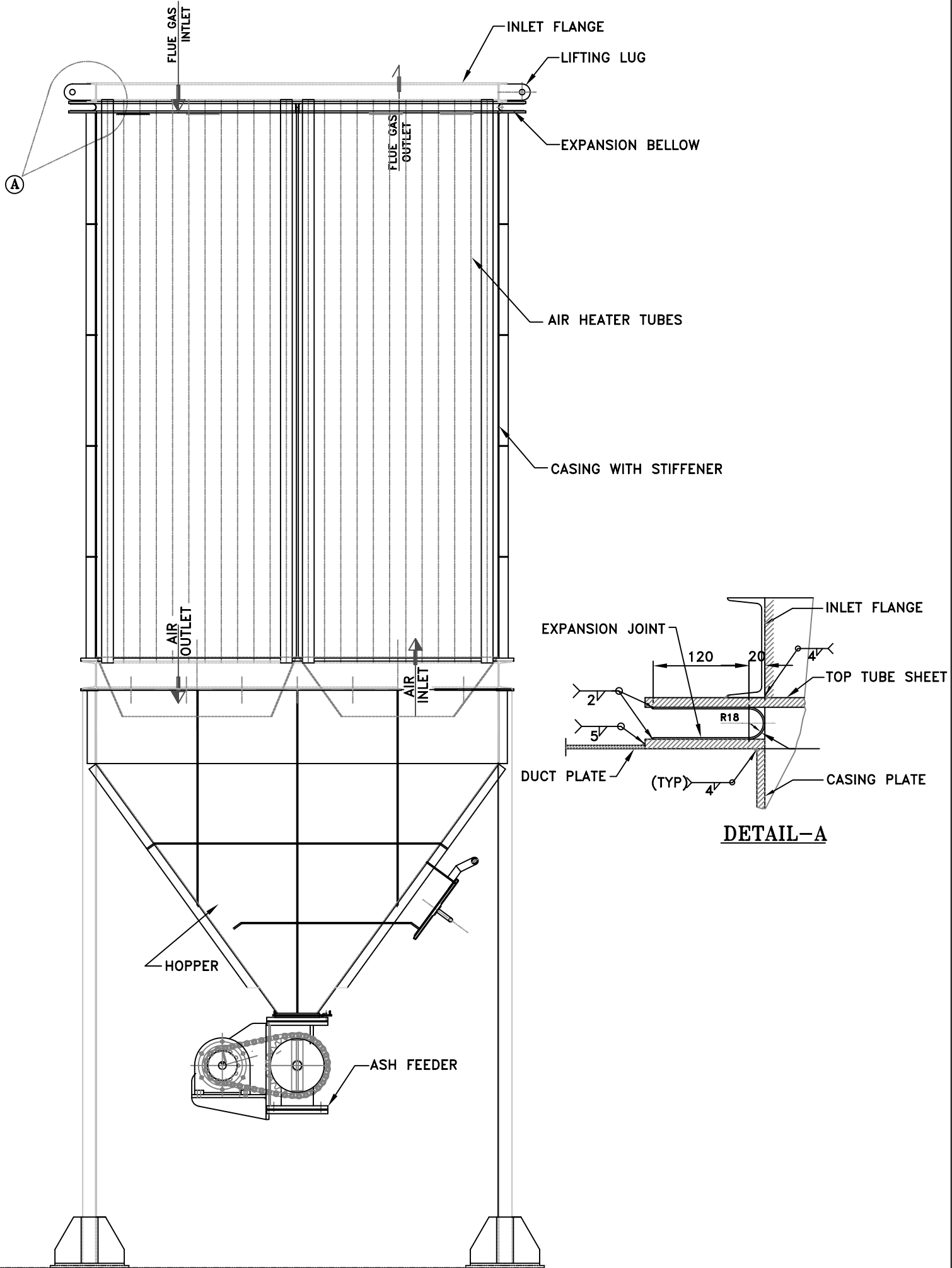
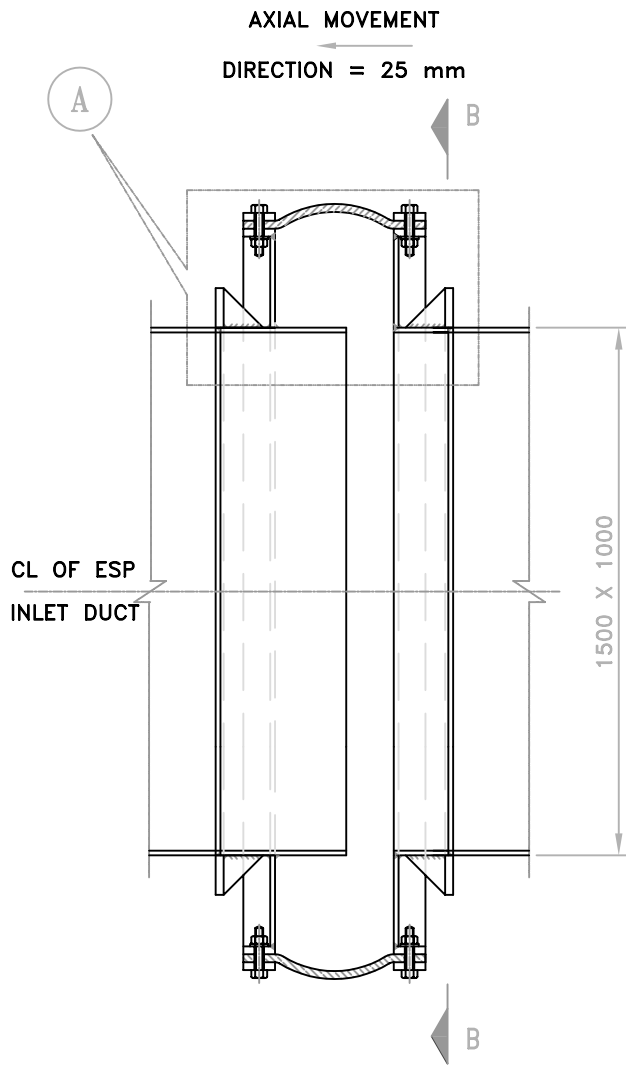
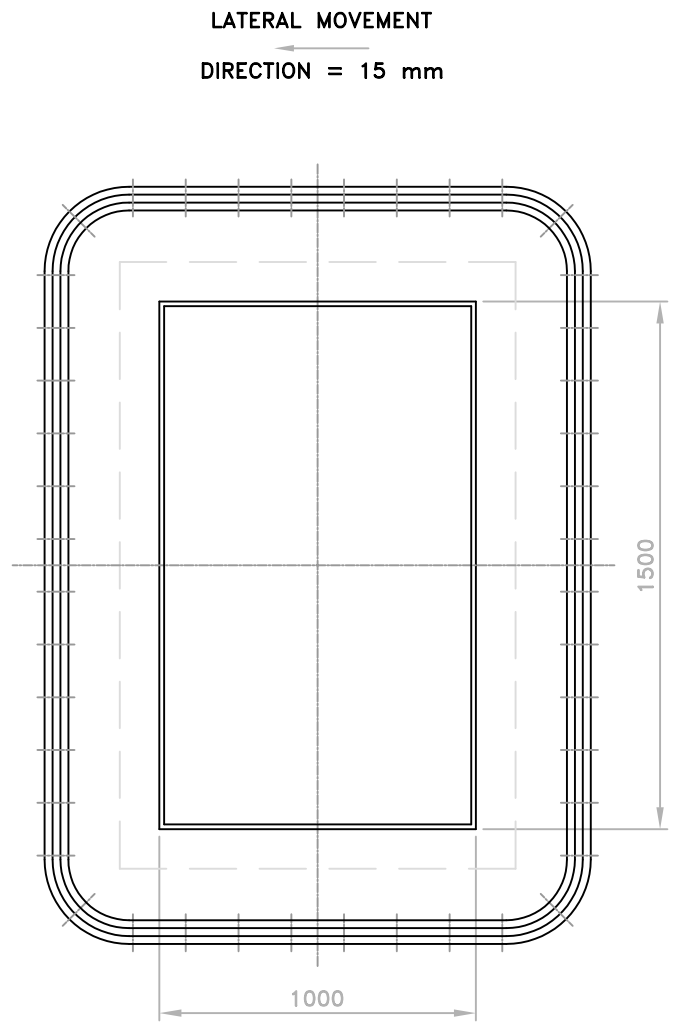


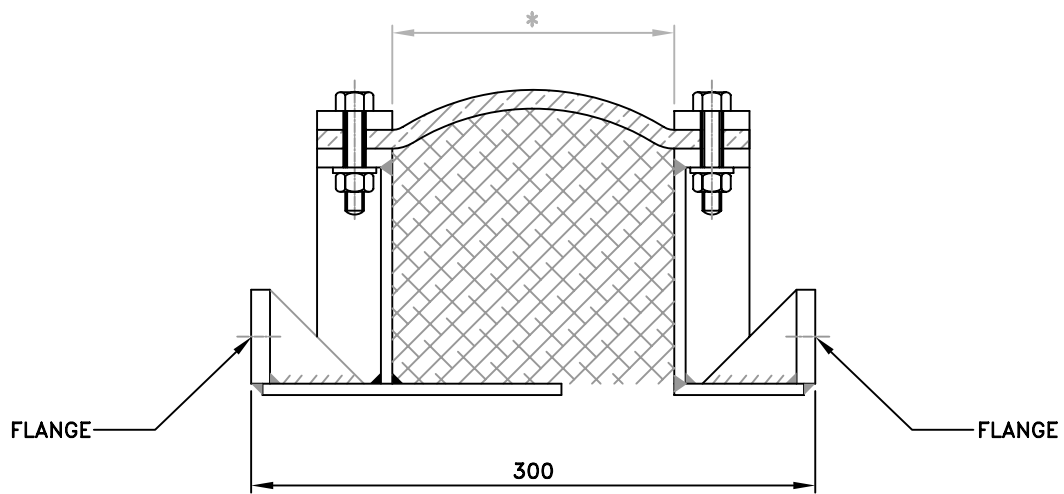
FIGURE NO.7 EXPANSION JOINT OF AIRPREHEATER



SECTIONAL ELEVATION



SECTION - BB



DETAIL - A

FIGURE NO.8 FABRIC EXPANSION BELLOW