Better Fired Heaters Specifications Pay Off

AFRC Meeting-2018 Salt Lake City

Ashutosh Garg – Furnace Improvements

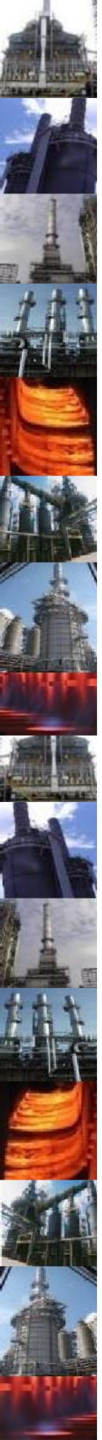
Sugar Land, TX

Fired Heaters Changes

- Changes in the last 30 years
  - No fuel oil firing
  - No sodium and vanadium in the fuel
  - No high sulfur content in the fuel oil/gas
  - No soot blowers
  - No IFB
- Lowest NOx emission
  - Burners flames are 2-3 times longer
- New alloys for tubes
- New refractory materials

Heater Reliability and Run Lengths

- Heater run lengths are very important to owners and operators.
- Any unexpected heater shutdown costs Millions of Dollars production loss.
- Major reasons for limited run lengths appear to be coking and high tube metal temperatures
- Over firing of heaters very common
- Fouling of upstream exchangers
- Current heaters are not able to provide the required run lengths.



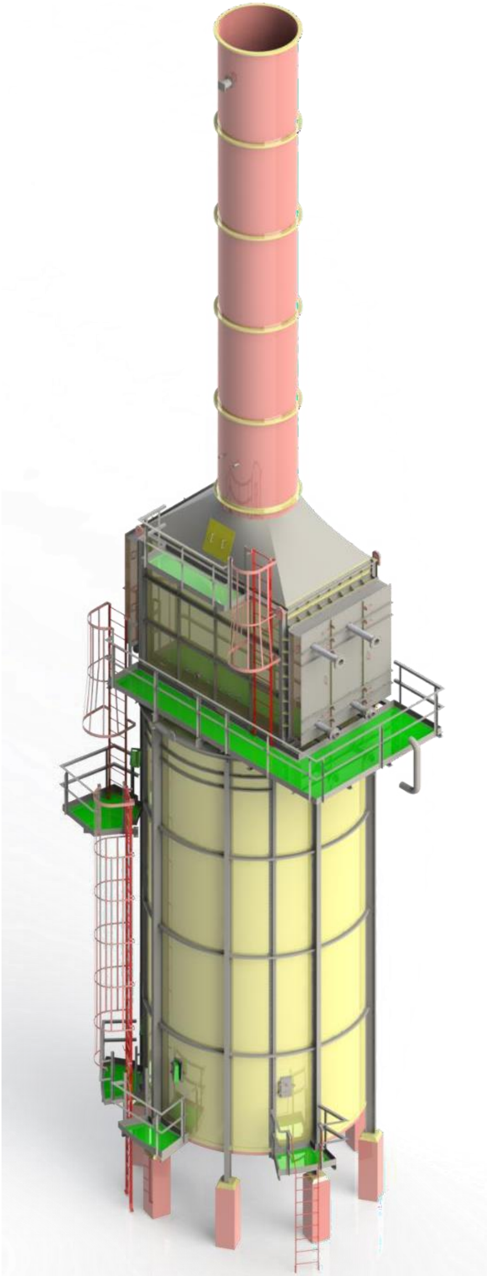
Heater Types

- **Vertical Cylindrical**
  - Low plot space
  - Lower number of burners
  - Compact Convection Design
  - Lower cost

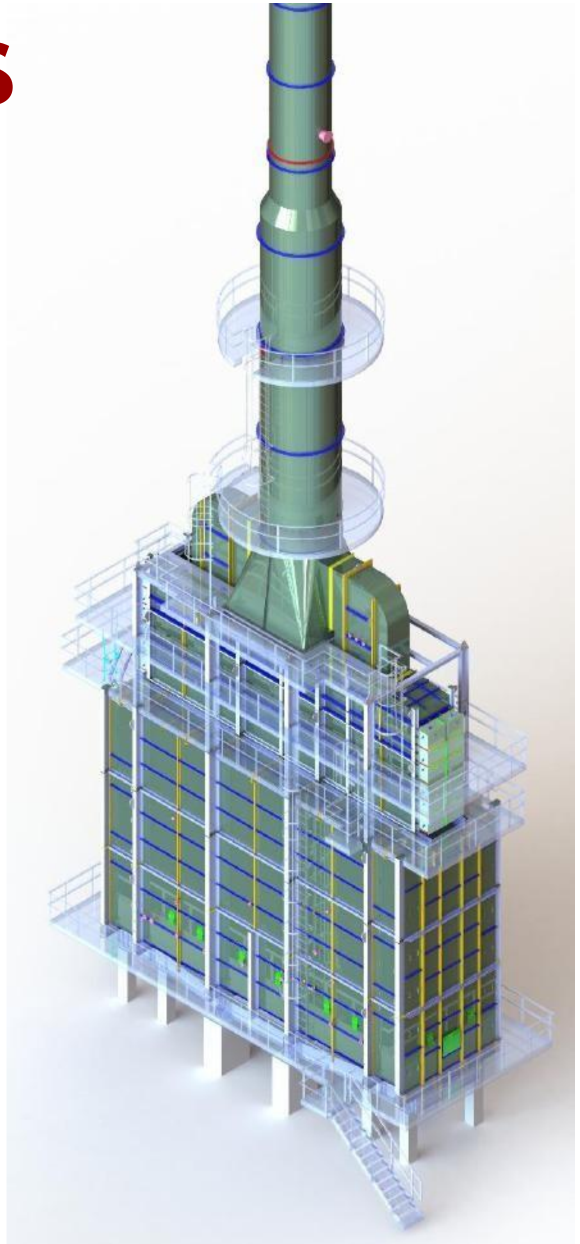
- **Horizontal Box**
  - More plot space needed (including tube pulling)
  - Higher number of burners
  - Long convection sections
  - Higher cost (+25%)

How did VC heaters become so popular?

Heater Types



VC Heater



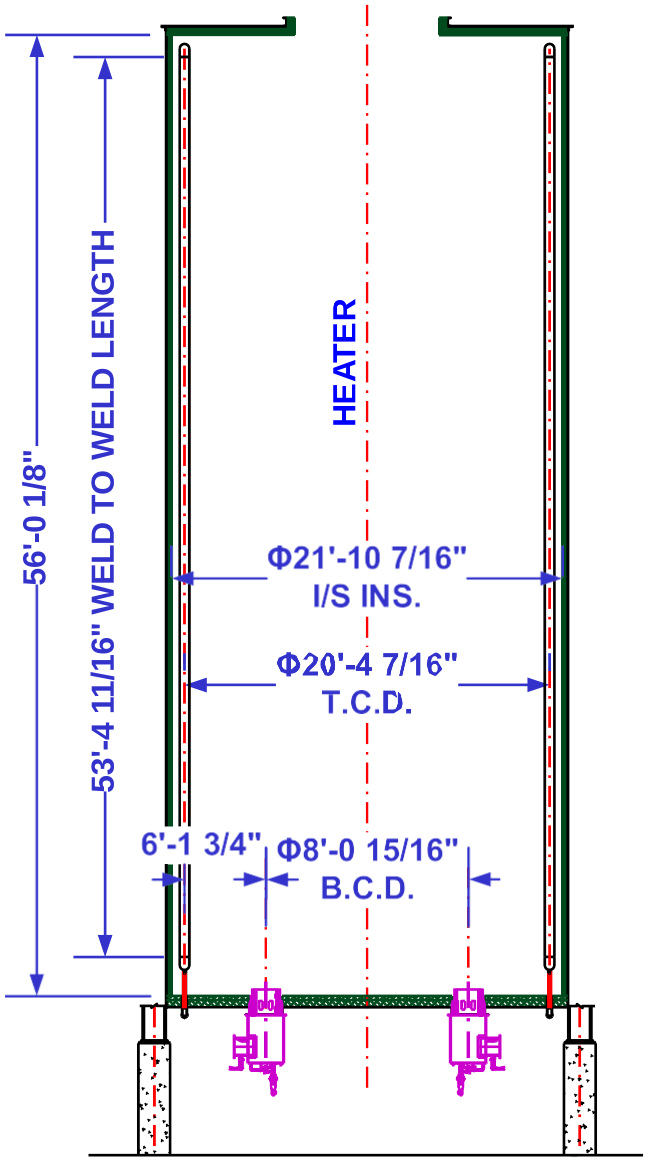
Horizontal Box Heater

Crude Heater Design Basis

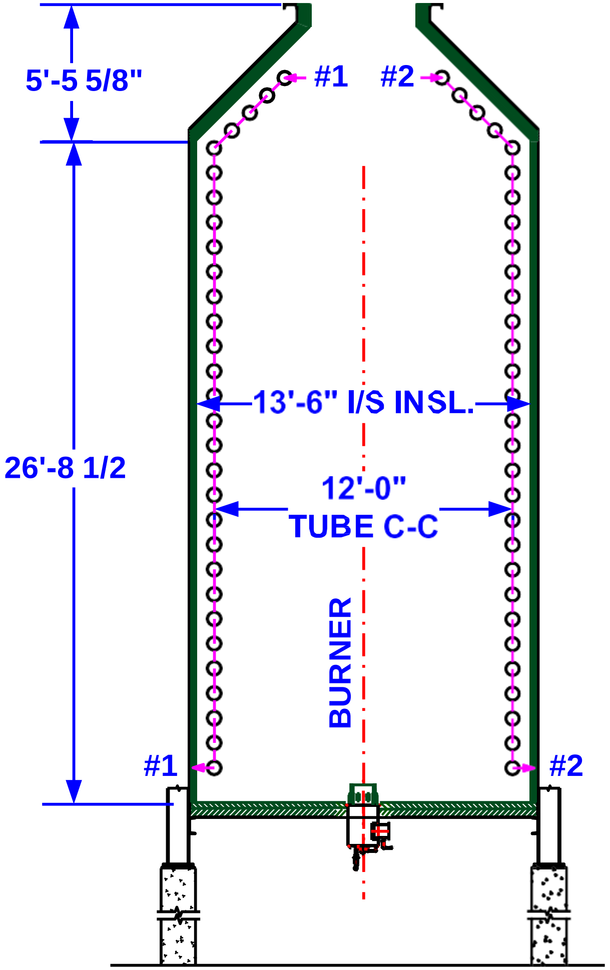
- A Crude heater with 100 MMBtu/hr heat duty is taken as basis for analysis in this presentation

Parameter	Units	Value
Total Heat Duty	**MMBtu/hr**	**100**
Charge Flow rate	lbs/hr	363,263
Feed Inlet/ Outlet Temperature	°F	353 / 660
Feed Inlet/ Outlet Pressure	psig	135 / 35
Design Radiant Heat Flux	Btu/hr.ft^2	10,000
Heater Efficiency	%	84.0
Tube Metallurgy	-	5Cr-1/2Mo

Radiant Section Comparison



VC Heater



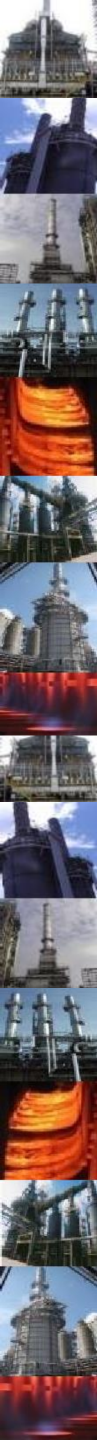
Cabin Heater

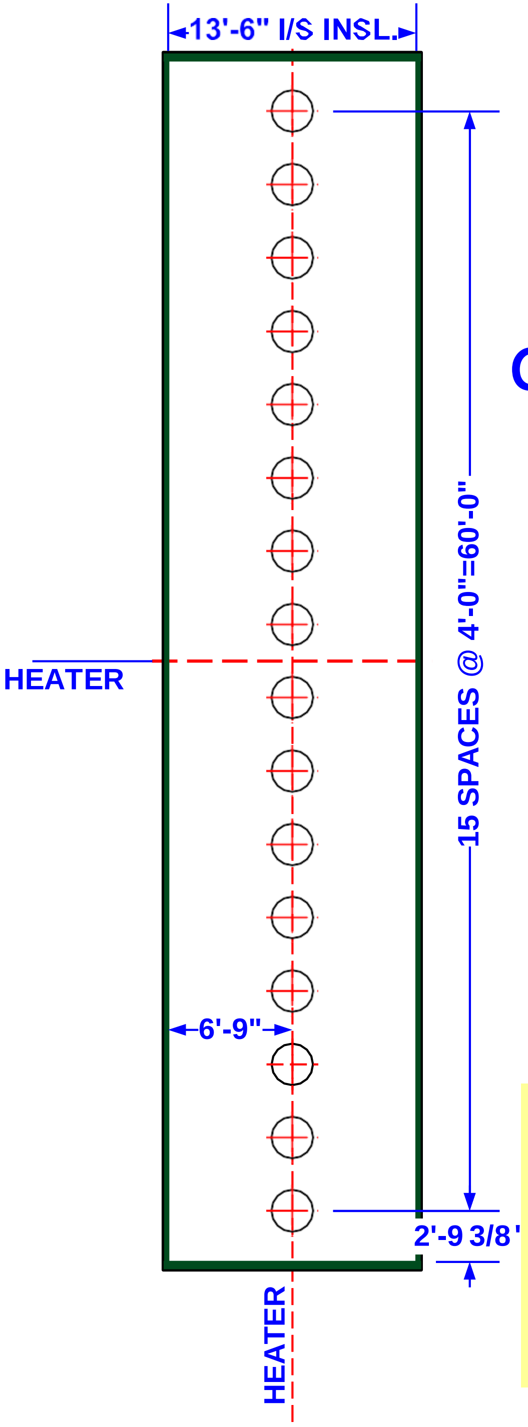
Radiant Section Comparison (Contd.)

Parameter	Units	VC	Cabin
No. of Radiant Tubes	-	64	60
No. of Passes	-	2	2
Tube Size	-	6” NPSXSch.40	
Centre to Centre Spacing	In	12	12
Effective Tube Length	ft	54.95	63.57
Heat Transfer Area	ft^2	6,100	6,615
Estimated Radiant Cost	Million USD	1.0	1.3

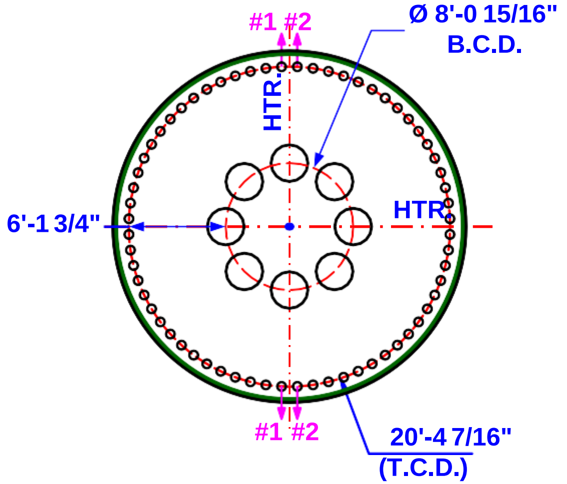
- Cabin heater require 10% more heat transfer area as compared to VC Heater
- Two phase flow is well defined in horizontal tubes as compared to vertical tubes

Floor Plan View





Cabin Heater



VC Heater

Parameter	Units	VC	Cabin
Number of Burners	-	8	12-16
Floor Flux Density	MMBtu/hr-ft^2	0.365	0.156
Burner to Tube Clearance Provided	ft	5.69	6.0
Minimum Burner to Tube Clearance (API)	ft	4.63	3.49

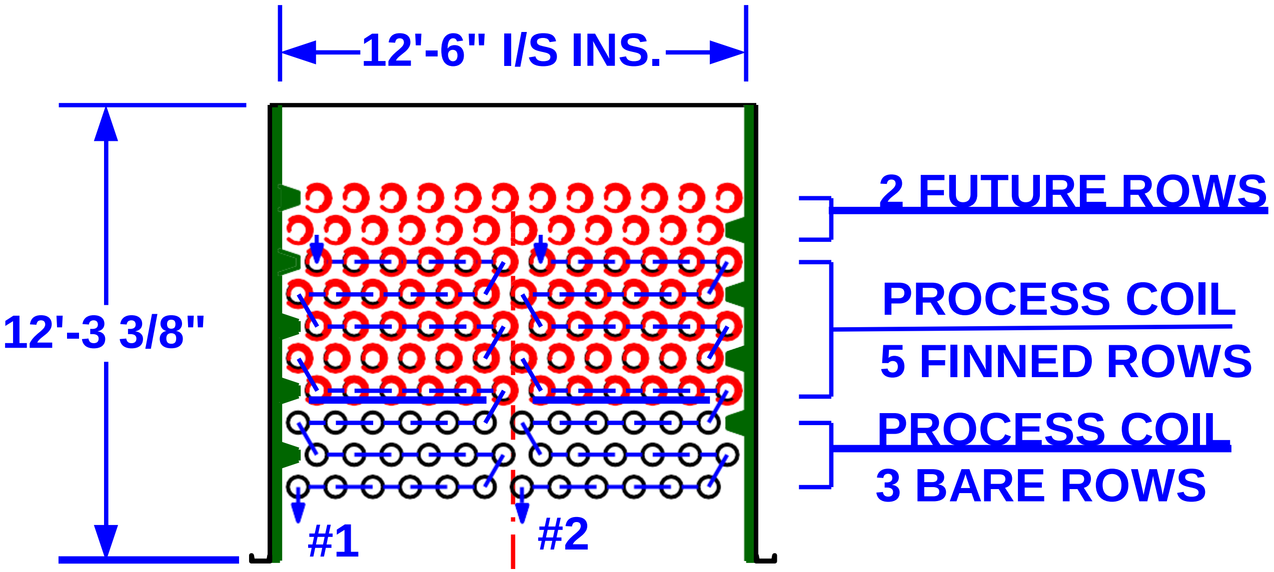
- Increasing the number of burners (up to 12-16) in VC design will increase the T.C.D and decrease the floor flux density
- Cabin heater has lower floor heat flux density and flexibility with number of burners

Convection Section Comparison

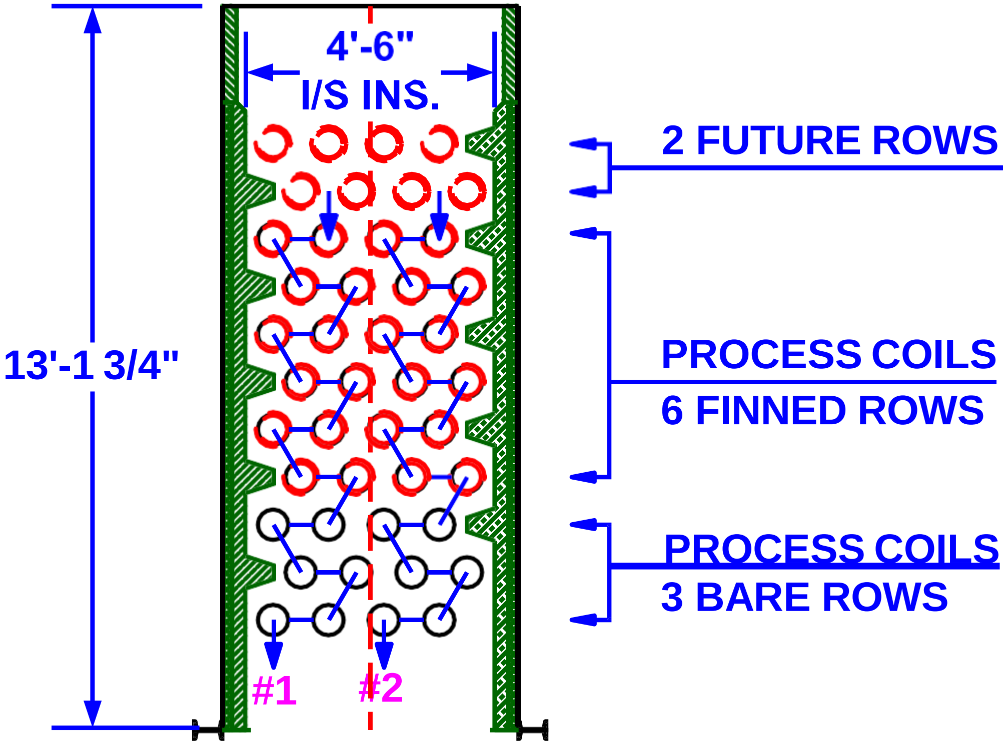
Parameter	Units	VC	Cabin
Height of Convection Section	ft	12.28	13.15
Width of Convection Section	ft	12.5	4.5
Effective Tube Length	ft	18.25	63.57
Heat Transfer Area (Bare / Finned)	ft^2	1,140 / 23,930	1,323 / 16,995
Flue Gas Mass Velocity	$lb/sec.ft^2$	0.371	0.30
Flue Gas Pressure Drop	In. WC	0.085	0.052

Convection Section Comparison (Contd.)

Parameter	Units	VC	Cabin
Total weight of Convection Module	lbs	130,000	160,000
Estimated Convection Cost	Million USD	0.49	0.63



VC Heater



Cabin Heater

Performance Comparison

Parameter	Units	VC	Cabin
Total Heat Duty	**MMBtu/hr**	**100.0**	**100.0**
Radiant Duty	MMBtu/hr	62.8	66.9
Bridgewall Temperature	°F	1,579	1,499
Volumetric Heat Release	$Btu/hr.ft^3$	6,516	5,261
Average Process Conv. Heat Flux (BOS)	$Btu/hr.ft^2$	12,242	8,339
Total Estimated Heater Cost	**Million USD**	**1.6**	**2.0**

- Firebox is 80°F cooler, volumetric heat release is lower. Is 25% extra cost for cabin heater worth ??

Radiant Flux Comparison

Radiant Heat Flux

- Lower Heat Flux
  - Higher radiant heat duty
  - Lower Bridge Wall Temperature
  - Larger Radiant Section

- Higher Heat Flux
  - Lower radiant heat duty
  - Higher Bridge Wall Temperature
  - Smaller Radiant Section

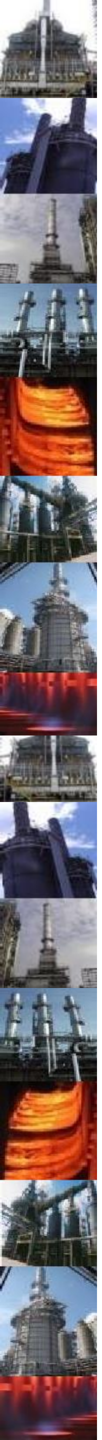
Relationship between Radiant Flux & Run Length

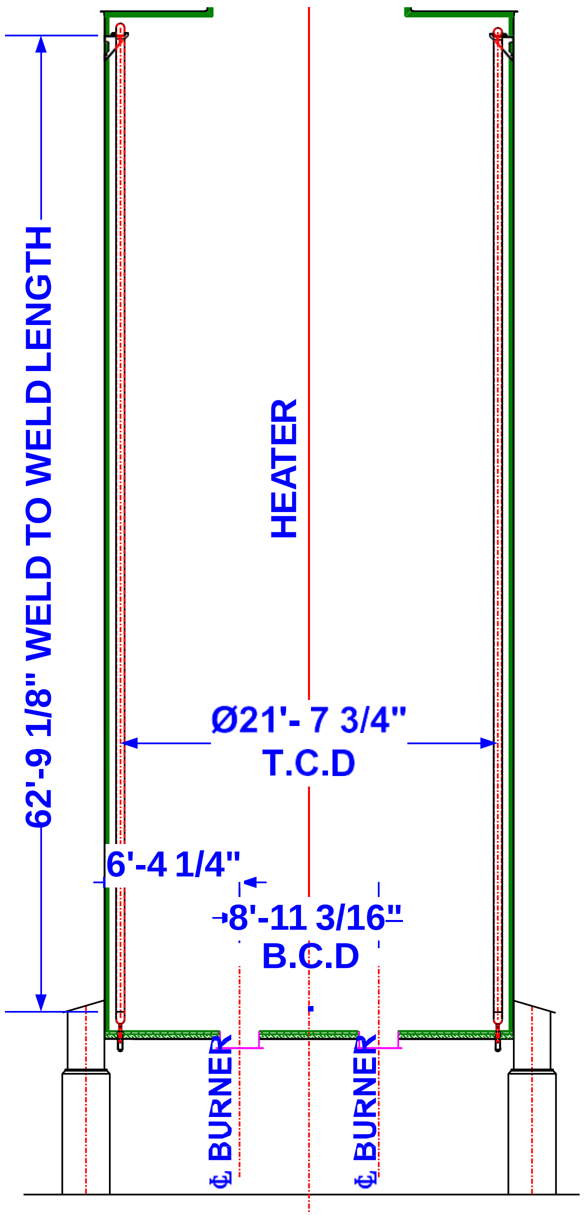
- Radiant flux determines film temperature
- Film temperature is directly proportional to coking rate
- Coking rate determines the run length
- Higher radiant flux leads to higher film temperature to higher coking rate
- Every 26^{o}F increase in film temperature doubles the coking rate in heaters
- Run length has become very important parameter for plant owners and one extra shutdown for cleaning can take away all the heater savings.

Radiant Flux (Contd.)

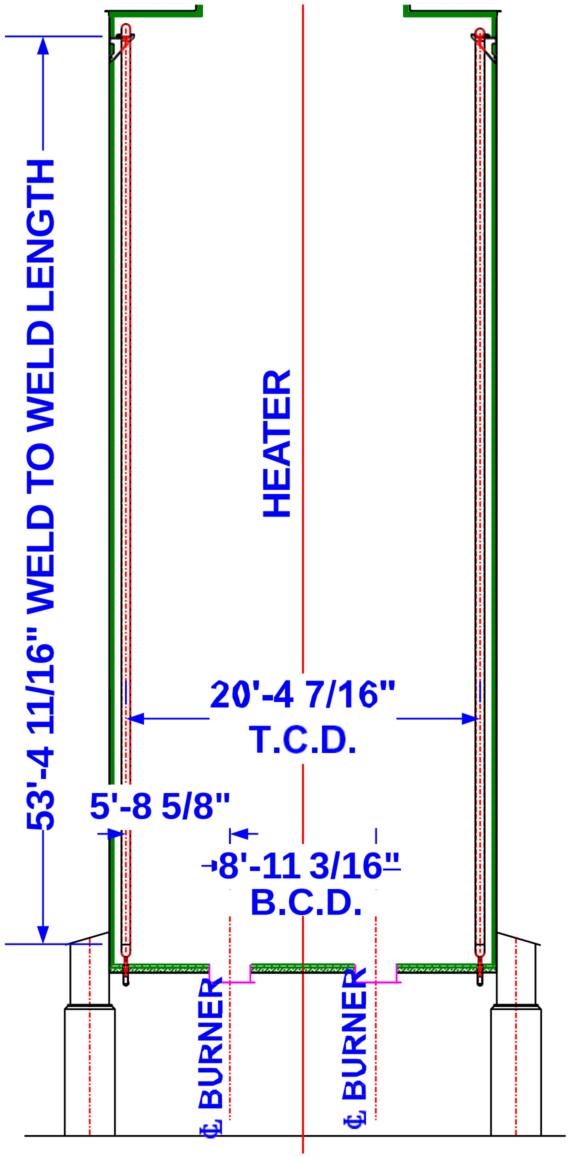
- For the radiant flux analysis, 3 VC heaters for crude heater services are designed
  - Case-1: 8,000 Btu/hr.ft^2
  - Case-2: 10,000 Btu/hr.ft^2
  - Case-3: 12,000 Btu/hr.ft^2
- Compare
  - Floor heat flux
  - Volumetric heat release
  - Radiant heat absorption
  - Comparative Cost

Radiant Section Layouts

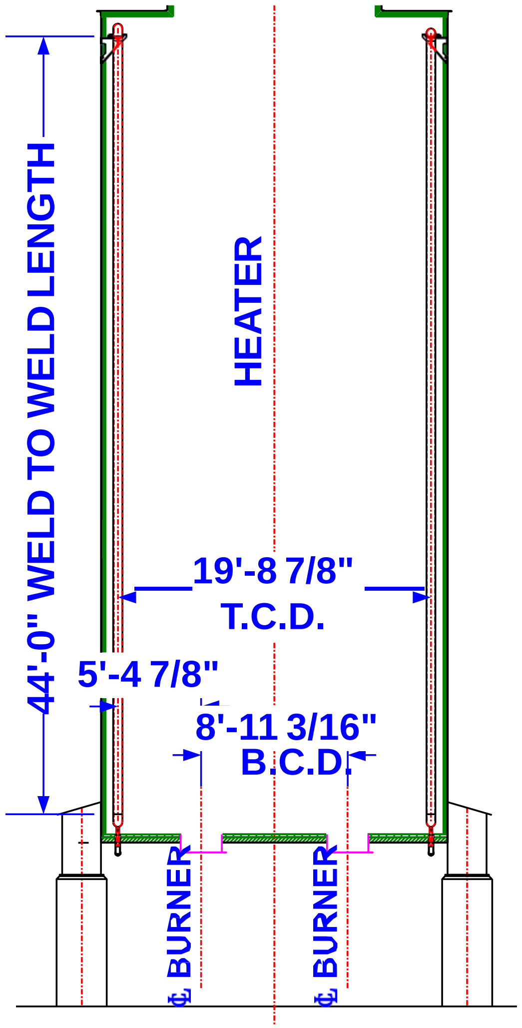




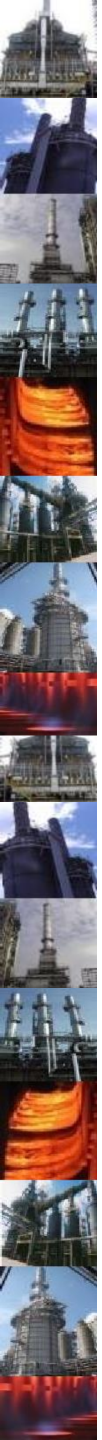
Case 1



Case 2



Case 3

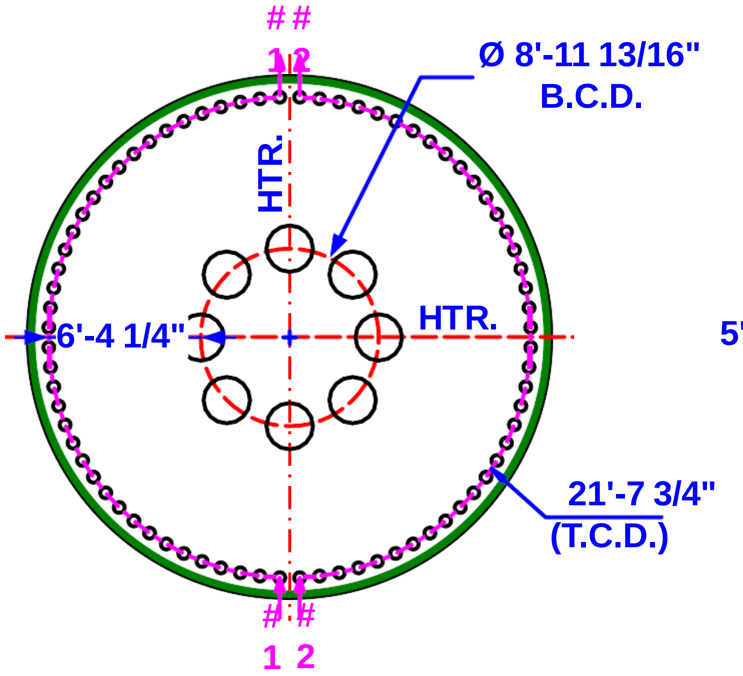


Radiant Section Layout

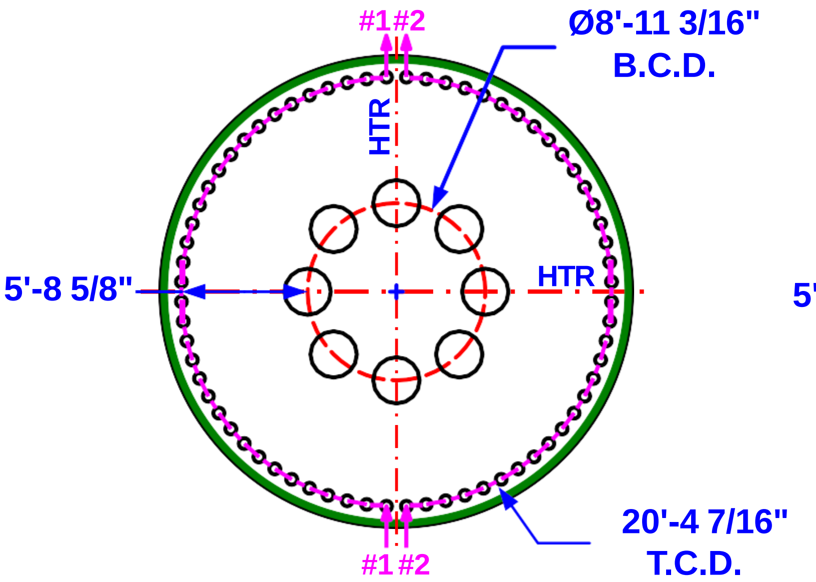
Parameter	Units	Case 1	Case 2	Case 3
Radiant Heat Flux	Btu/hr.ft^2	8,000	10,000	12,000
H/D Ratio	-	2.69	2.75	2.44
Estimated Radiant Cost	Million USD	1.2	1.0	0.85

- Would you like to pay 20% more for heater with 8,000 average heat flux?
- Would you want to save even more with 12,000 heat flux?

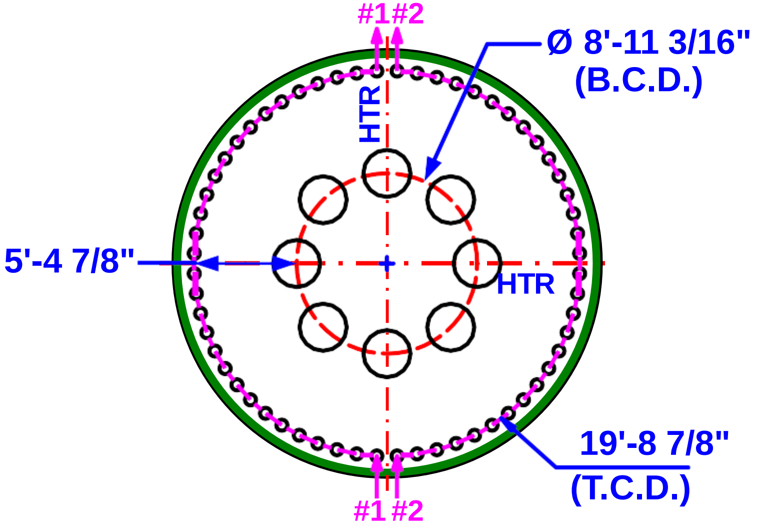
Burners and Radiant Tube Layout



Case 1 : 8,000 Btu/hr.ft²



Case 2 : 10,000 Btu/hr.ft²

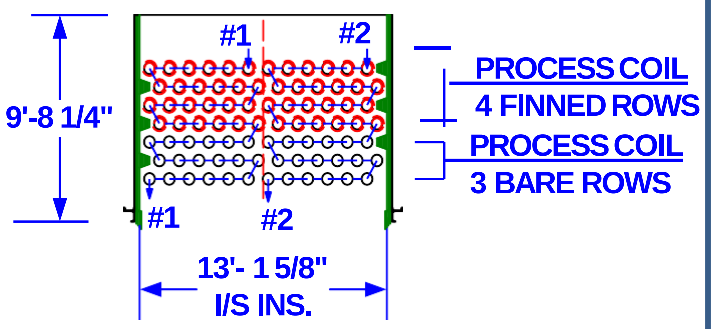


Case 3 : 12,000 Btu/hr.ft²

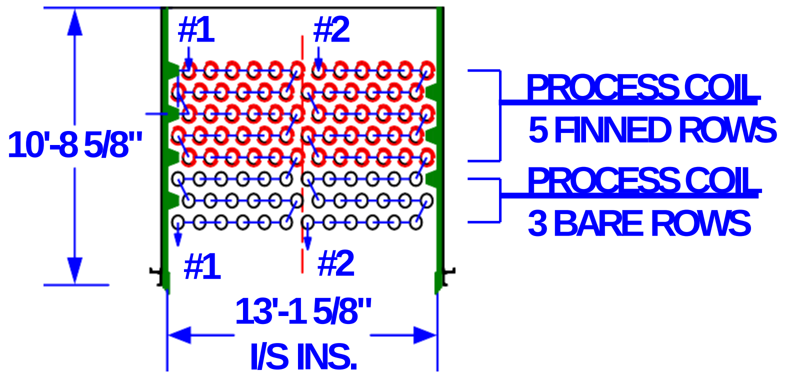
Parameter	Units	Case-1	Case-2	Case-3
Floor Flux Density	MMBtu/hr-ft²	0.323	0.365	0.388
Burner to Tube Clearance	ft	6.35	5.72	5.41
Min. Burner to Tube Clearance (API)	ft	4.63		

Convection Sections Comparison

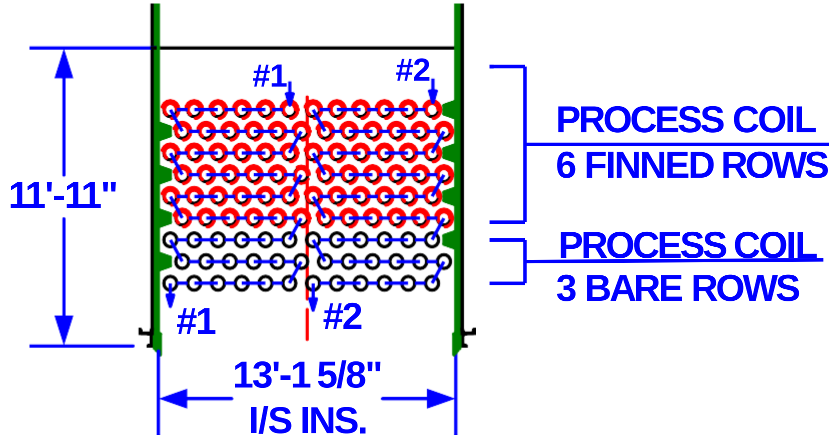
Parameter	Units	Case-1	Case-2	Case-3
Effective Tube Length	ft	19.02	18.25	17.17
Heat Transfer Area (Bare + Finned)	ft^2	1,187 + 19,208	1,140 + 23,930	1,072 + 26,035
Estimated Convection Cost	**Million USD**	**0.47**	**0.49**	**0.51**



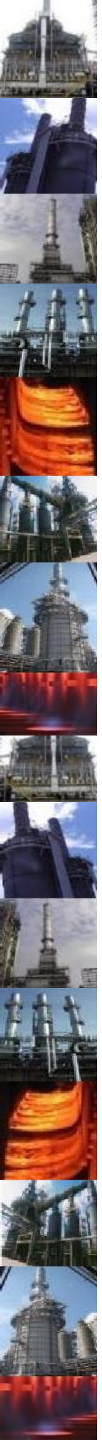
Case 1 : 8,000 Flux



Case 2 : 10,000 Flux



Case 3 : 12,000 Flux



Performance Comparison

Parameter	Units	8000 Avg Flux	10000 Avg Flux	12000 Avg Flux
Radiant Heat Duty	MMBtu/hr	70	62.9	58.85
Radiant Heat Transfer Area	ft^2	8,705	6,230	4,900
Bridgewall Temperature	°F	1,400	1,571	1,685
Max. Radiant Inside Film Temp.	°F	693	702	710
Volumetric Heat Release	Btu/hr.ft3	3,708	6,495	8,072
Total Estimated Heater Cost	**Million USD**	**1.75**	**1.60**	**1.45**

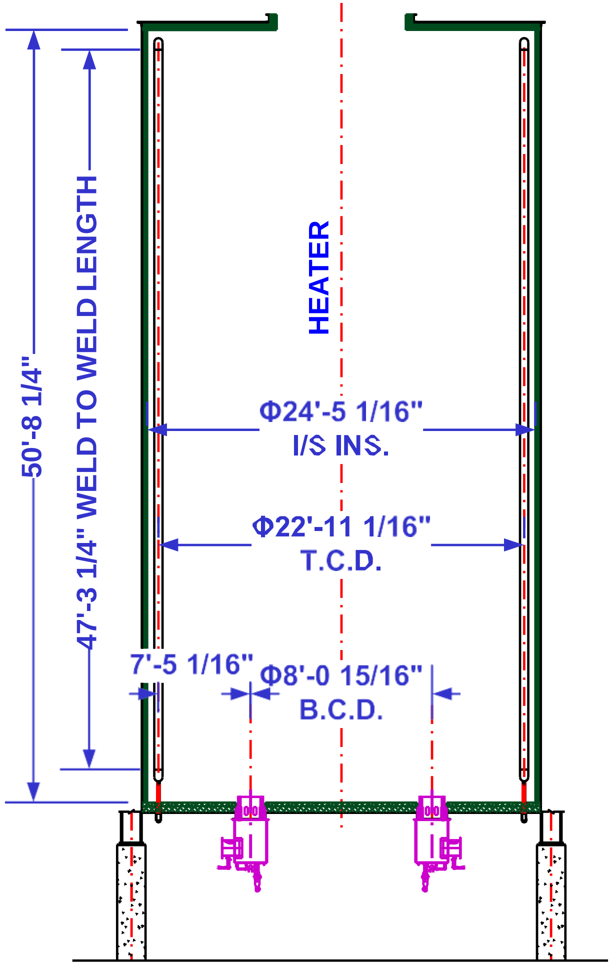
❖ Lower heat flux heater runs almost 300^{o}F cooler. It has almost 75% more heat transfer area in the radiant section and is only 20% higher cost

H/D Ratio Comparison

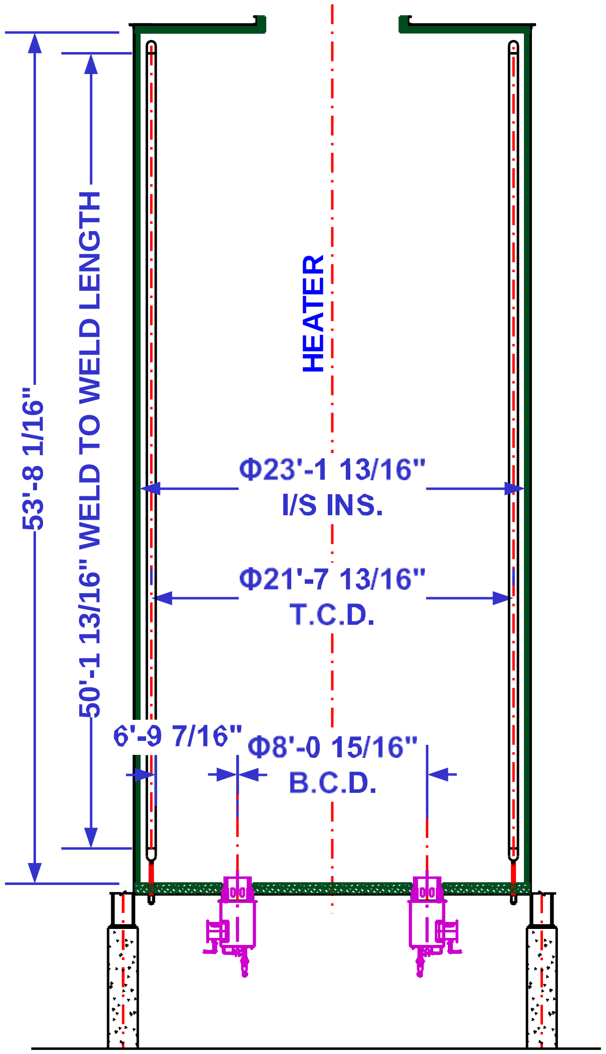
Firebox Proportions

- Vertical Cylindrical
  - Height to diameter ratio 2-2.75 : 1
- Box/Cabin Heater
  - Height to width ratio 1.5-2.75 : 1
- Large firebox is better for uniform heat transfer
- Tall firebox can have heat flux variations
- Three H/D ratios of radiant sections are compared
- Average Radiant Flux- 10,000 Btu/hr. ft^2

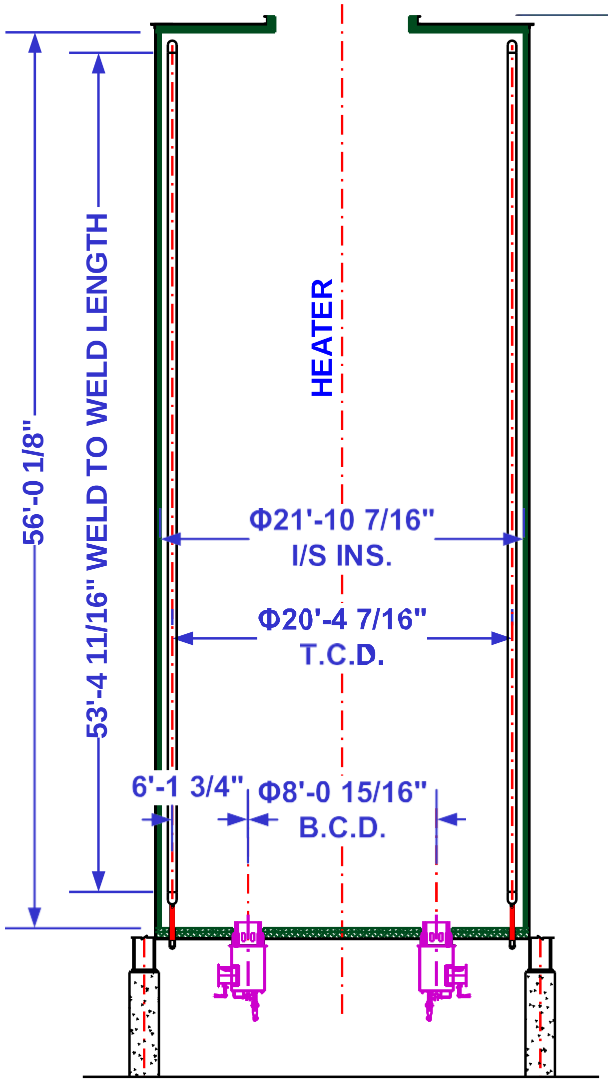
VC Heaters With Different H/D Ratios



Case 1 : H/D Ratio: 2.21

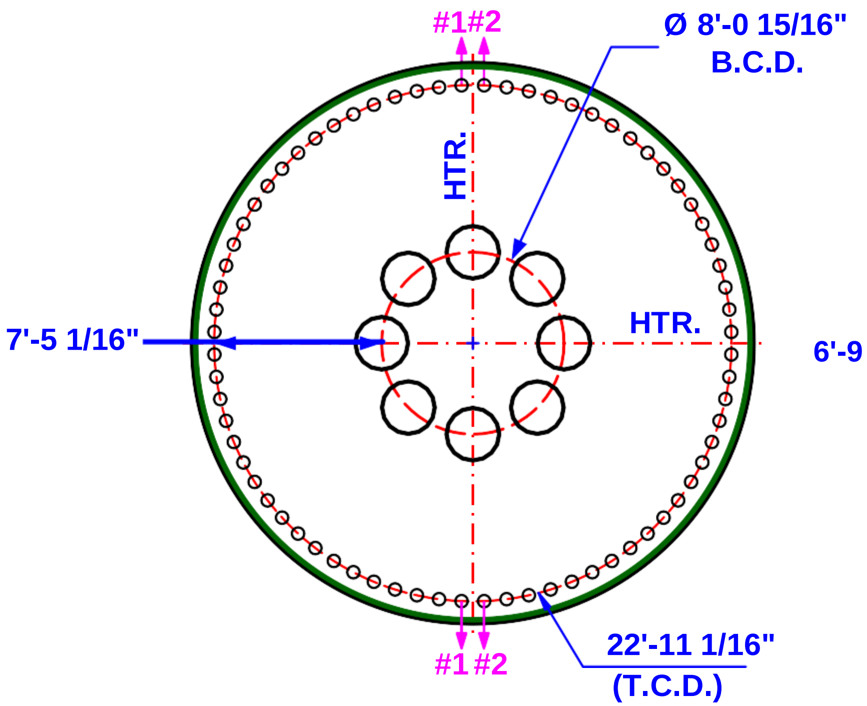


Case 2 : H/D Ratio: 2.48

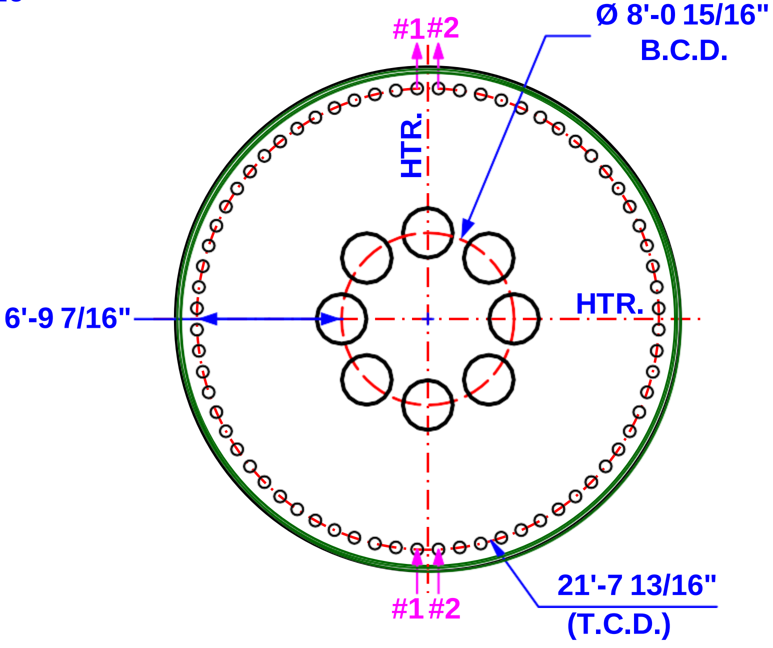


Case 3 : H/D Ratio: 2.75

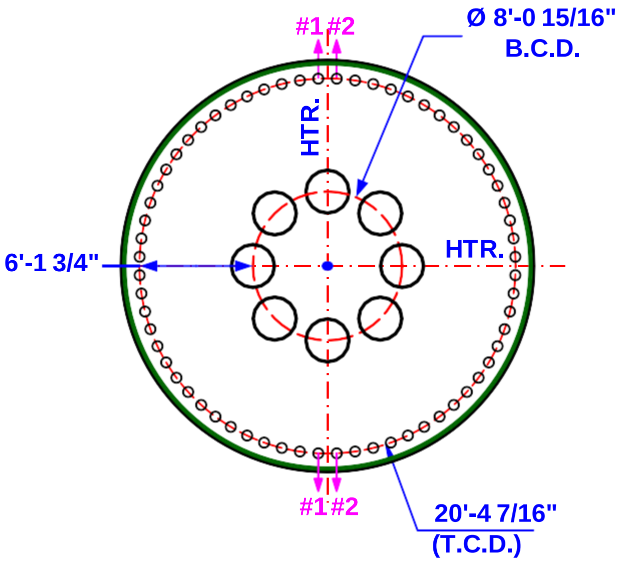
Burner and Radiant Tube Layout



Case 1 : H/D Ratio: 2.21



Case 2 : H/D Ratio: 2.48



Case 3 : H/D Ratio: 2.75

Parameter	Units	Case-1	Case-2	Case-3
Floor Flux Density	MMBtu/hr-ft²	0.288	0.323	0.365
Burner to Tube Clearance	ft	7.42	6.79	6.15

VC Heaters With Variable H/D Ratio Observations

Parameter	Units	Case-1	Case-2	Case-3
No. of Radiant tubes	**-**	**72**	**68**	**64**
Straight tube length	ft	47.27	50.15	53.38
Effective tube length	ft	48.84	51.72	54.95
Height of Fire Box	Ft	50.69	53.62	56.01
Diameter of Firebox	Ft	24.42	23.15	21.87
Tube circle diameter	Ft	22.92	21.65	20.37
H/D Ratio	**-**	**2.21**	**2.48**	**2.75**
Total Estimated Heater Cost	**Million USD**	**1.64**	**1.60**	**1.57**

Effect of Tube Sizes and Passes On Heater Design

Passes vs. Tubes Size

- More passes
- Smaller tube size
- Lower cost
- Better heat transfer coefficients
- More flow controllers and control valves needed
- Pass flow and balancing becomes critical
- Multiple passes may not receive uniform heat absorption

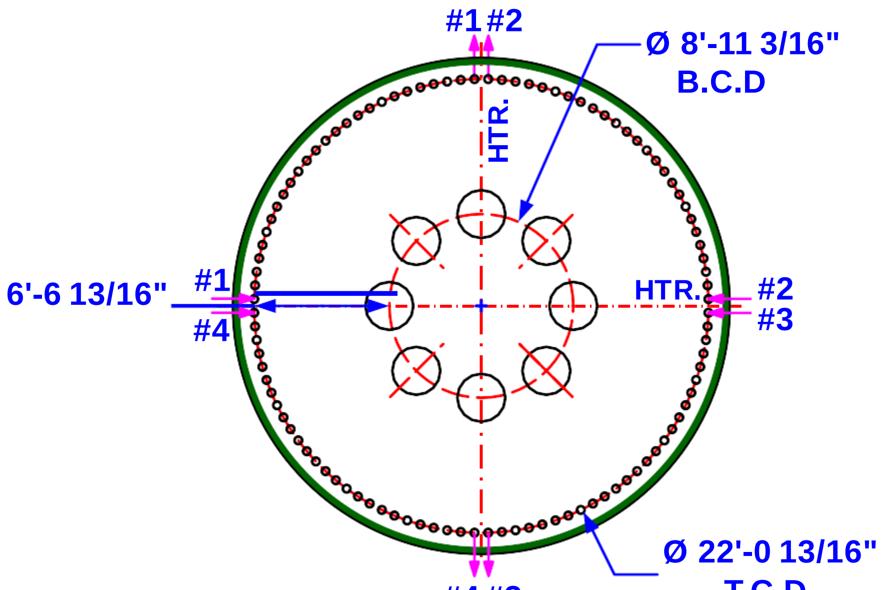
- Fewer passes
- Larger tube size
- Higher cost
- Fewer flow controllers and control valves
- Single pass heater-most reliable

Radiant Section Details

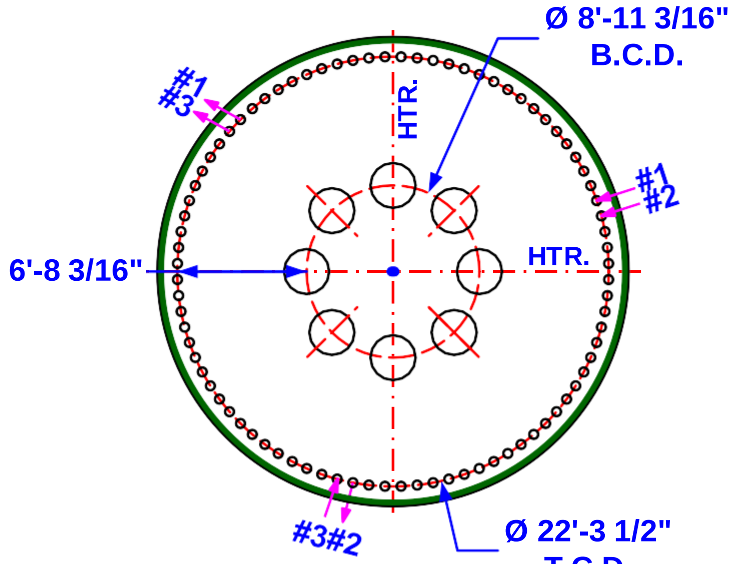
Parameter	Units	Case-1	Case-2	Case-3
Tube Size	-	4” NPSx Sch.40	5” NPSx Sch.40	6” NPSx Sch.40
No. Of Passes	-	4	3	2
No. of Radiant tubes	**-**	**104**	**84**	**64**
Radiant Tube Center To Center Spacing	in	8	10	12
Straight tube length	ft	48.74	48.55	53.39
Effective tube length	ft	49.78	49.86	54.96
Radiant Heat Transfer Area	**ft^2**	**6,100**	**6,100**	**6,100**

Radiant Section Details (Contd.)

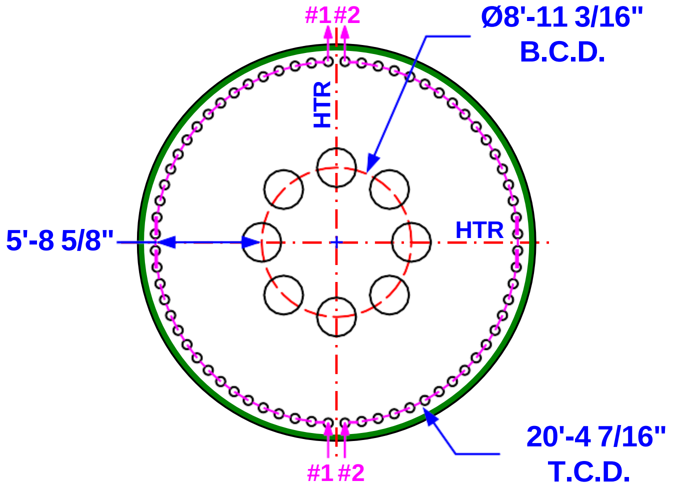
Parameter	Units	Case-1	Case-2	Case-3
Estimated Radiant Cost	Millio n USD	0.97	0.98	1.0



Case 1



Case 2



Case 3

Convection Section Details

Parameter	Units	Case-1	Case-2	Case-3
Tube Size	-	4” NPSx Sch.40	5” NPSx Sch.40	6” NPSx Sch.40
No. of Passes	-	4	3	2
No. of Tube Rows (Bare / Finned)	-	3 / 5	3 / 5	3 / 5
Effective tube length	ft	21.51	21.10	18.25
Heat transfer area (Bare / Finned)	ft^2	912 / 19,240	1,106 / 22,573	1,140 / 23,930
Estimated Convection Cost	**Million USD**	**0.42**	**0.45**	**0.49**

Performance Comparison

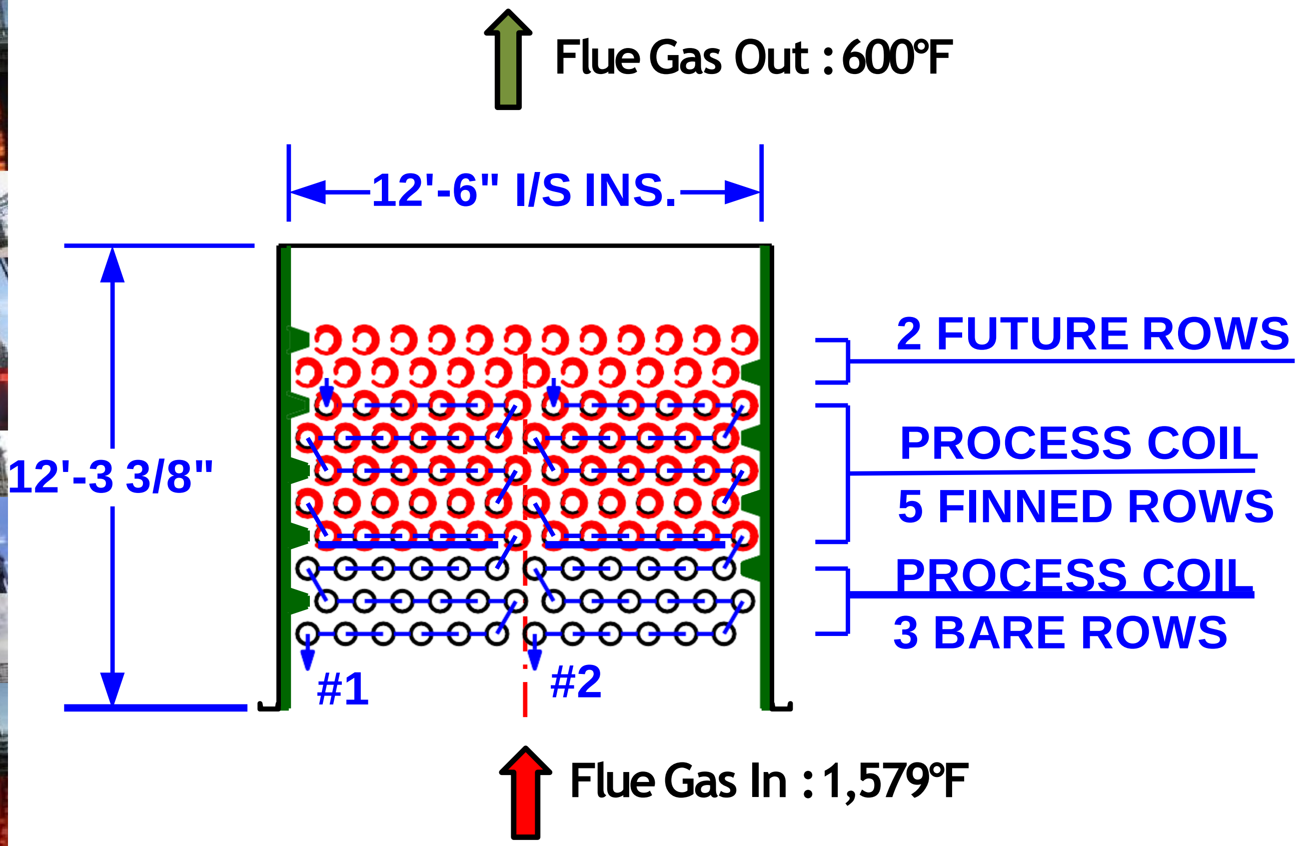
Parameter	Units	4" NPS 4 Passes	5" NPS 3 Passes	6" NPS 2 Passes
Coil pressure drop	psi	73.67	56.66	62.9
Fluid Mass Velocity in Radiant Section	$lb/sec.ft^2$	285.4	242.1	251.5
Inside heat transfer coefficient	$Btu/hr/ft^2/^oF$	560	471	467
Maximum radiant inside film temperature	^oF	678	703	710
Volumetric Heat Release	$Btu/hr.ft^3$	6,030	5,767	6,519
Convection Heat Transfer Area (Bare + Finned)	ft^2	912 + 19,240	1,106 + 22,573	1,139 / 23,930
Flue gas mass velocity in conv. Section	$lb/sec.ft^2$	0.491	0.398	0.371
Total Estimated Heater Cost	**Million USD**	**1.50**	**1.55**	**1.60**

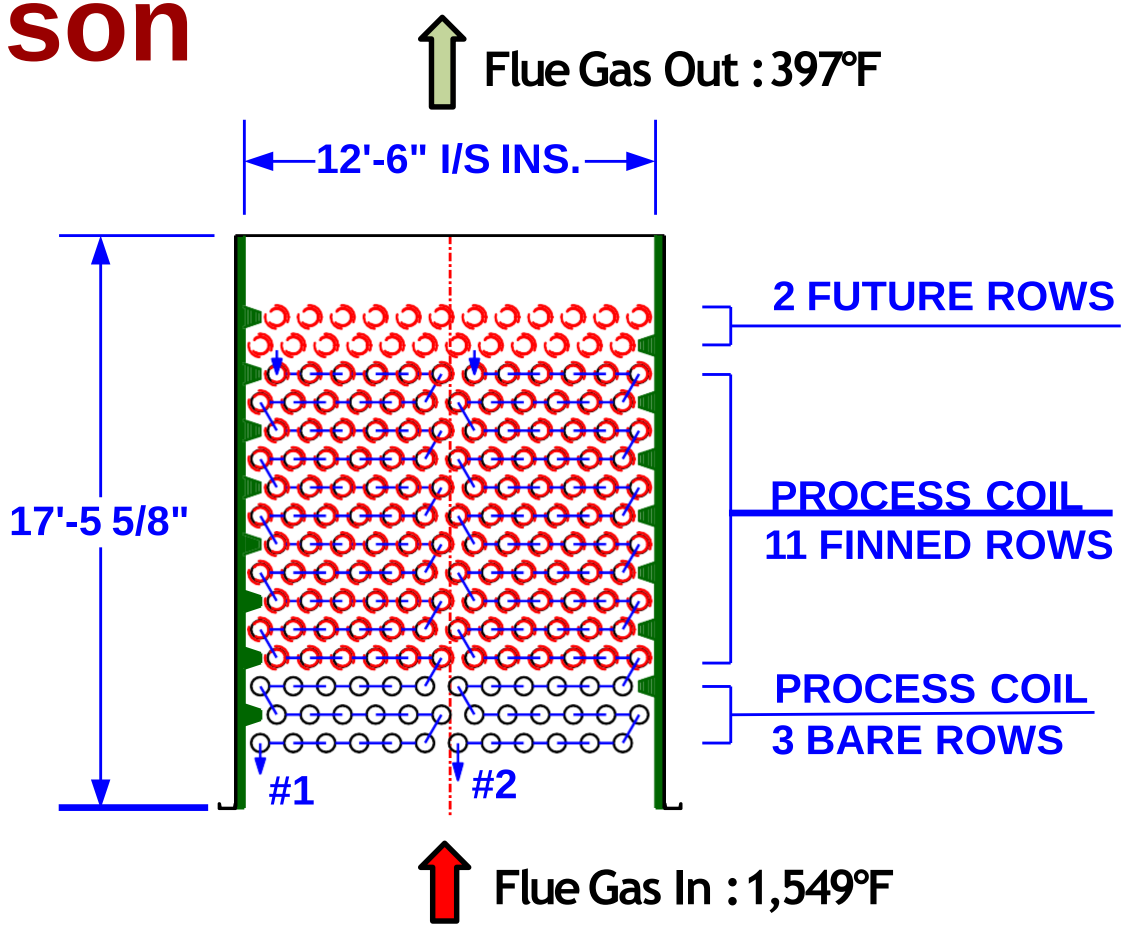
Flue Gas Temperature Approach Comparison

Flue Gas Temperature Approach

- Flue gas temperature approach is typically 150-250°F
- Lower the flue gas temperature approach to almost 50-75°F
- Maximum thermal efficiency fired heaters
- Two cases of temperature approaches are considered
  - Case 1 : 247°F
  - Case 2 : 50°F

Flue Gas Temperature Approach Comparison





Parameter	Units	Case1	Case2
Temperature Approach	°F	247	50
Estimated Convection Cost	**Million USD**	**0.49**	**0.74**

Performance Comparison

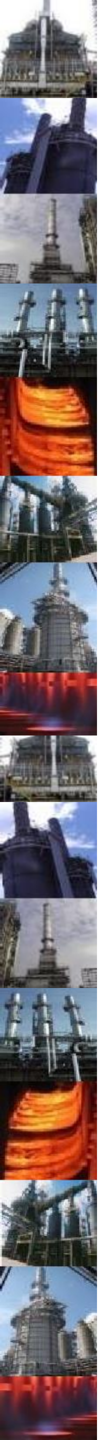
Parameter	Units	Case-1	Case-2
Coil pressure drop	Psi	**66.0**	**73.9**
Radiant Duty	MMBtu/hr	62.8	60.0
Avg. Radiant Heat Flux	Btu/hr.ft^2	**10,295**	**9,836**
Bridgewall Temperature	°F	**1,579**	**1,549**
Volumetric Heat Release	Btu/hr.ft^3	6,519	6,113
Convection Heat Transfer Area (Bare + Finned)	ft^2	**1,140 / 23,930**	**1,140 / 52,646**
Average Process Conv. Heat Flux (BOS)	Btu/hr.ft^2	12,242	7,522
Flue gas mass velocity in conv. Section	lb/sec.ft^2	**0.371**	**0.348**
Flue gas convection exit temperature	°F	600	397

Performance Comparison (Contd.)

Parameter	Units	Case-1	Case-2
Flue Gas Temperature Approach	°F	247	44
Heater Firing Rate	MMBtu/hr	119	112
Fuel Flow Rate	lbs/hr	5,791	5,430
Heater Efficiency	**%**	**84.0**	**89.2**
Total Estimated Heater Cost	**Million USD**	**1.6**	**1.85**
Total fuel saved per hour	**lb**	**361**	
Fuel Saving per year	**Million USD**	**0.196** **(Assuming $3/ MMBtu heat release)**	
Payout Period	**Years**	**1.3**	

Heater Specifying Process

- Process Licensor/Client provides the process heat duty and terminal conditions (in/out)
- It is provided to Engineering Companies for developing FEL-2/3 estimates
- Engineering Companies add missing details and floats inquiries to heater vendors to get their budgetary proposals
- Engineering Companies firm up heater specifications and issue firm inquiries for supply in EPC stage
- Clients end up having most economical heater



API 560 for Fired Heaters

- Very good standard for general refinery services
- It leaves the process design of the heater to vendors.
- How can you compare the heater designs if they are designed differently?
- Most engineering companies lean on heater vendors and choose the most economical design (lowest cost)
- Better way would be to start with heater thermal design

Thank You

- We hope you will find our presentation helpful and informative
- Questions and comments are welcome