Methanol-Hydrogen-Ammonia
Fired Heater Construction

A fired heater has various components which are thoroughly explained in the following paragraphs.

1.Catalyst tubes

2.Hairpins

3.Radiant section

4.Convection section

1.Catalyst tubes

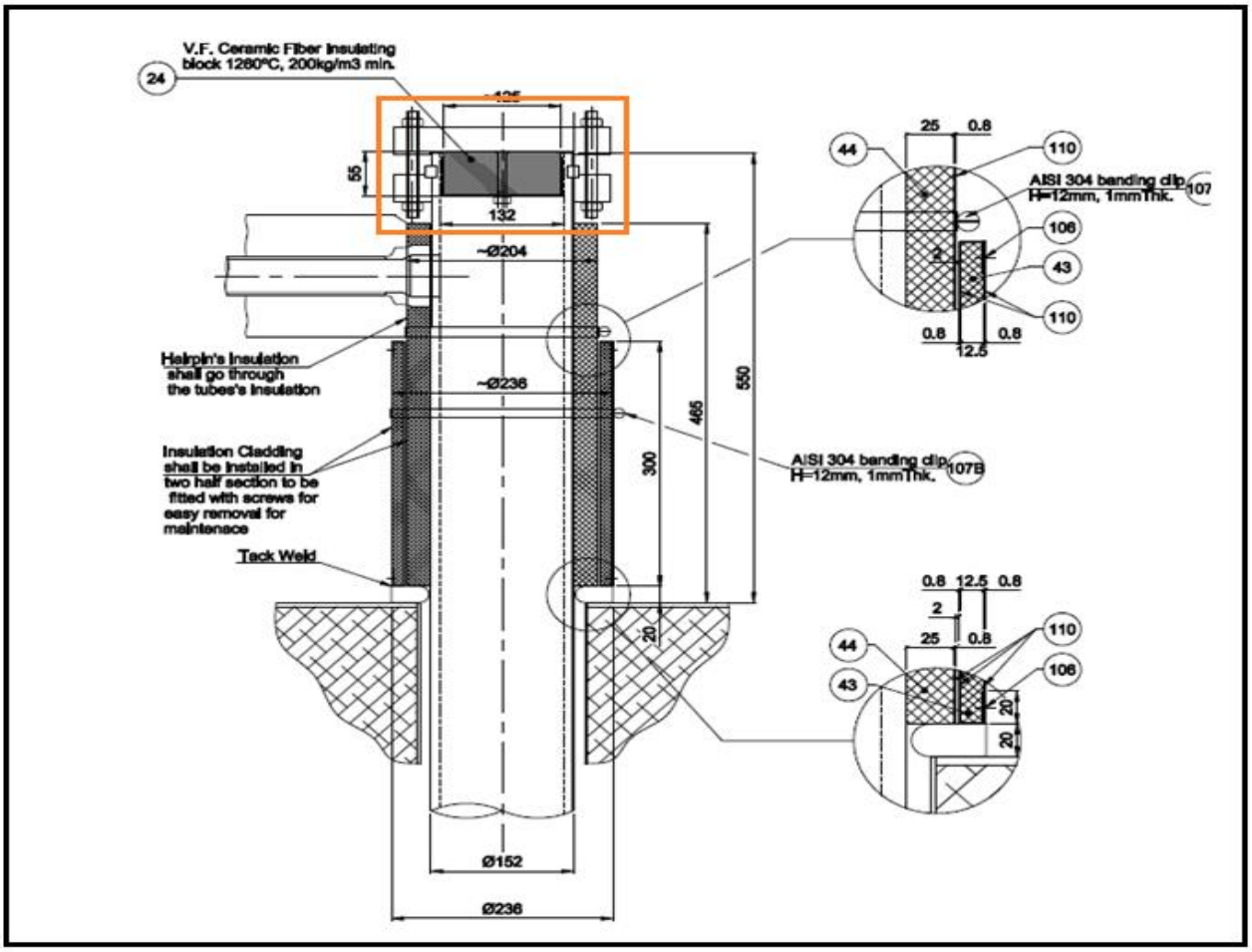
Typically, 312 tubes in the reformers are used which are divided between two chambers; it means that each chamber has 156 tubes. Now each chamber has 6 subsections which means that each subsection has 26 tubes. The tubes are butt-welded to cold collector. It should be stated that the life time of each catalyst tube is 100000 hr.

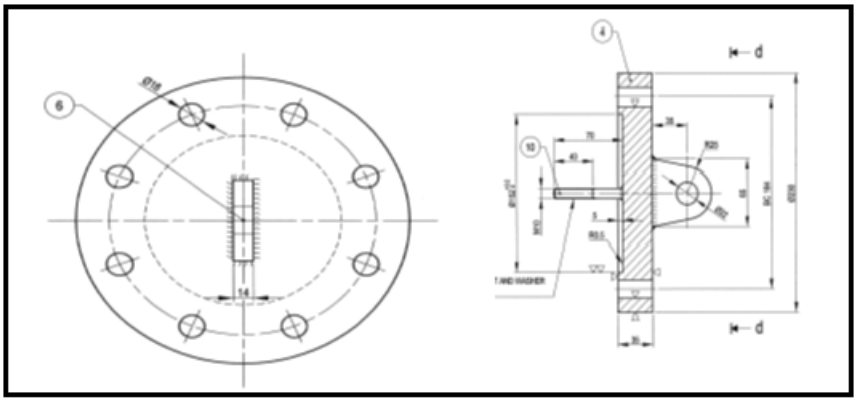
Each catalyst tube itself has the following components:

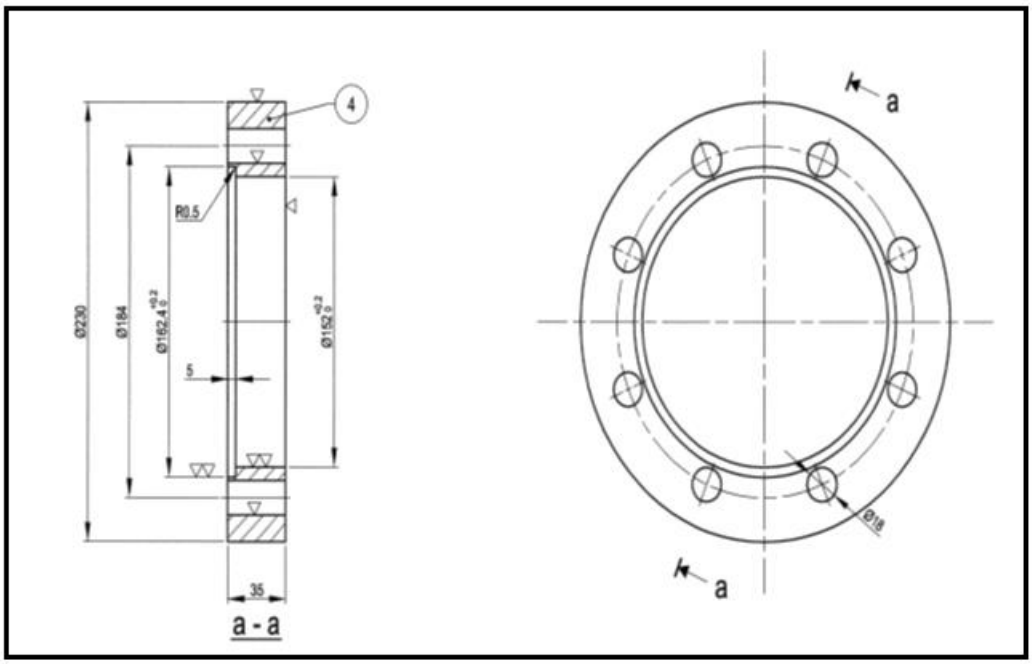
- Loose blind flange
- Two-part ring
- Inlet nozzle-pig tale
- Main tube
- Grid
- Reducer

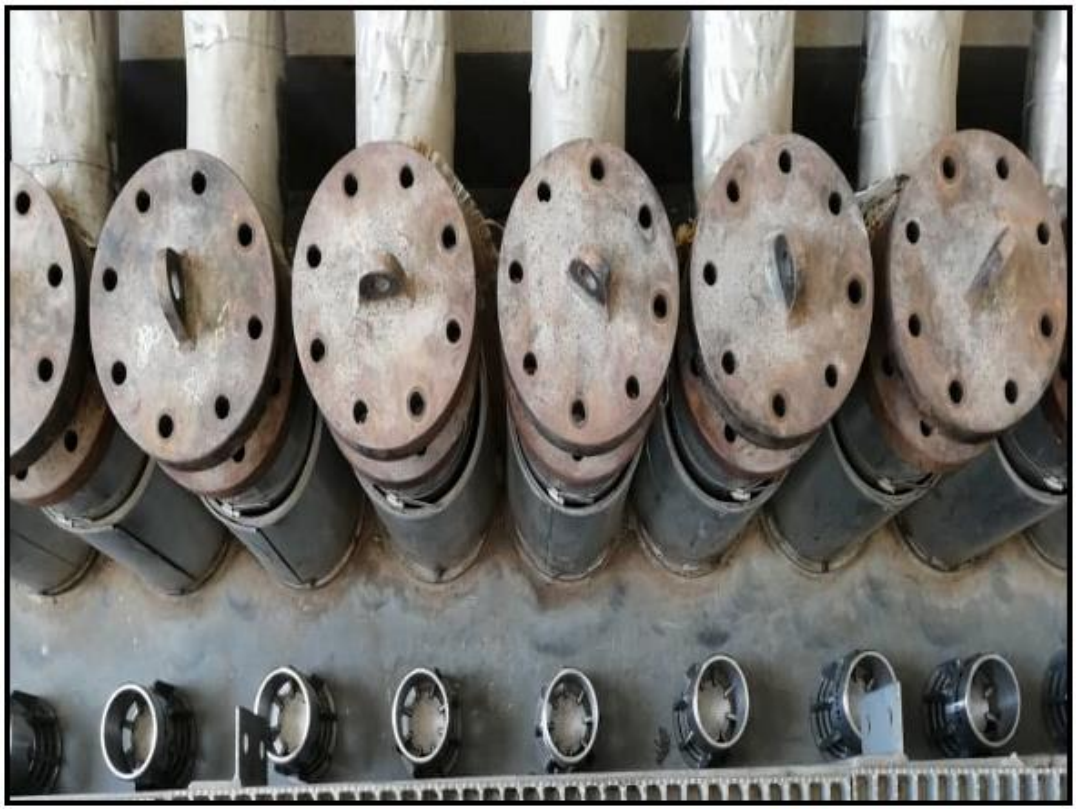
1.1. Loose blind flange

As its name suggests, it consists of loose and blind flange as shown in next page. The blind flange is connected to a hanger and under the blind flange there is cover bolt which holds a fiber insulating block which prevents the flow of the heat to the surrounding atmosphere. The fiber insulating block is of class of 1260C and is vacuum formed. It should be noted that a ceramic paper is installed before the block. The internal diameter of the flange is the same as tube diameter. The material used for blind and loose flange is typically ASTM A 182 F22.Since the flanges are not exposed that much to heat then there is no need to insulate them. In order to enhance the flange welding it is typical to carry out post weld heat treatment. The post weld heat treatment is done with temperature increase of 220C/hr. and the holding time is between 705-725C with the cooling rate of 280C/hr.


V.F. Ceramic Fiber insulating block 1260°C, 200kg/m3 min.
24
55
132
~Ø204
~Ø236
Hairpin's Insulation shall go through the tubes's insulation
Insulation Cladding shall be installed in two half section to be fitted with screws for easy removal for maintenace
Tack Weld
550
465
300
20
Ø152
Ø236
25
0.8
44
110
AISI 304 banding clip H=12mm, 1mmThk.
107
106
43
2
0.8
12.5
107B
20


6
4
d


4
R0.5
Ø230
Ø184
Ø162.4
Ø152
5
35
a - a
a
a
Ø18

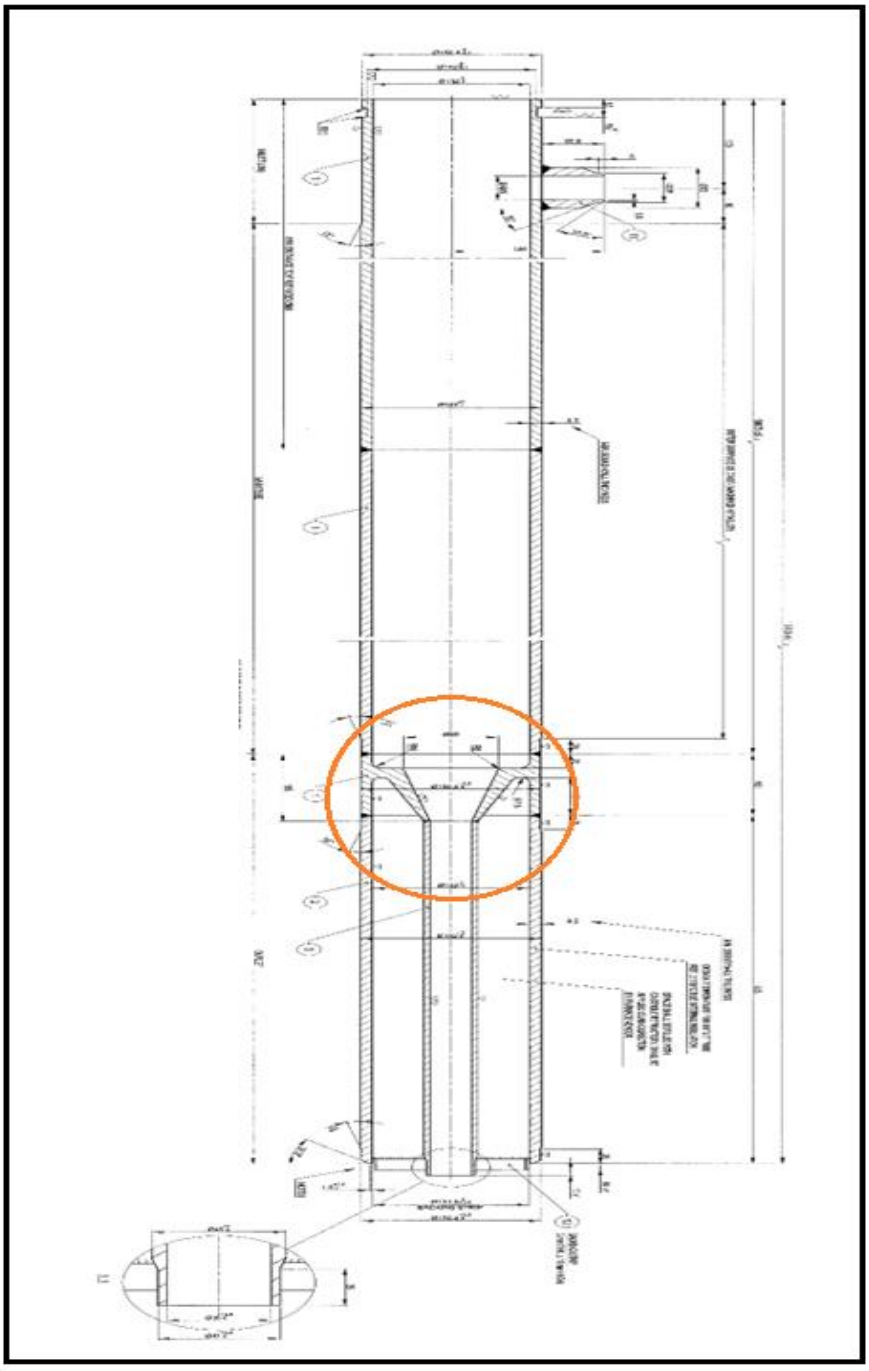


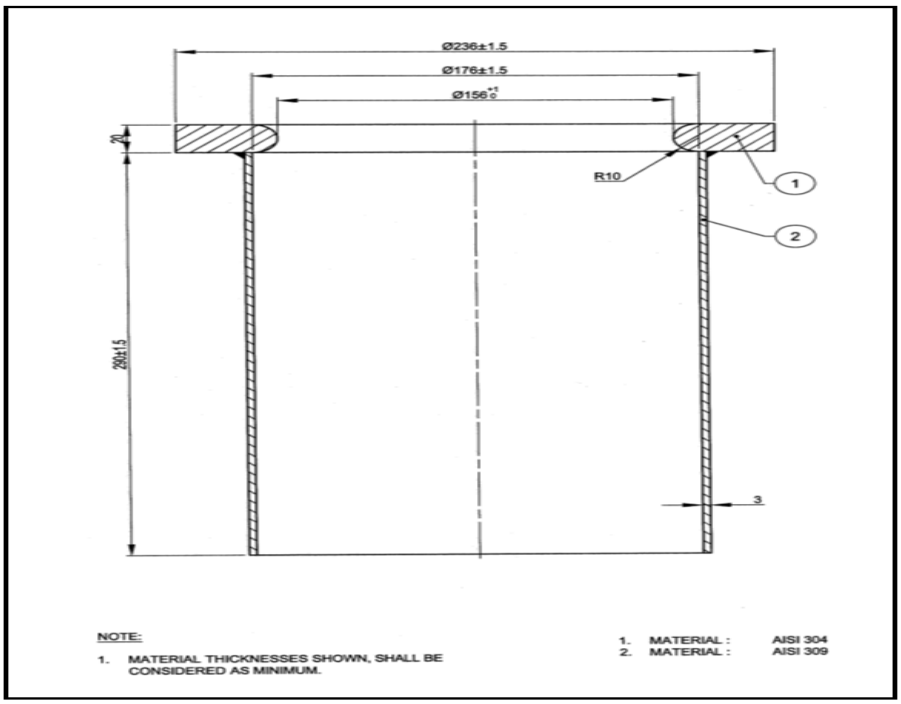
1.2. Inlet nozzle

The purpose of inlet nozzle is to connect the hairpins to catalyst tubes with the inner diameter of 40mm and outer diameter of 70mm. The typical material used is ASTM A182 F321 H. The inlet nozzle is located typically 120mm below the flanges.

1.3. Main tubes

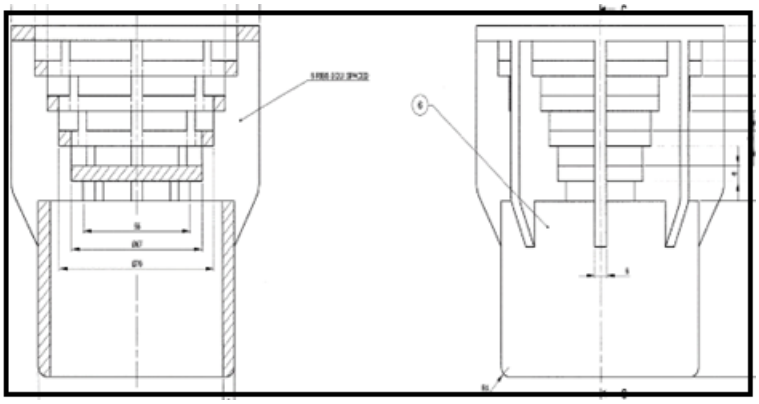
Typical length of the tube for methanol, ammonia and hydrogen plant is approximately 13m and the material used is Cr25Ni35NbTi. Based on tube stress analysis of different vendors the minimum sound wall temperature for such reformer is 9.2mm. Typical ID for the tubes is approximately 13cm and OD is 15cm. The main tube has three cast part, the minimum length of which is 2.5m. The parts are butt-welded to each other. Based on the next page picture the end of the main tube is reduced from 80mm to 45mm. As it is shown, at the of the main tube we have an internal tube and external tube; the internal tube is welded to the reducer. The upper end of the main tube is exposed to the atmosphere but there is a guide ring between the catalyst tubes and fiber modules of furnace arc. The length and thickness of the ring is 300mm and 3m respectively.




Ø236±1.5
Ø176±1.5
Ø156
20
R10
1
2
200±1.5
3
NOTE:
1. MATERIAL THICKNESSES SHOWN, SHALL BE CONSIDERED AS MINIMUM.
1. MATERIAL : AISI 304
2. MATERIAL : AISI 309

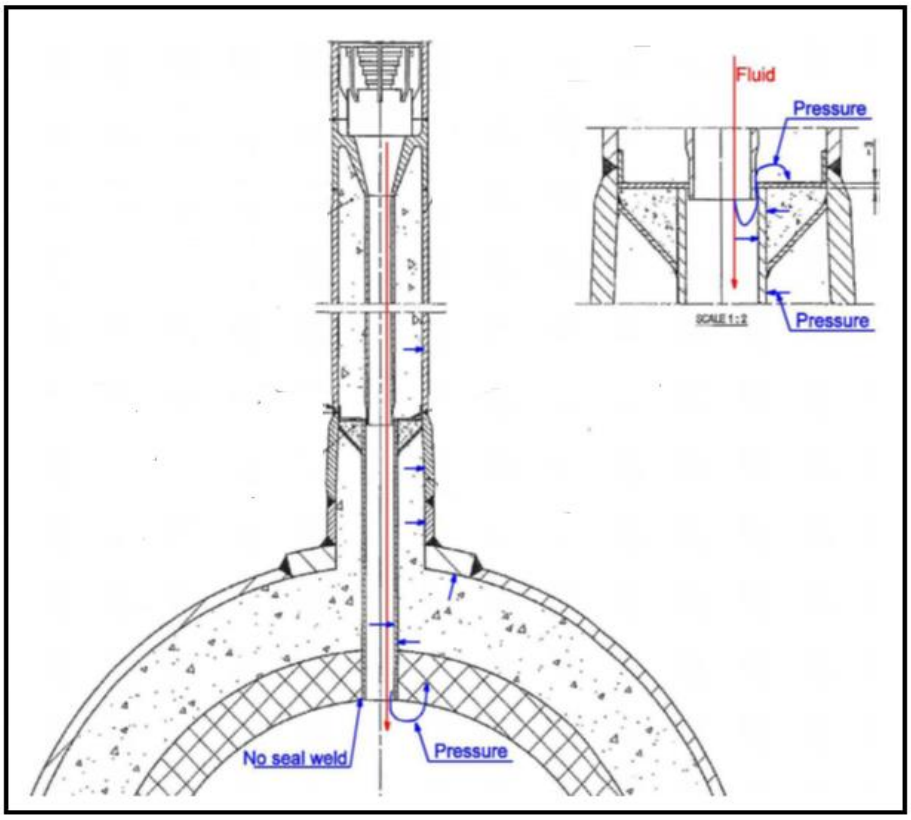
1.4. Grids

Grids, which serve the function of holding the catalysts inside the tube are installed at the end of catalyst tubes or at the inlet of reducer to internal tube. Gas stream can simply go through the circular holes.

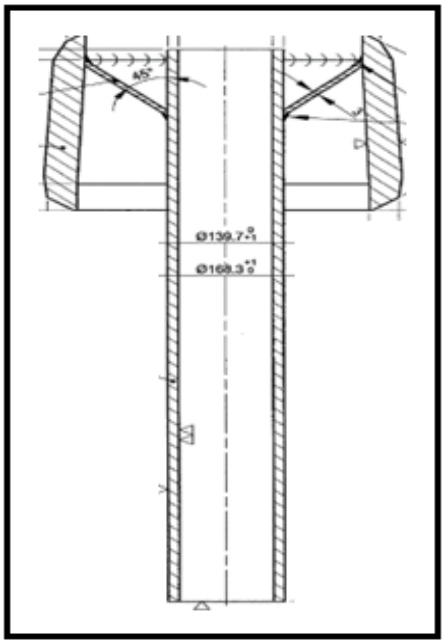


1.5. Reducer

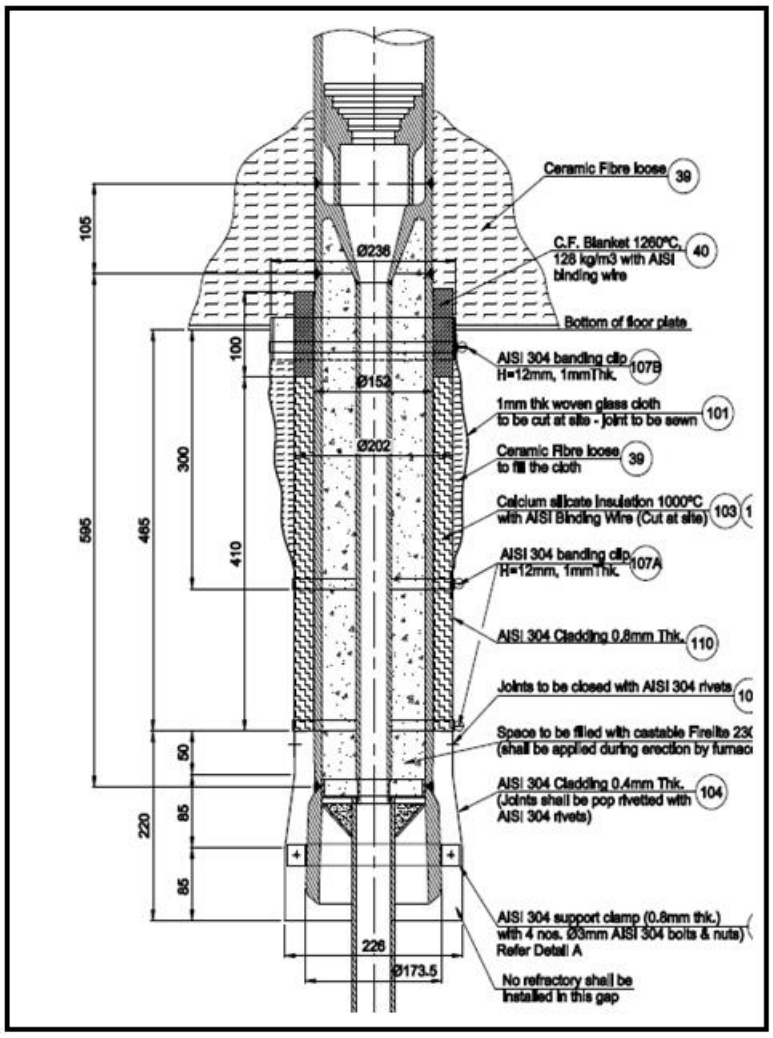
The function of the reducer at the end of the catalyst tubes is to connect catalyst tubes to cold collector. The way they are connected is shown below. The internal tube is reduced and is welded to internal tube of cold collector.



Before welding the catalyst tubes to cold collector, the volume between internal and external tubes is filled with insulating castable firelite 2300VL, then we have ceramic fiber paper compressed and finally we have castable refractory in the triangle section.

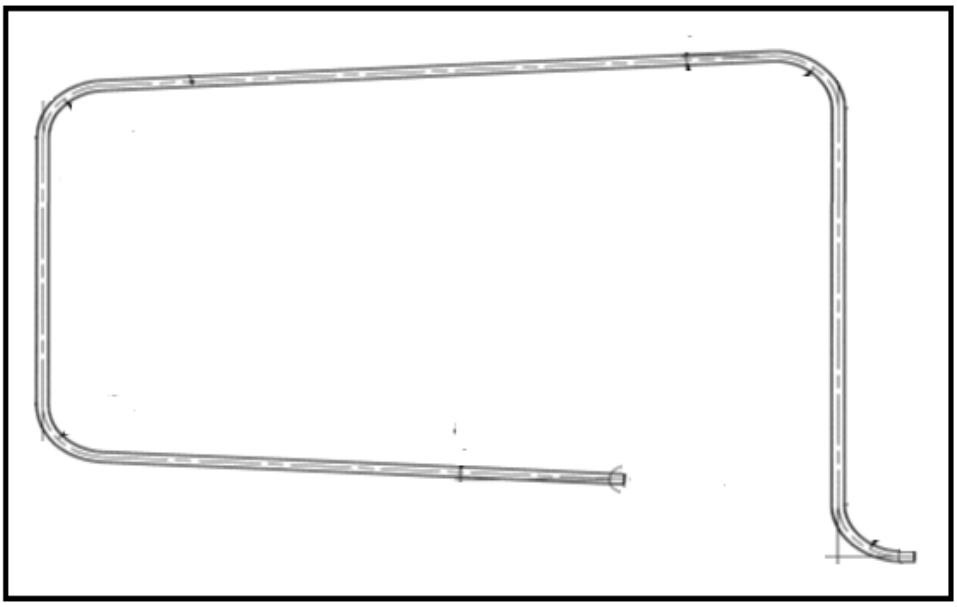


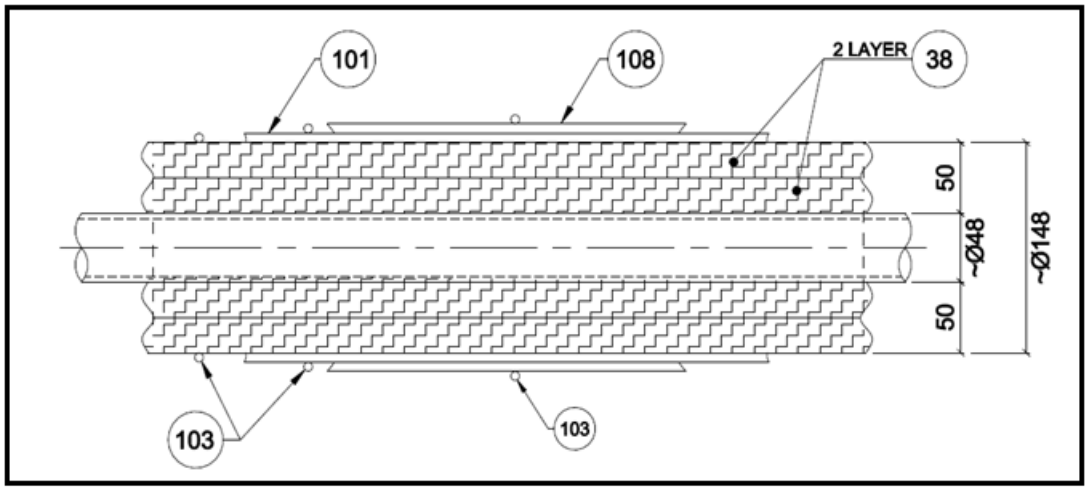
Before installation of catalyst tubes, they should be washed with acetone free of sulfur or chlor. Also, in order to remove moisture in castable dry-out procedure should be performed. 600 mm of catalyst tube end plus the reducer should be covered by electrical coil. During the dry-out the temperature should be increased 60C/hr. and the holding temperature is around 120C with holding time of 1-4hr. The criteria to finish dry-out is when there is no amount of steam coming out. The cooling rate is 60C/hr.



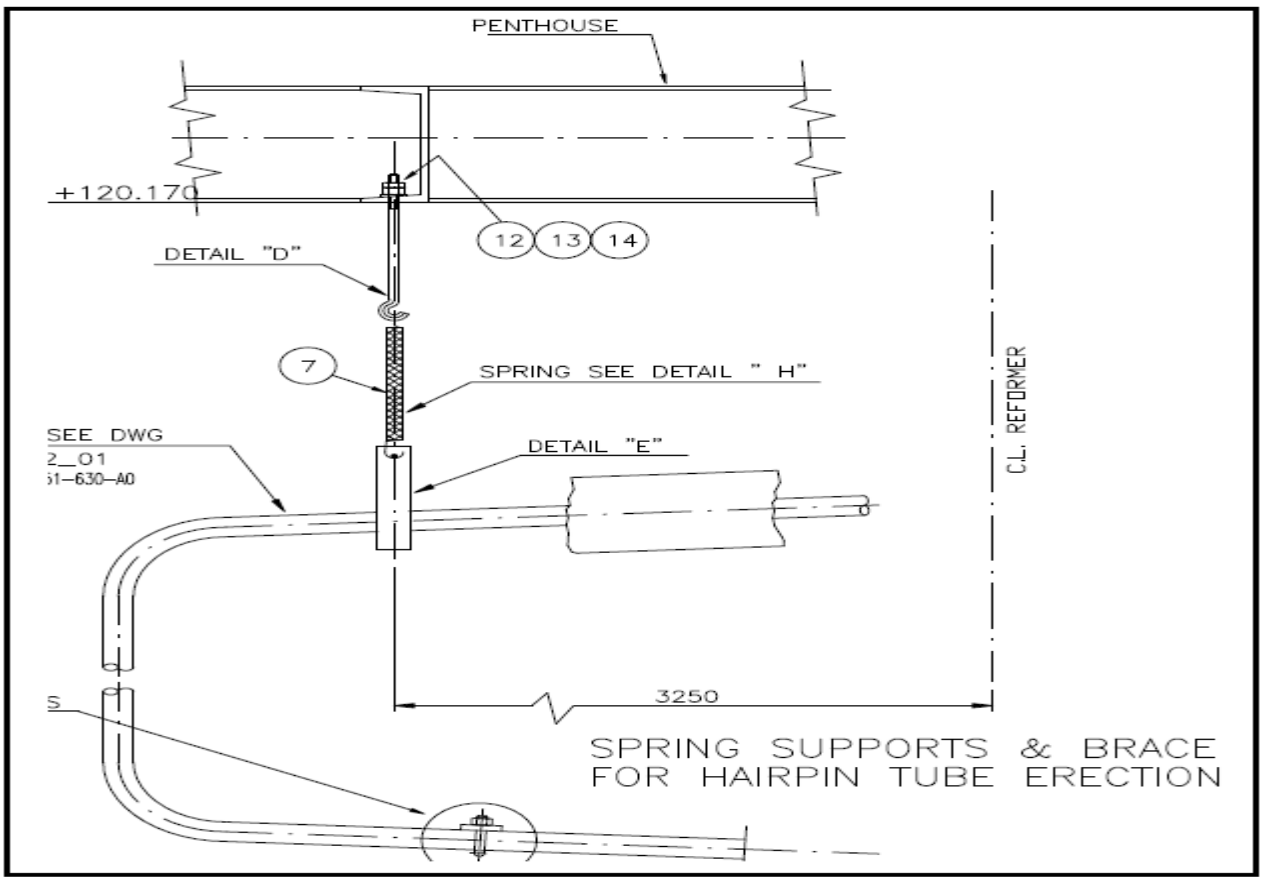
2.Hairpins

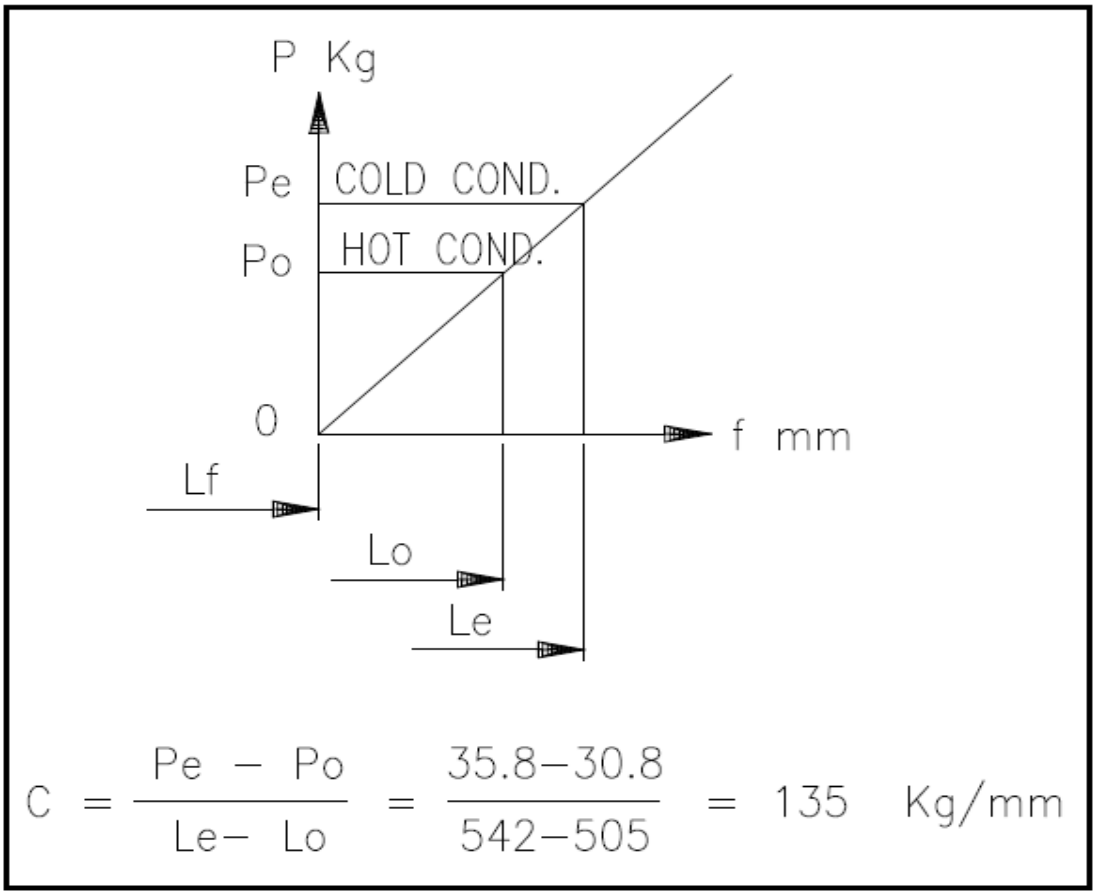
Hairpins serve to connect the inlet distributer and catalyst tubes and the material used for hairpins is ASTM A312 TP 321H. In order to maintain the load they are bended to 4 parts. In order to prevent heat loss, hairpins are covered by 2 layers of Ceramic Fiber Blanket AES160 Kg/m2, one layer of Wrapping Glass Fiber Cloth and one layer of foil. To be able to maintain such structure together, binding wire is used.





In order to balance all forces, a spring support with the following design is used. It is noteworthy that the length of spring during fabrication, installation, and operation is 276,506, and 542 mm respectively.





In order to fabricate such hairpins, the following steps are taken:

2.1. Re-inspection of Pipes

2.2. Marking for cold bending

2.3. Cold bending

2.4. Marking for cold bending

2.5. Adjustment

2.6. Cutting

2.7. Beveling

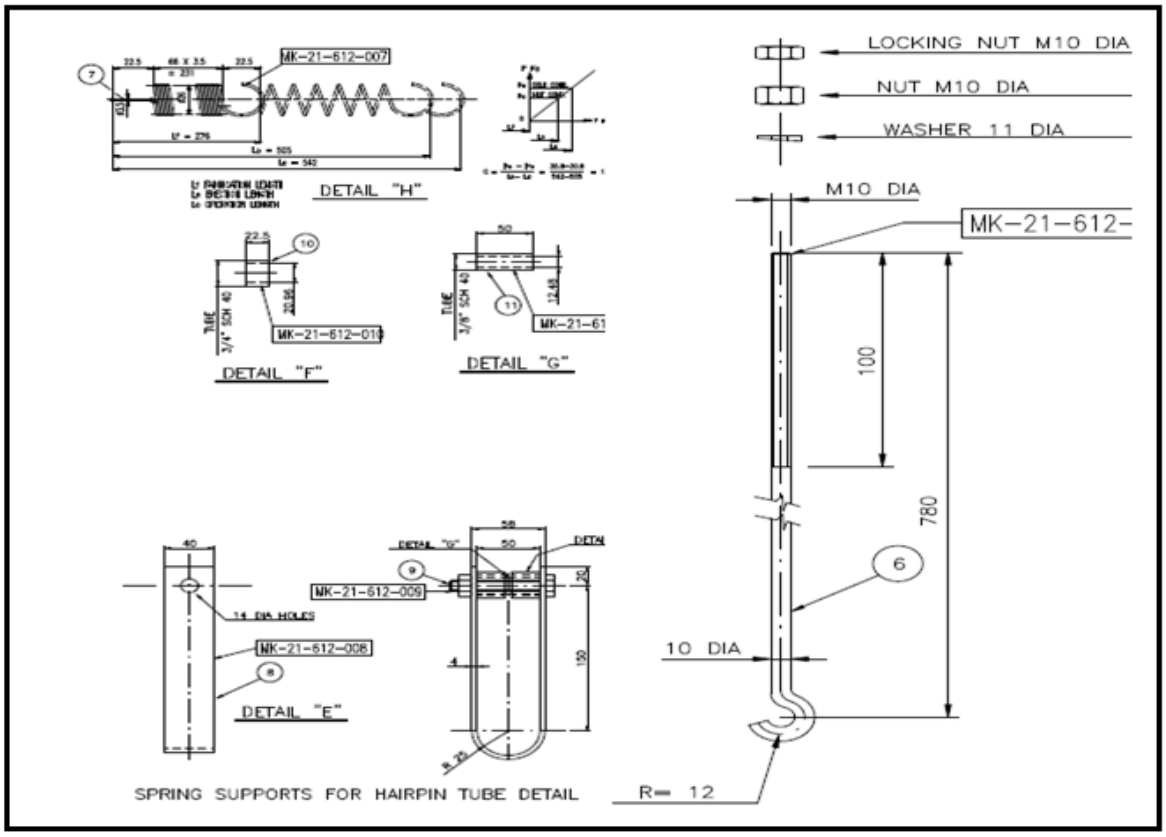
2.8. NDT

2.9. Pickling and Passivation

2.10. Cleaning

2.11. Air Blow

2.12. Final Inspection



3.Radiant section

Radiant section itself has the following sections:

3.1. Side wall burners

3.2. Side wall peep holes

3.3. End wall peep holes

3.4. Side wall burners in-between

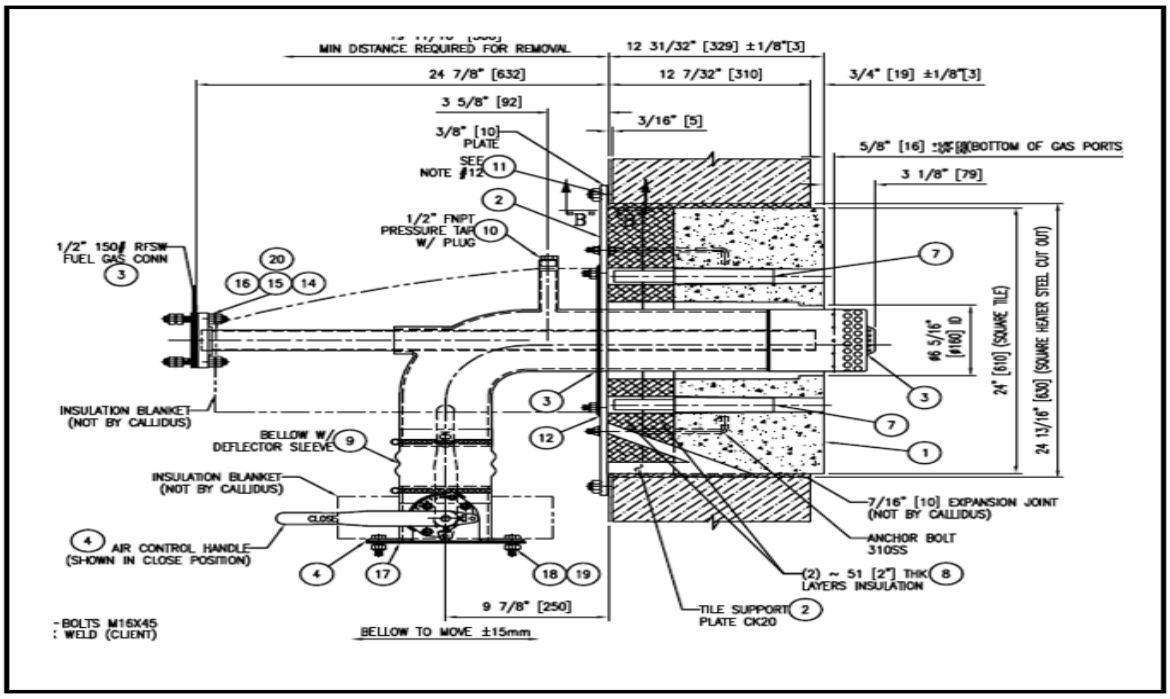
3.5. Floor

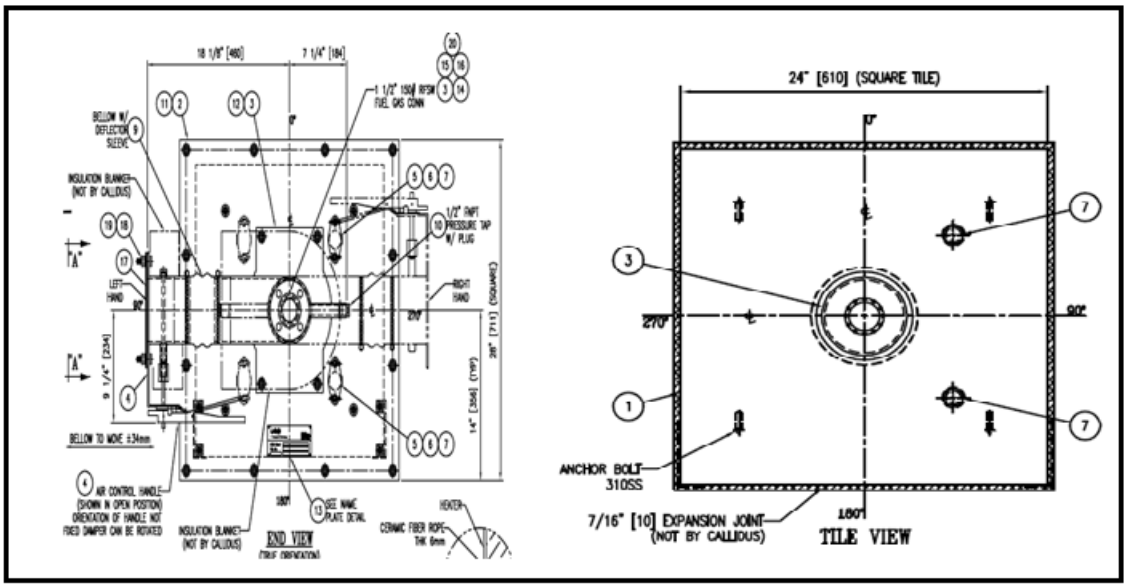
3.6. Radiant Arch

The mentioned sections do not have special design consideration; the thing that makes each section special and unique is the refractory used in each section. Generally, a layer of block insulation and a layer of insulating firebricks are used for side-wall burners and floor section. Also, ceramic fiber modules are used for side wall, end wall, arch, and flue gas duct.

3.1. Side wall burners

The side wall burners arrangement consists of 3 layers which starts with insulation block, then firebrick Gr.23 and firebrick Gr.26 from viewing direction. From lower part it starts with ceramic fiber module, ceramic fiber blanket, firebricks, dry expansion joint and burner plate.




24" [610] (SQUARE TILE)
270°
90°
180°
ANCHOR BOLT
310SS
7/16" [10] EXPANSION JOINT
(NOT BY CALLIOUS)
TILE VIEW
END VIEW
BELLOW TO MOVE ±3mm
INSULATION BLANKET
(NOT BY CALLIOUS)
CERAMIC FIBER ROPE
THK 6mm
HEATER

Notes:

- Insulation blocks, which are fabricated under vacuum have a maximum operating temperature of 1100 C with the density and thermal conductivity of 300-360 kg/m^3 and 0.06-0.08 w/m.k respectively. The typical thickness used are 25 and 50 mm.
- Firebrick Gr.23 has the following characteristics:

Standard Length	230×114
Composition	TiO_2+Al_2O_3: 35-45% SiO_2:40-55% Fe_2O_3: max 1%
Maximum Operating Temperature	1260C
Density	480-530 kg/m^3
Thermal Conductivity	0.15-0.26 w/m.k @ 600-800C
Permanent Linear Change	-1%

- Firebrick Gr.26 has the following characteristics:

Standard Length	230×114
Composition	TiO_2+Al_2O_3: 55-65% SiO_2:35-40% Fe_2O_3: max 0.8%
Maximum Operating Temperature	1425C
Density	650-800 kg/m^3
Thermal Conductivity	0.27-0.35 w/m.k @ 600-1200C
Permanent Linear Change	-0.5%

- There are two grades of ceramic fiber modules including 1260C and 1425C. For this project 1425C grade was used. Here are other characteristics:

Density	128 kg/m^3 before compression 160-170 kg/m^3 after compression
Composition	Al_2O_3: 35% ZrO_2:15%
Maximum Operating Temperature	1425C
Thermal Conductivity	0.15-0.18 w/m.k @ 600-1200C

- There are two grades of ceramic fiber blankets including 1260C and 1425C. For this project 1260C grade was used. Here are other characteristics:

Density	128 kg/m^3 before compression
Composition	Al_2O_3 + ZrO_2:45%
Maximum Operating Temperature	1260C
Thermal Conductivity	0.15 w/m.k @ 600C
Thickness	25 mm

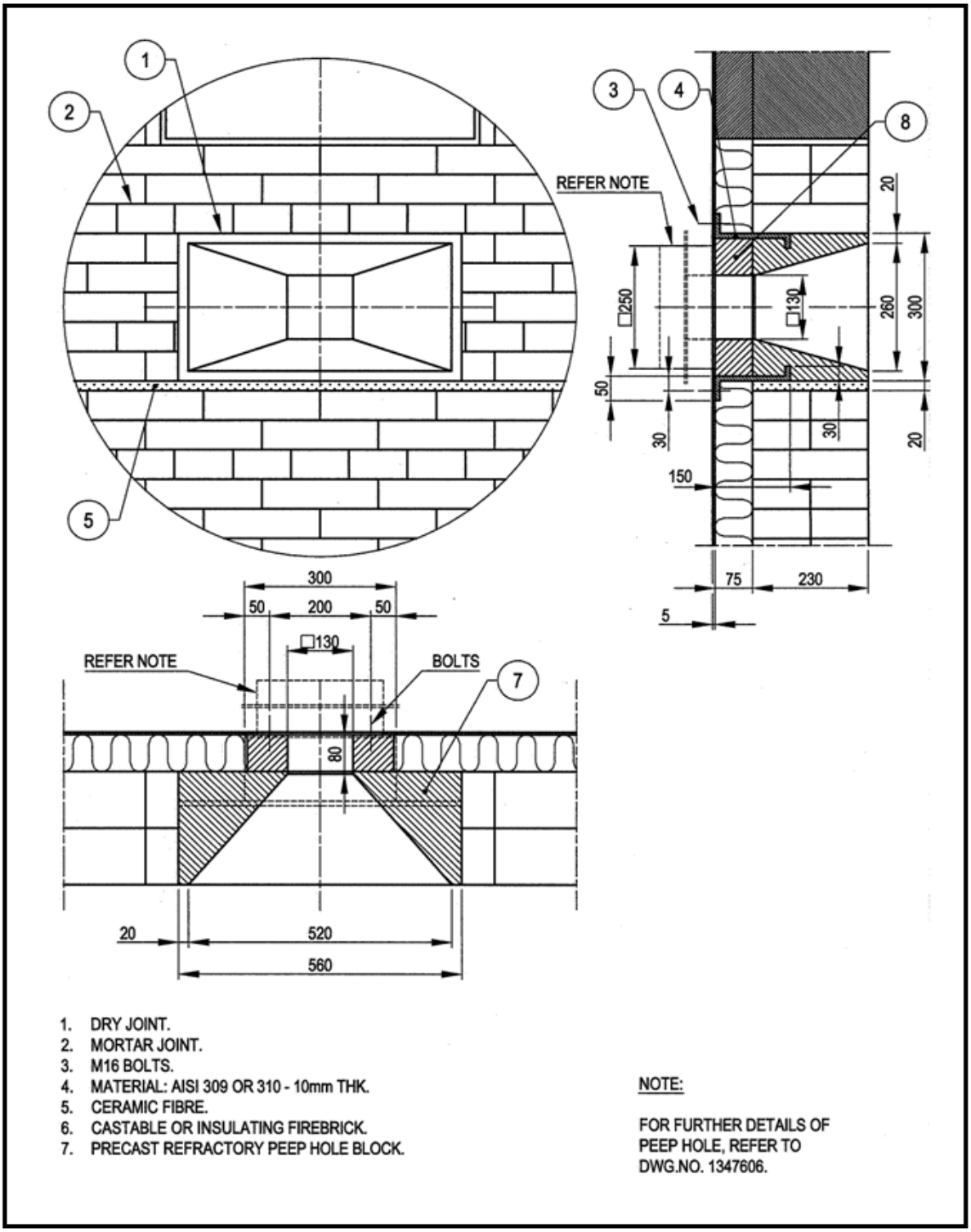
- There are two grades of ceramic fiber blankets including 1260C and 1425C. For this project 1425C grade was used as expansion joint around burners. Here are other characteristics:

Density	128 kg/m^3 before compression
Composition	Al_2O_3: 35% ZrO_2:15%
Maximum Operating Temperature	1260C
Thermal Conductivity	0.15 w/m.k @ 600C
Thickness	10 mm

- The arrangement around burner tips is like this : At first we have two layers of insulating blocks (Vacuum formed fiber module + Calcium silicate 1000C), then one layer of Tile LE-Carw-6 Perforated with the composition of 60 % alumina.

3.2. Side wall peep holes

At first, we have precast refractory peep hole block and castable firebrick surrounded by dry joint and fire bricks. Mortar joint are used in firebricks in-between. In order to keep refractories in position M16 bolts are used. On next page there is a drawing which illustrates the above explanation.



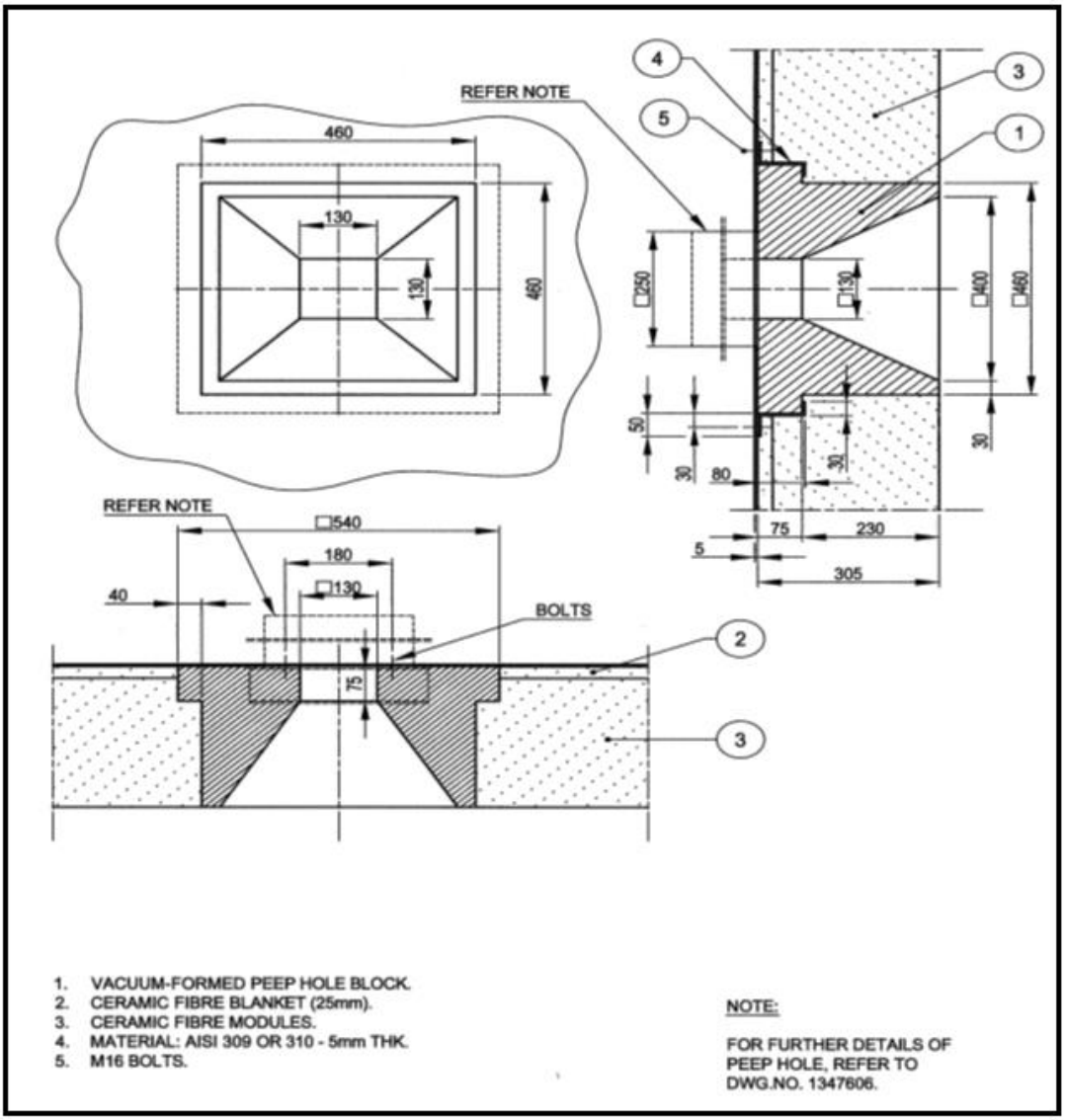
1. DRY JOINT.
2. MORTAR JOINT.
3. M16 BOLTS.
4. MATERIAL: AISI 309 OR 310 - 10mm THK.
5. CERAMIC FIBRE.
6. CASTABLE OR INSULATING FIREBRICK.
7. PRECAST REFRACTORY PEEP HOLE BLOCK.

NOTE:

FOR FURTHER DETAILS OF PEEP HOLE, REFER TO DWG.NO. 1347606.

3.3. End wall peep holes

Since the temperature in end-wall and side-wall is different different material is used for side-wall peep holes. In this purpose vacuum formed peep hole block surrounded by ceramic fiber module is used.



3.4. Side wall burners in-between

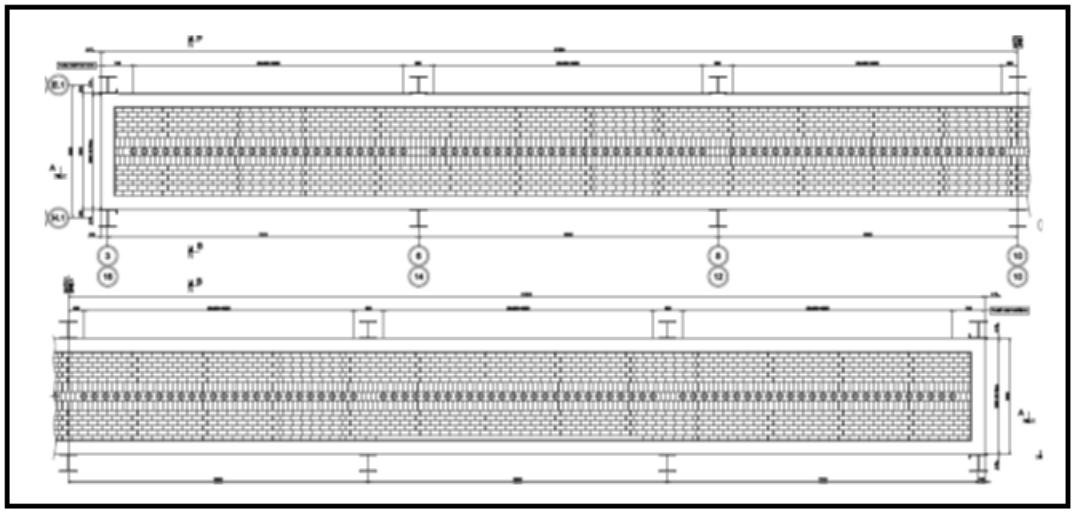
The typical arrangement consists of ceramic fiber blanket 1260 C and ceramic fiber module.

3.5. Floor

The floor arrangement is made up of 6 layers from upper part to lowest part starting with one layer of high duty firebricks, three layers of firebricks Gr. 23 and two layers of insulation block 1100 C with the thickness of 25 and 50 mm.

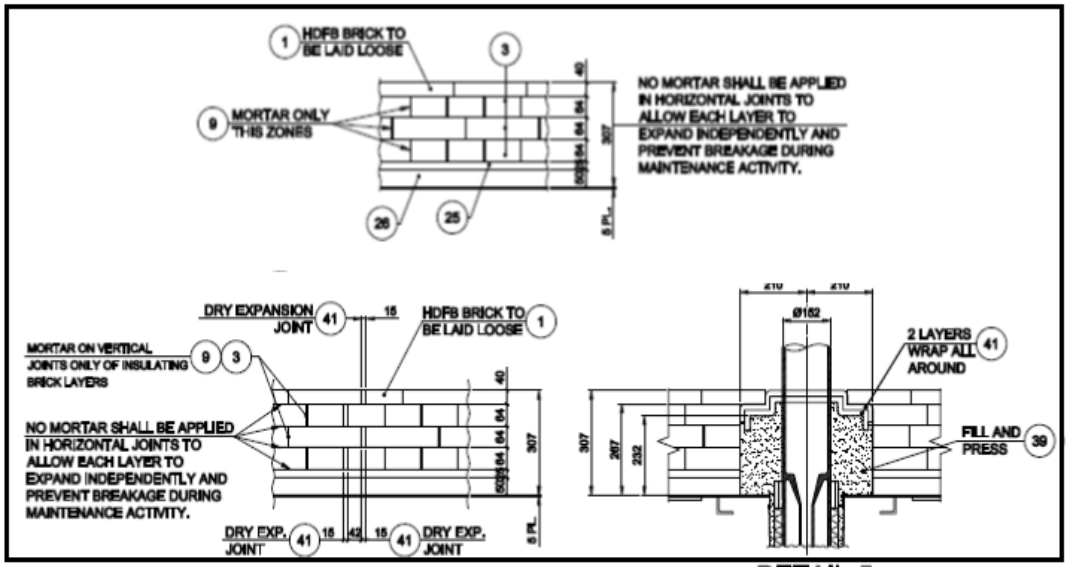
- High duty firebricks
  As its name suggests the firebricks are high duty and are used just in first row. It is noteworthy that the firebricks are installed in a loose manner so that there is space for thermal expansion. Based on API it is recommended installing dry expansion joint with the material of ceramic fiber blanket (grade 1425 and Thk. Of 15 mm) after each seven firebricks. Here are some characteristics of high duty firebricks.

Density	1900-2100 kg/m^3
Composition	Al_2O_3 + TiO_2 : 38-42%
Thermal Conductivity	1.33 w/m.k



- Firebricks Gr.23 are used for rows 2-3-4 and air setting mortar are installed vertically between those firebricks. Remember mortars should not be used horizontally so that there is enough space for firebricks to expand. Here is a summary of mortar characteristics.

Density	1700 kg/m^3
Composition	Al_2O_3: 34% SiO_2:60% Alkalis:3%
Operating temperature	1425


1 HDFB BRICK TO BE LAID LOOSE
3
9 MORTAR ONLY THIS ZONES
NO MORTAR SHALL BE APPLIED IN HORIZONTAL JOINTS TO ALLOW EACH LAYER TO EXPAND INDEPENDENTLY AND PREVENT BREAKAGE DURING MAINTENANCE ACTIVITY.
26
25
DRY EXPANSION JOINT 41
15
HDFB BRICK TO BE LAID LOOSE 1
MORTAR ON VERTICAL JOINTS ONLY OF INSULATING BRICK LAYERS 9 3
NO MORTAR SHALL BE APPLIED IN HORIZONTAL JOINTS TO ALLOW EACH LAYER TO EXPAND INDEPENDENTLY AND PREVENT BREAKAGE DURING MAINTENANCE ACTIVITY.
DRY EXP. JOINT 41
DRY EXP. JOINT 41
Ø152
2 LAYERS WRAP ALL AROUND 41
FILL AND PRESS 39

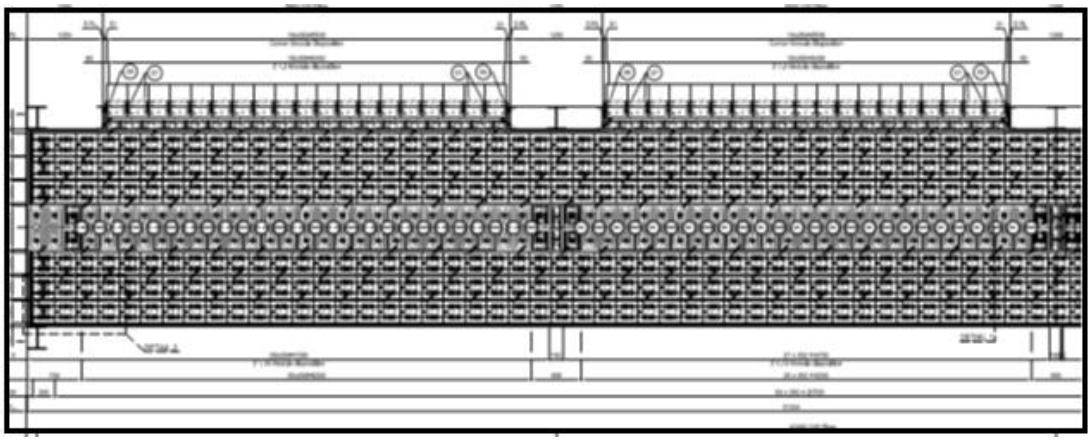
- In rows 5-6 insulation blocks with 25 and 50 mm thicknesses are used.

- It should be noted that the arrangement of firebricks around the catalyst tubes is different and it is in such a way that from the bottom of the floor we fill around the catalyst tubes with loose fiber with the vertical length of 230 mm and dr of 100 mm. Loose fibers are alumina silica with 45% Al_2O_3 , density of 100 kg/m^3, operating temperature of 1260C and thermal conductivity of 0.1. In addition, 2 layers of ceramic fiber blanket 1425C with thickness of 25 mm are used.


35

3.6. Radiant Arch

For the radiant arch of reformer, it is normal to use fire blanket 1260 and fiber module.

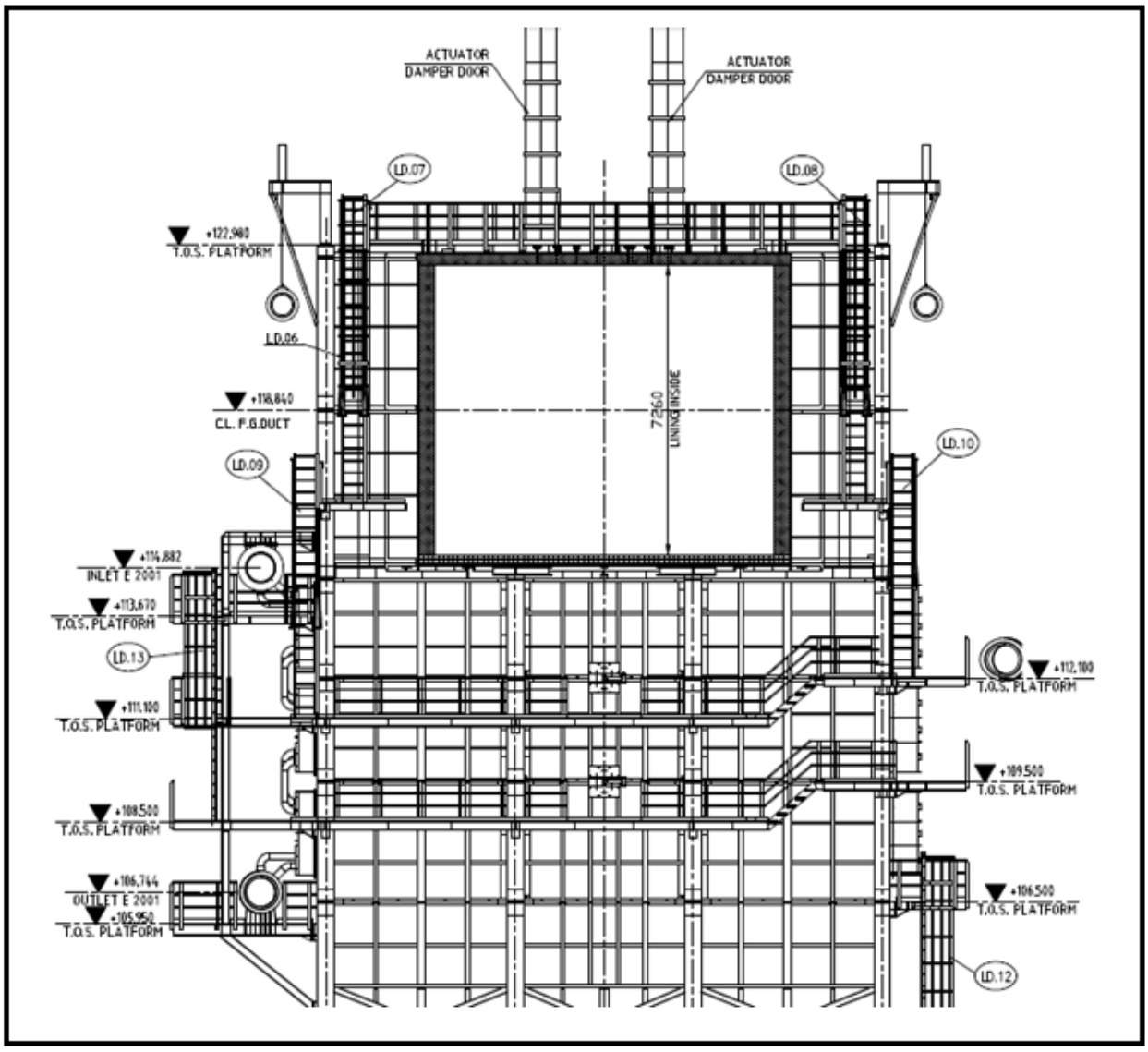


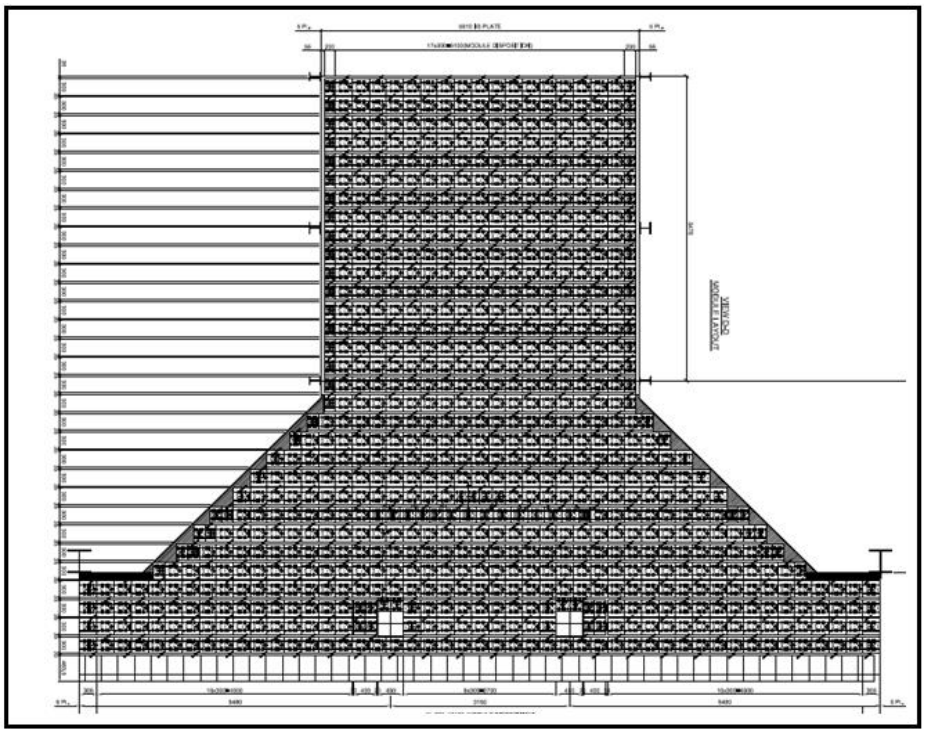
4.Convection section

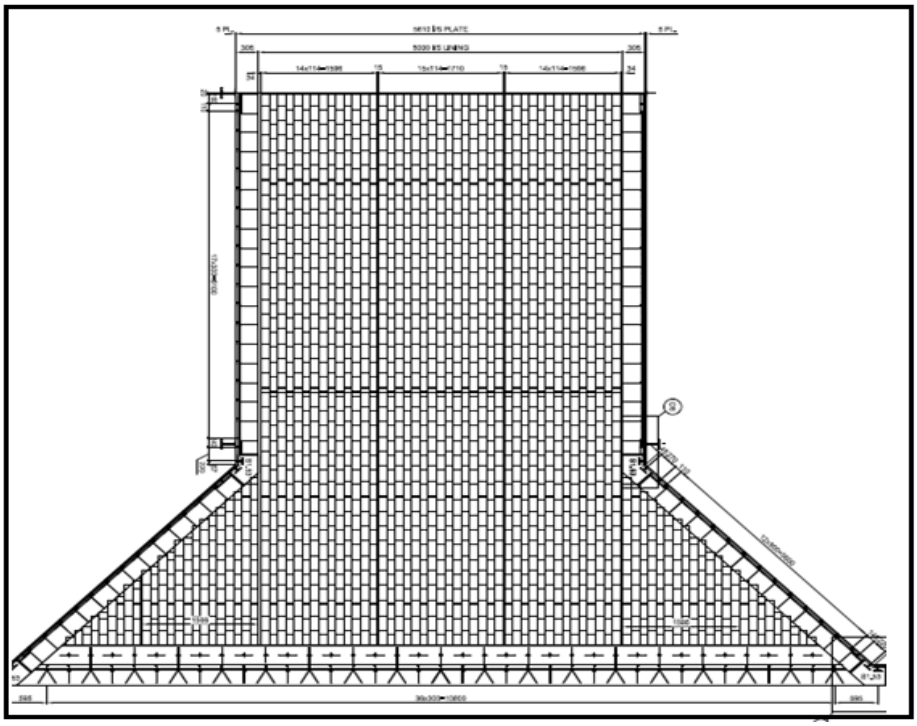
High flow of flue gas passes the flue gas duct which has a mild slope and then it exchanges heat with different heat exchangers.

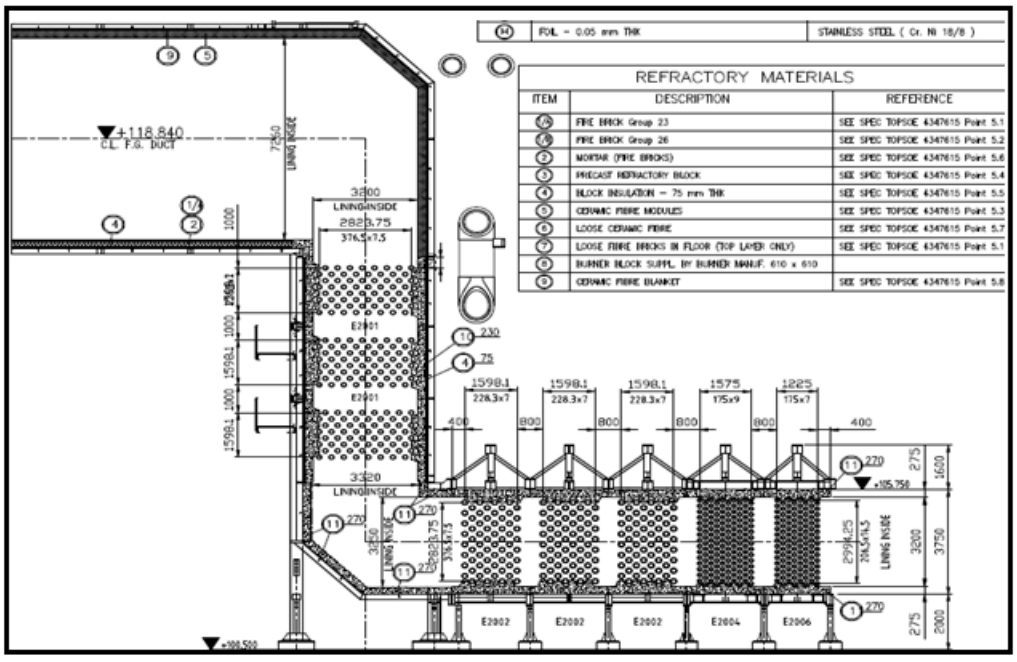
4.1. Flue gas duct

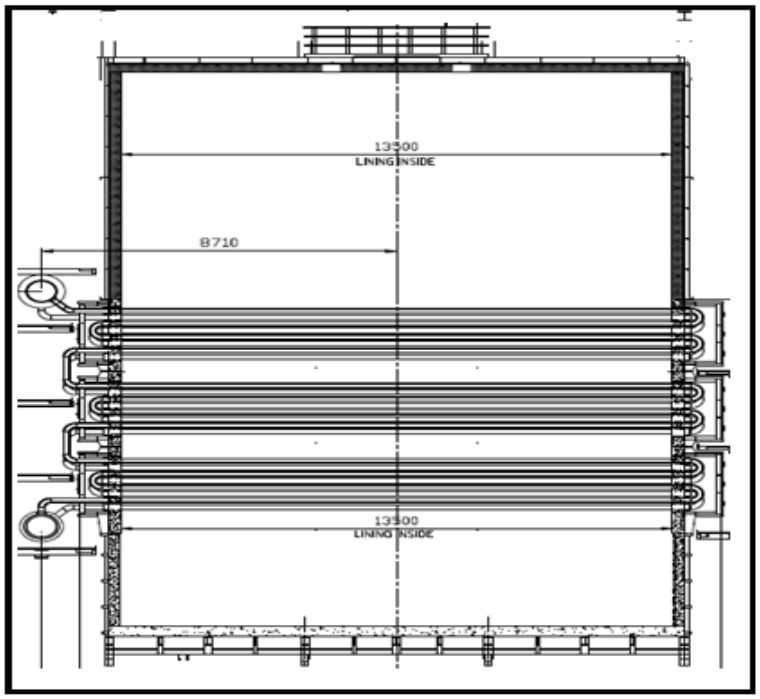
The flue gas with the temperature of 1092C goes through flue gas duct, which has a length of 42 m and height increase of 8 m. Its floor arrangement consists of 76 mm of insulating firebricks with thermal conductivity of 0.18-0.24 w/k.m and density of 530 kg/m^3 and 2 layers of insulating blocks (25 mm and 50 mm). On its wall at first, we have ceramic fiber blanket 1260 and then ceramic fiber module 1260.

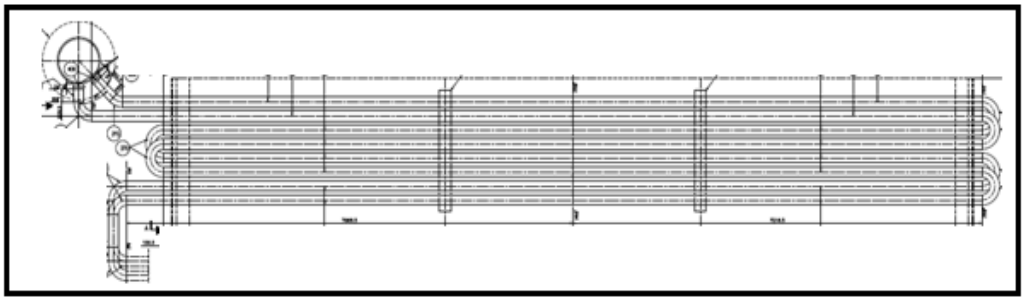







REFRACTORY MATERIALS
ITEM
DESCRIPTION
REFERENCE
FOIL - 0.05 mm THK
STAINLESS STEEL (Cr. Ni 18/8)
FIRE BRICK Group 23
FIRE BRICK Group 26
MORTAR (FIRE BRICKS)
PRECAST REFRACTORY BLOCK
BLOCK INSULATION - 75 mm THK
CERAMIC FIBRE MODULES
LOOSE CERAMIC FIBRE
LOOSE FIBRE BRICKS IN FLOOR (TOP LAYER ONLY)
BURNER BLOCK SUPPL. BY BURNER MANUF. 610 x 610
CERAMIC FIBRE BLANKET
+118.840
CL. F.G. DUCT
LINING INSIDE
LINING INSIDE
E2001
E2001
E2002
E2002
E2002
E2004
E2006


13500
LINING INSIDE
8710
13500
LINING INSIDE



5.Cold collector

The cold collector is located horizontally at the gas outlet of the reforming furnace. Its fuction is to collect the process gases from the catalysts tubes and to transfer them to the next process unit. The collector is lined internally with refractory materials and the temperature on the steel shell is thus appreciable lower than the temperature of the contained gases.

The operating and design conditions for the cold collector are as follows :

- Design pressure: 35 barg
- Operating pressure: 32 barg
- Operating temperature (process gas): 740C
- Design temperature(shell): 300C
- Main shell temperature: max 150C
- Max design gas velocity: 20 m/s
- Ambient design temperature: 40C
- Gas composition: H_2, N_2, CO, CO_2, CH_4, H_2O

5.1. Materials for cold collector refractory lining

5.1.1. Inner castable lining

High alumina castable refractory. The castable material shall conform to the following:

Type	Firecrete 95
Composition	Al_2O_3 : 94% SiO_2 <0.1% Fe_2O_3 <0.1
Thermal conductivity @1100C	1.25 kcal/m.h.c
Bulk density	2.3-2.9 kg/dm^3
Cold crushing strength ASTM C-133	450 kg/cm^2 .min

5.1.2. Impervious layer

An impervious layer shall be installed between the inner castable lining and the insulating castable refractory in order to prevent propagation of cracks from one component of the lining to another.

The layer can be achieved by means of a heavy coat of non-soluble paint or oil. Great care must be taken to choose a material which will have no adverse effects on the process or the lining materials under operating condition.

5.1.3. Insulating castable refractory

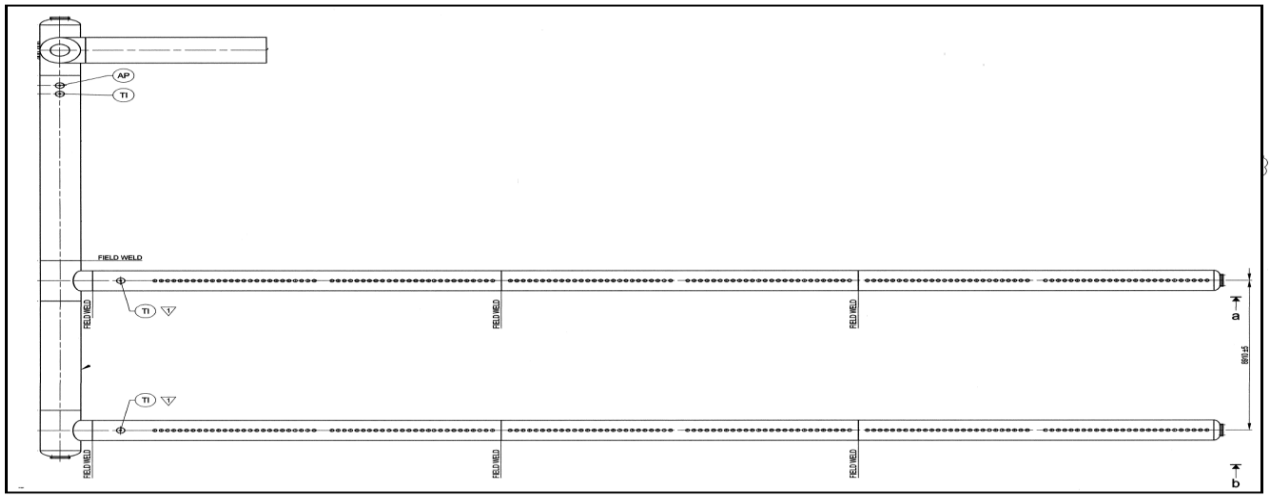
The main insulating component of the lining is installed between the inner castable lining and the shell. The material shall be characterized by low thermal conductivity (especially with regard to the hydrogen content of the process gas), reasonably low silica content, low linear shrinkage and high thermal stability.

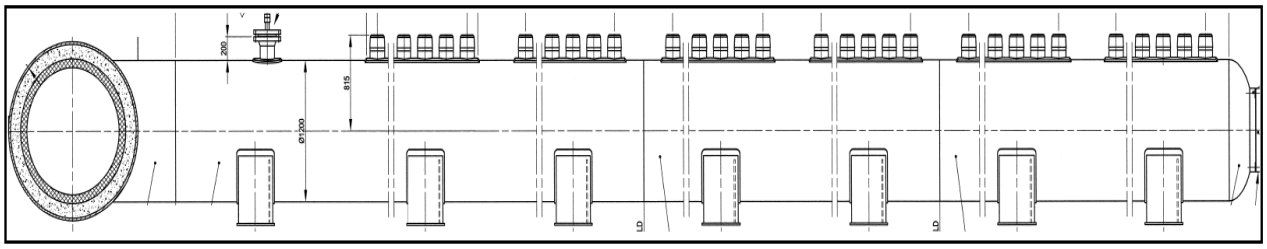
There is a possibility of condensation within this layer and the material shall therefore be completely insoluble in water. In cases where this component is relatively thick, it is advisable to divide into two layers of equal thickness, thus preventing cracking due to excessive differential temperature between the inner and outer surfaces. In such cases the two layers shall be separated by an impervious layer. The material shall conform to the following:

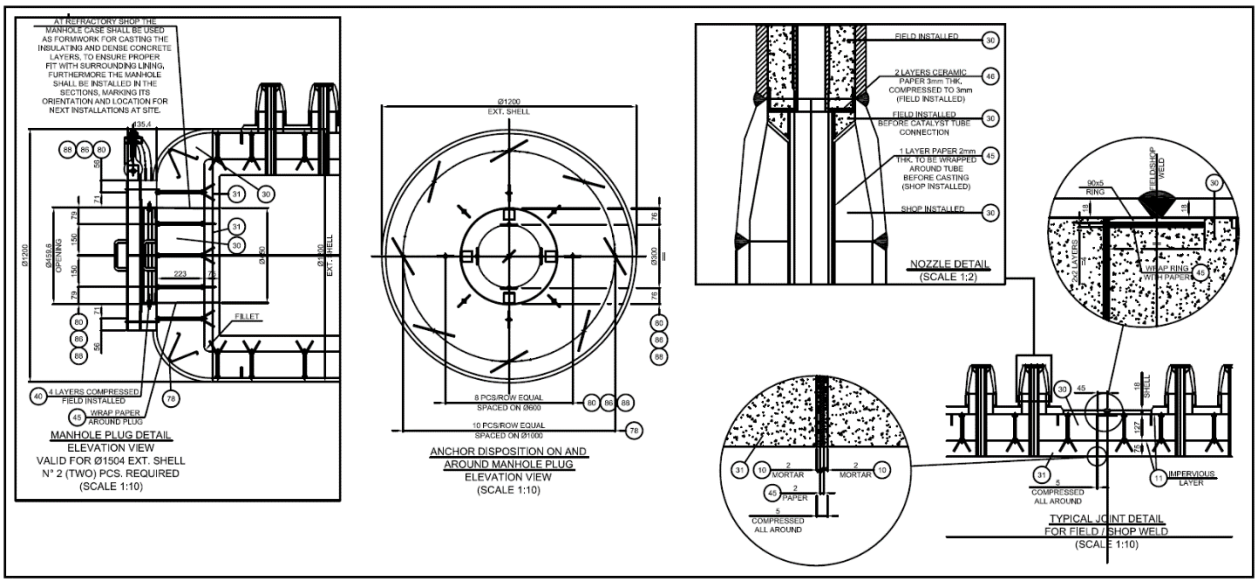
Classification	ASTM C-401 Class P/Q
Temperature limit	1260
Material	Firelite 2300 VLI
Principal analysis	Al_2O_3 : 45% Fe_2O_3 < 0.6% SiO_2 < 35%
Cold crushing strength-ASTM C-133	35 kg/cm^2
Thermal Conductivity at 500C	0.2 kcal/m.h.c
Density	0.83-1.03 kg/dm^3

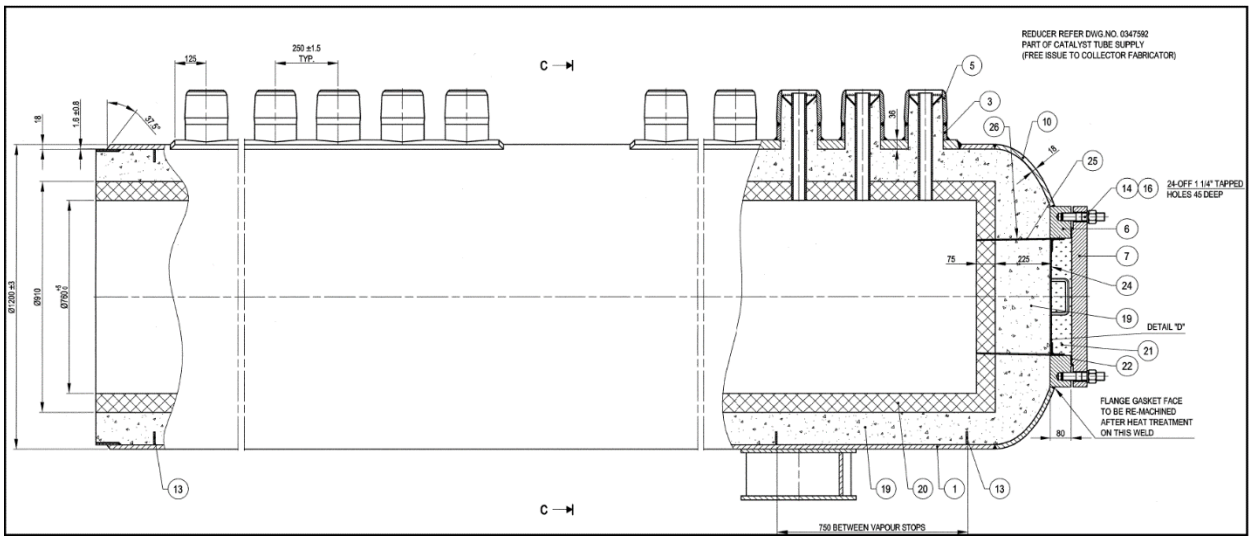
5.1.4. Bonding cement

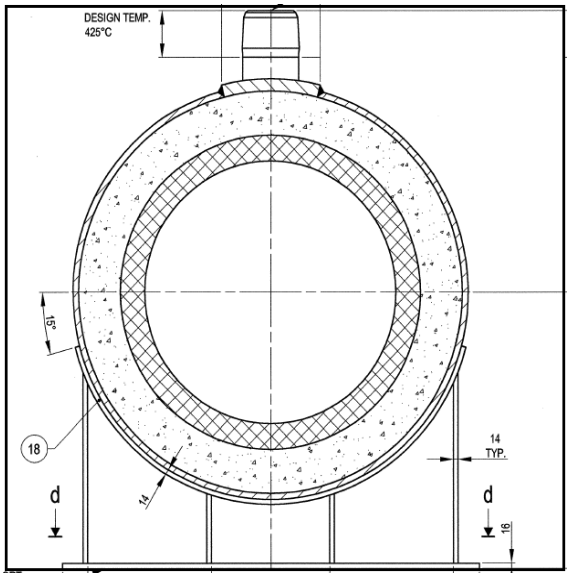
To ensure good adhesion between the insulating castable and the inner surface of the shell, a coating of bonding cement shall be applied to the shell before the castable is installed. The cement shall have good adhesive properties and shall be non-soluble in water. It must not contain any ingredient which can be harmful to the steel shell under design condition.

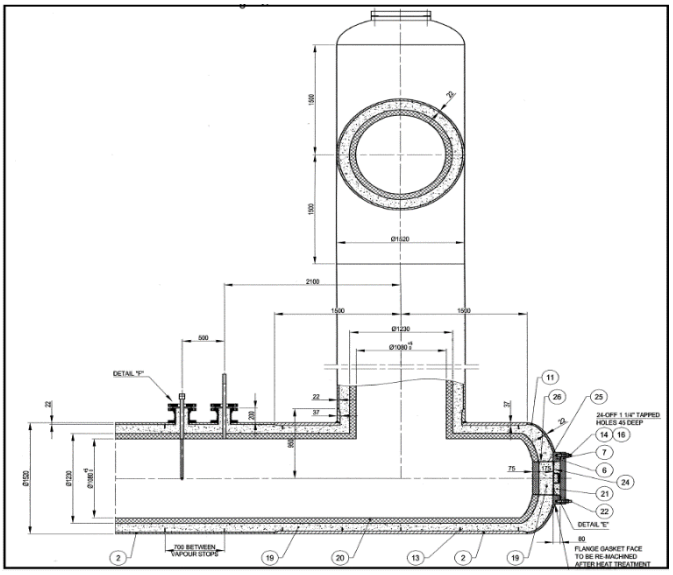

AP
TI
FIELD WELD
FIELD WELD
FIELD WELD
FIELD WELD
FIELD WELD
FIELD WELD
a
b


200
815
Ø1200
LD
LD


AT REFRACTORY SHOP THE MANHOLE CASE SHALL BE USED AS FORMWORK FOR CASTING THE INSULATING AND DENSE CONCRETE LAYERS, TO ENSURE PROPER FIT WITH SURROUNDING LINING. FURTHERMORE THE MANHOLE SHALL BE INSTALLED IN THE SECTIONS, MARKING ITS ORIENTATION AND LOCATION FOR NEXT INSTALLATIONS AT SITE.
Ø1200
Ø1504
EXT. SHELL
FILLET
4 LAYERS COMPRESSED FIELD INSTALLED
WRAP PAPER AROUND PLUG
MANHOLE PLUG DETAIL
ELEVATION VIEW
VALID FOR Ø1504 EXT. SHELL
N° 2 (TWO) PCS. REQUIRED
(SCALE 1:10)
Ø1200
EXT. SHELL
8 PCS/ROW EQUAL SPACED ON Ø600
10 PCS/ROW EQUAL SPACED ON Ø1000
ANCHOR DISPOSITION ON AND AROUND MANHOLE PLUG
ELEVATION VIEW
(SCALE 1:10)
FIELD INSTALLED
2 LAYERS CERAMIC PAPER 3mm THK, COMPRESSED TO 3mm (FIELD INSTALLED)
FIELD INSTALLED BEFORE CATALYST TUBE CONNECTION
1 LAYER PAPER 2mm THK, TO BE WRAPPED AROUND TUBE BEFORE CASTING (SHOP INSTALLED)
SHOP INSTALLED
NOZZLE DETAIL
(SCALE 1:2)
FIELD/SHOP WELD
90x5 RING
2 LAYERS
WRAP RING WITH PAPER
MORTAR
PAPER
COMPRESSED ALL AROUND
IMPERVIOUS LAYER
TYPICAL JOINT DETAIL FOR FIELD / SHOP WELD
(SCALE 1:10)


REDUCER REFER DWG.NO. 0347592
PART OF CATALYST TUBE SUPPLY
(FREE ISSUE TO COLLECTOR FABRICATOR)
250 ±1.5
TYP.
125
C
C
5
3
26
10
25
14
16
24-OFF 1 1/4" TAPPED
HOLES 45 DEEP
6
7
24
19
DETAIL "D"
21
22
75
225
80
FLANGE GASKET FACE
TO BE RE-MACHINED
AFTER HEAT TREATMENT
ON THIS WELD
13
19
20
1
13
750 BETWEEN VAPOUR STOPS


DESIGN TEMP.
425°C
15°
18
14
TYP.
d
d
14
16


DETAIL "E"
24-OFF 1 1/4" TAPPED
HOLES 45 DEEP
DETAIL "D"
FLANGE GASKET FACE
TO BE RE-MACHINED
AFTER HEAT TREATMENT

6.Stack

Calculation of stack diameter

$$V = \frac{m'}{\rho g(\frac{\pi D^2}{4})} > 9\ m/s$$

Temperature: 161 ℃

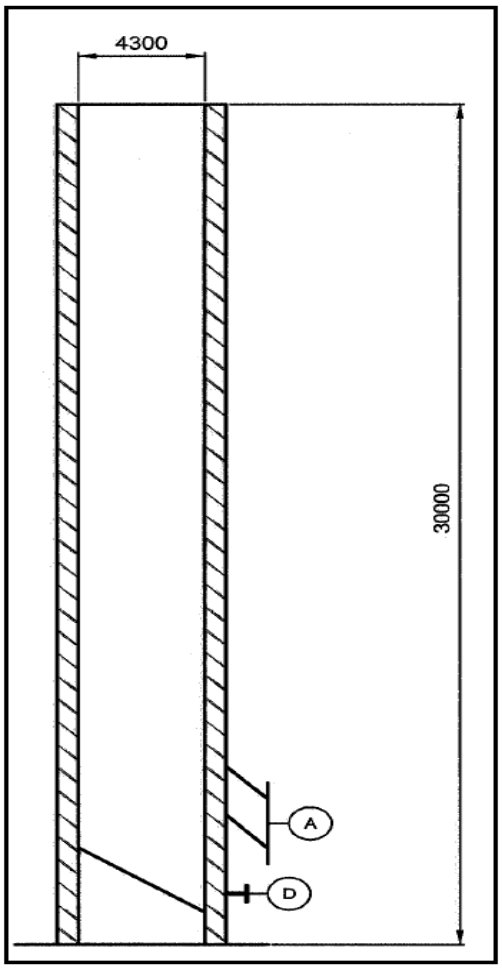
Pressure: 0 mm WG

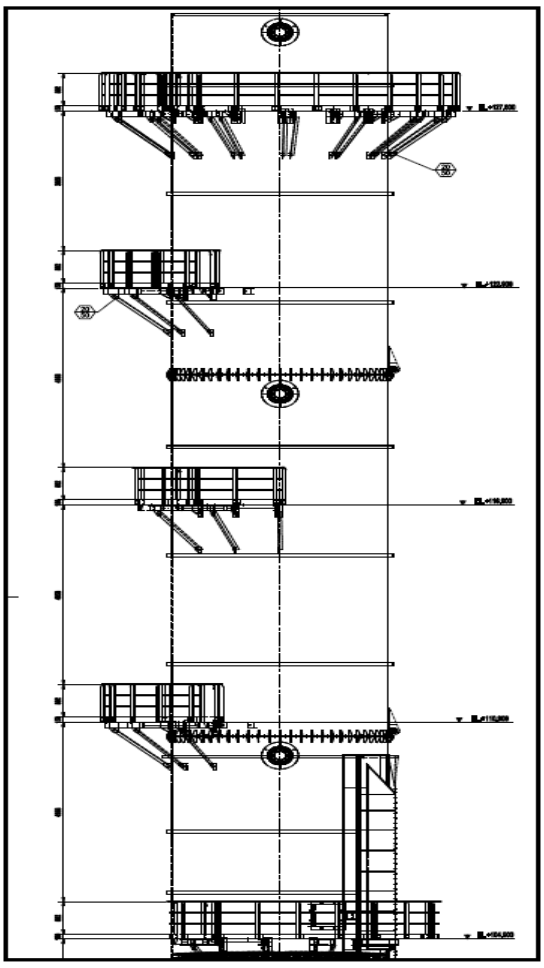
Flow: 469314 kg/h = 130 kg/s

Gas Density: $\frac{342}{161+273.15} = 0.78 = 0.75$

V = $\frac{130}{0.75\times(0.78\ D^2} > 9\ m/s$

D = 4300 mm






29
96
15

7.Burners

The burners must be of the forced draught radiant wall type provided with a single fuel nozzle. It is essential that no forward flame propagation occurs.

The burners are mounted in the side-walls of the refractory-lined furnace chambers. The furnace consists of two chambers.

The fuel for the burners is a mixture of natural gas fuel and purge gas. Also, the combustion air is preheated.

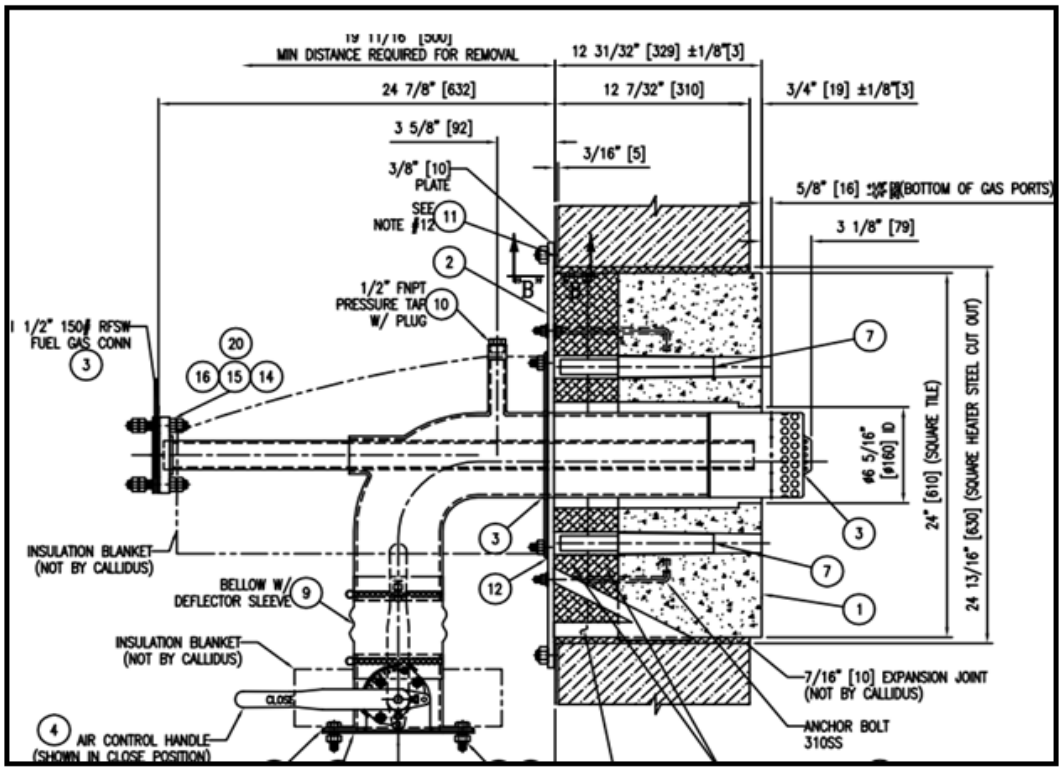
Natural gas and purge gas LHV are 34.5-37 KJ/Nm^3 and 9.85-10.45 KJ/Nm^3. Combustion air is preheated by means of plate heat exchanger to reach a temperature of 175C. Also its pressure is increased via FD fan to 200 mmWG. The excess air should be 10% so that excess O_2 at stack outlet is 1.6-2%.

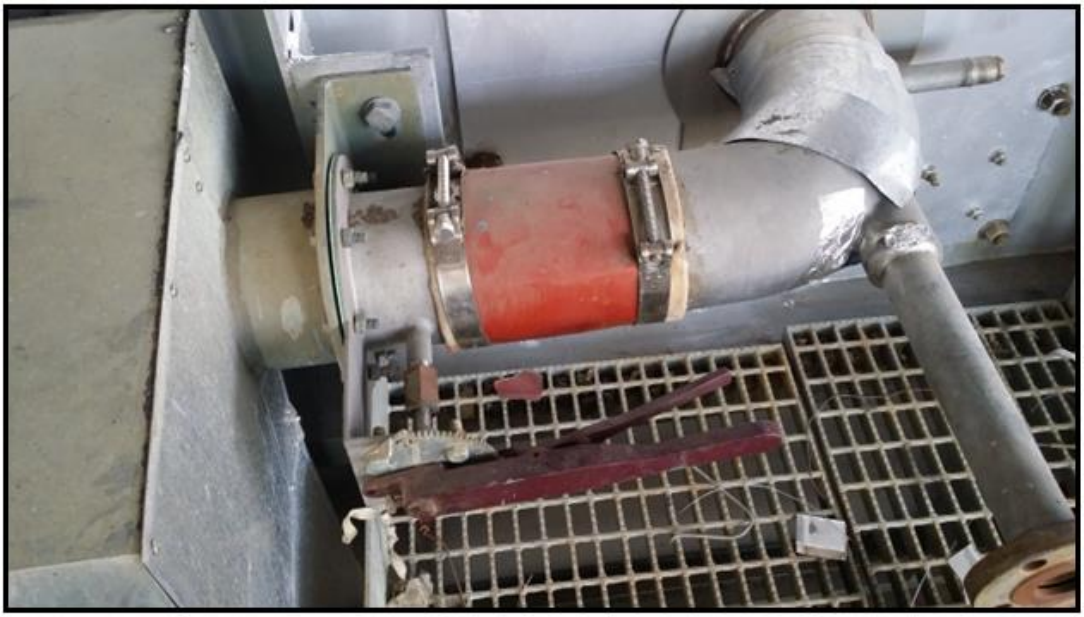
The burners should be operated in a way that the heat released based on purge gas should be maximum 75% of the whole heat release.

The combustion gas temperature at burner tips is approximately 1200 C. Based on environmental standard, the dry mole ppm for NO_x and CO at 3% of O_2 should be between 20-100 ppm.

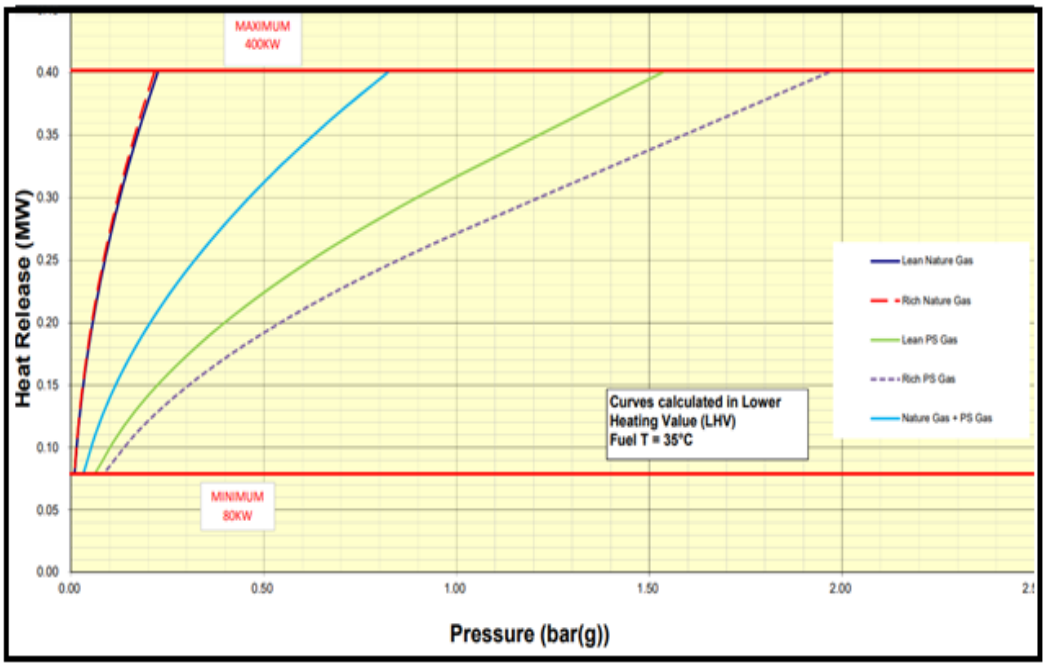
Burner plate consists of one layer of insulation block [vacuum formed ceramic fiber 1260 and calcium silicate 1000] with the thickness of 50 mm and a layer of 60% Al_2O_3 in pre-fired form. The quality of insulating material between burner block and mounting plate should be in such a way that the burner plate temperature during normal operation should be maximum 70 C more than ambient temperature.

Before the combustion, the fuel gas is premixed with combustion air as shown in next page. An orifice restriction is used to control the pressure. Based on operating and design condition, the material used is CS with the rating of 150. Combustion air connection includes air control handle and Bellows deflector sleeve. Maximum leakage should be less than 10%.


MIN DISTANCE REQUIRED FOR REMOVAL
12 31/32" [329] ±1/8"[3]
24 7/8" [632]
12 7/32" [310]
3/4" [19] ±1/8"[3]
3 5/8" [92]
3/16" [5]
3/8" [10] PLATE
SEE NOTE #12
5/8" [16] (BOTTOM OF GAS PORTS)
3 1/8" [79]
1/2" FNPT PRESSURE TAP W/ PLUG
1 1/2" 150# RFSW FUEL GAS CONN
#6 5/16" [#160] ID
24" [610] (SQUARE TILE)
24 13/16" [630] (SQUARE HEATER STEEL CUT OUT)
INSULATION BLANKET (NOT BY CALLIDUS)
BELLOW W/ DEFLECTOR SLEEVE
INSULATION BLANKET (NOT BY CALLIDUS)
7/16" [10] EXPANSION JOINT (NOT BY CALLIDUS)
ANCHOR BOLT 310SS
AIR CONTROL HANDLE (SHOWN IN CLOSE POSITION)
CLOSE



When we use NG as the source of the fuel, the pressure changes between 0-0.3 barg. Flame pattern is round. The minimum pre-firing temperature is 260C and the maximum service temperature is 1650 C.-



Based on the drawing, we expect the maximum duty when the pressure is around 0.8-0.9 barg and normal duty when the pressure is 0.6-0.7 barg.