energy API

Fired Heaters for General Refinery Service

API 560 Standard – 1986-2016

By

FURNACE IMPROVEMENTS

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HIGHEST EFFICIENCY LOWEST EMISSIONS LONGEST RUN LENGTH

MAY 2017

Table of Contents

Section 1
Introduction

API Specifications (standards) are published by American Petroleum Institute as an aide to procurement of standardized equipment and materials API publications may be used by anyone desiring to do so.

API-560 standard for fired heater for general refinery service is based on accumulated knowledge and experience of petroleum refiners, fired heater manufacturers and engineering contractors. The primary purpose of this standard is to establish minimum mechanical requirements.

API subcommittee of heat transfer (SCHTE) meets twice a year and all the efforts and hours put into this standard are voluntary and selfless service. Thanks to all the participants who have donated their time and know-how in improving this standard.

API 560 first edition which was issued in 1986 was a mere 62 pages long. The fifth edition of API-560, which was issued in 2016, is almost 327 pages long. There have been a lot of additions and some deletions/ modifications to the specifications as the industry developed and started using it.

Furnace Improvements team decided to trace the API-560 history and compare all the first editions to show the changes that have taken place over time. We hope it will be a useful document to all the people who are dealing with fired heaters.

Section 2

API 560 Standards Comparison

Furnace Improvements, Sugar Land, TX

www.heatflux.com

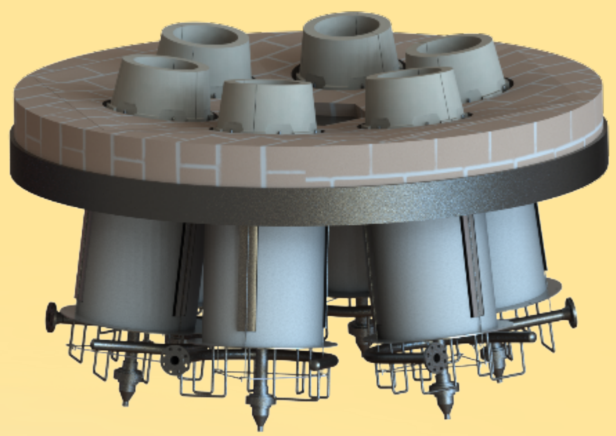
Section 2
API 560 Standard Comparison

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Section 2- Design Considerations				
Multi-pass heaters shall be designed for hydraulic and thermal symmetry of all passes	Multi-pass heaters shall be designed for hydraulic symmetry of all passes.			
The number of passes shall be minimized.	The number of passes shall be minimized for vaporizing fluids.			
Added in 4th Edition			Where the average radiant heat flux density is specified based on two nominal diameters, the vendor may increase the flux rate for other coil arrangements, e.g. for three nominal diameters or double-sided firing, provided the maximum flux, including maldistribution, shall not exceed that based on two nominal diameters.	
Added in 4th Edition			Margins provided in the combustion system are not intended to permit operation of the heater at greater than the design process duty.	
Calculated and actual efficiencies shall be based on the lower heating value of the primary fuel and shall include a minimum radiation loss of 1.5 percent of the calculated normal heat release. Heaters employing air preheat systems shall include a minimum radiation loss of 2.5 percent of the total fuel heat input.		Calculated and actual efficiencies shall be based on the lower heating value of the input fuel and shall include a minimum radiation loss of 1.5 percent of the calculated normal heat release. Heaters employing flue gas air preheat systems shall include a minimum radiation loss of 2.5 percent of the total fuel heat input based upon the lower heating value.	Calculated fuel efficiencies shall be based on the lower heating value of the design fuel and shall include a radiation loss of 1.5 % of the calculated normal fuel heat release. Heaters employing flue gas/air preheat systems shall include a radiation loss of 2.5 % of the fuel heat release based on the lower heating value.	Calculated fuel efficiencies shall be based on the lower heating value of the design fuel and shall account for the rate of heat loss from the exterior surfaces of the heater; along with heat loss from associated ducts, fans, air preheater and selective catalytic reduction (SCR); to cooler surroundings. 11.2.2 NOTE 2 The rate of heat loss from the exterior surfaces of the heater; along with heat loss from associated ducts, fans, air preheater and SCR; to cooler surroundings is typically in the range of 1.5 % to 2.5 % of the calculated normal fuel heat release, based on the fuel's lower heating value.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Inclined Firing System

Most tube failures in fired heaters occur due to high tube metal temperatures (TMTs). Flame impingement due to long burner flames results in higher TMTs and coking that affect the performance of the heater. Furnace Improvements developed the patented **Inclined Firing System (IFS)** to reduce flame impingement on heater tubes.



With this burner arrangement, a heater will have the following advantages:

- Elimination of hot spots
- Longer tube life
- Increased heater run lengths
- More uniform heat transfer along the tubes' lengths
- Lower coking rates of internal tube surfaces

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	The heater efficiencies shall be calculated using the specified fouling resistances.		The heater efficiencies and tube metal temperatures shall be calculated using the specified fouling resistances.	
Added in 2nd Edition	Table 2: Extended surface materials, for stud and fin material, 25Cr-20Ni stainless steel maximum tip temperature of 1800°F (982°C) is added.			
Added in 4th Edition			Table 2: Extended surface materials, in 21/4-1Mo, 5Cr-1/2Mo material maximum fin tip temperature of 1000°F (549°C) is added.	
Heaters shall be designed such that a negative pressure of at least 0.10 inches of water is maintained in the radiant and convection sections at maximum heat release with the design excess air.	Stacks and flue gas systems shall be designed so that a negative pressure of at least 0.10 inches of water is maintained in the radiant and convection sections at 120% of normal heat release with the design excess air and maximum ambient temperature.	Stack and flue gas system shall be designed so that the negative pressure of at least 25 pascals (0.10 inches of water column) is maintained in the radiant and convection sections at maximum ambient temperature and 120% of normal heat release with design excess air and design stack temperature.	Stack and flue-gas systems shall be designed so that a negative pressure of at least 25 Pa (0.10 in of water column) is maintained in the arch section or point of minimum draught location (which is typically below the shield section) at 120 % of normal heat release with design excess air and design stack temperature.	

<table>
<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td colspan="4">Added in 5th Edition</td><td>If specified by the purchaser, the layout of tubes in the convection section shall incorporate a 450 mm (18 in.) fin tip to fin tip vertical gap or space every eight tube rows to allow access for inspection. Provide a minimum of one access door, having a minimum clear opening of 600 mm × 600 mm (24 in. × 24 in.), in the space between each set of tube sheets in each vertical gap. Permanent platforms are not required.</td></tr>
<tr><td colspan="3">The convection-section tube layout shall include space for future installation of sootblowers, water washing or steam-lancing doors.</td><td colspan="2">If specified by the purchaser, the convection-section tube layout shall include space for future installation of sootblowers, water washing or steam-lancing doors.</td></tr>
<tr><td>The convection section shall incorporate space for future addition of two rows of tubes.</td><td colspan="4">The convection section design shall incorporate space for the future addition of two rows of tubes, including the end and intermediate tube sheets. Placement of sootblowers and cleaning lanes shall be based upon the addition of future tubes. Holes in the end tube sheets shall be plugged off to prevent flue gas leakage.</td></tr>
<tr><td>When heater is designed for fuel-oil firing, soot-blowers shall be provided for convection section cleaning.</td><td colspan="4">When heater is designed for fuel-oil firing, soot-blowers shall be provided for convection section cleaning. When light fuel oils such as naphtha are fired, the purchaser shall specify if sootblowers are to be supplied.</td></tr>
<tr><td colspan="2">Vertical cylindrical heaters shall be designed with a maximum height-to-diameter ratio of 2.75, where the height is the radiant section height (inside refractory face) and the diameter is the tube circle diameter, both measured in consistent units</td><td colspan="3">Vertical cylindrical and vertical tube box heaters shall be designed with a maximum height-to-width ratio of 2.75, where the height is the radiant section height (inside refractory face) and the width is the distance between tube centrelines.</td></tr>
<tr><td>Added in 2nd Edition</td><td>Horizontal tube, floor-fired heaters shall have a maximum height-to-width ratio of 2.75, where the height is the dimension from the floor to the arch refractory or tubes on the centreline of the chamber and width is the distance between refractory walls.</td><td colspan="3"><table><tr><th>Design Absorption (MMBTU/h)</th><th>Max H/W</th><th>Min. H/W</th></tr><tr><td>Up to 12</td><td>2.00</td><td>1.50</td></tr><tr><td>12 to 24</td><td>2.50</td><td>1.50</td></tr><tr><td>Over 24</td><td>2.75</td><td>1.50</td></tr></table>Horizontal tube floor fired heaters shall have a maximum height to width ratio of 2.75, where the height is the dimension from the floor to the arch refractory or tubes on the centreline of the chamber, and the width is the distance between refractory walls.</td></tr>
</table>

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Except for the first shield row, convection sections shall be designed with corbels to minimize the amount of flue gas bypassing the heating surface.			Except for the first shield row, convection sections shall be designed with corbels or baffles to minimize the amount of flue gas bypassing the heating surface.	

Split Flow Technology

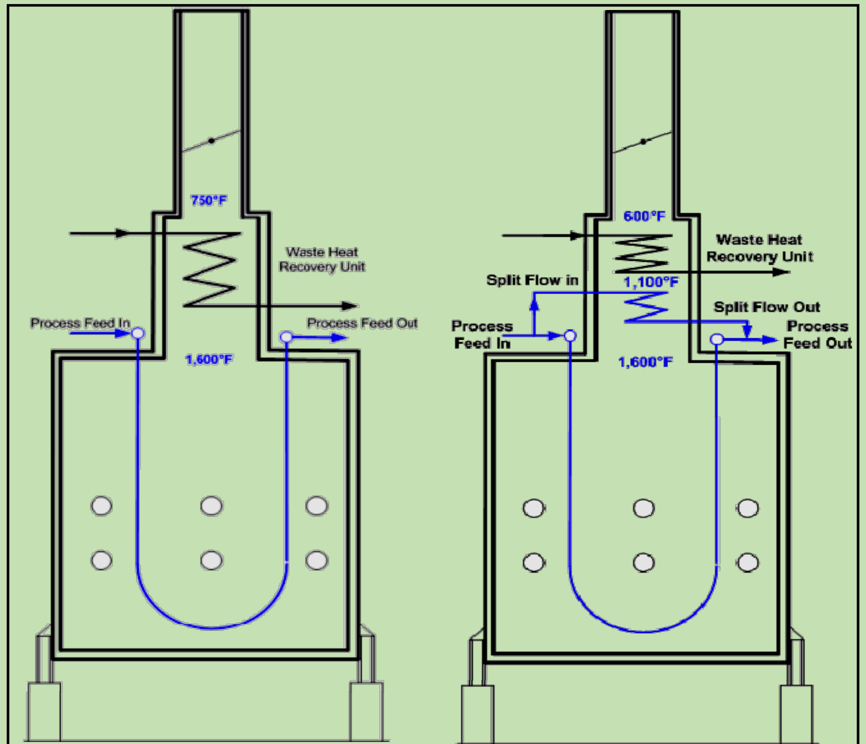
When refiners wish to increase the capacity of their fired heaters, "**Split Flow**" aims to improve the utilization of thermal energy for process heating. This objective is achieved by splitting the process fluid into two parallel streams:

Main Stream: The fluid in the first stream is heated predominantly by the convective and radiant heat transfer mechanism

Split Stream: The fluid in the second stream is heated predominantly by the convective heat transfer mechanism.

The streams are then combined at the heater outlet. This technology has been used very successfully for capacity increase revamps of fired heaters particularly in Platformer heaters. It is suitable for increasing the capacity of a heater by 15-30%. Other advantages of the **Split Flow Technology** include:

**** Higher heater efficiency***
**** Lower process pressure drop***
**** Lower firing rate***
**** Lower firebox temperatures***
**** Lower radiant heat fluxes***
**** Lower TMTs***
**** Lower installation costs***



Typical Reformer Heater   Split Flow Reformer Heater

Convection sections shall be designed with corbels to minimize flue gas bypassing the heating surface. Corbels or baffles may be employed		Except for the first shield row, convection sections shall be designed with corbels to minimize flue gas bypassing the heating surface.		
The heater arrangement shall allow for replacement of individual tubes without disturbing adjacent tubes	The heater arrangement shall allow for replacement of individual tubes or hairpins without disturbing adjacent tubes			
Added in 3rd Edition		Convection sections with an effective tube length over 12.2 meters (40 feet) shall have more than one flue gas off take to the stack(s).		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Section 3- Tubes

Calculations made to determine tube wall thickness for coils shall include considerations for erosion and corrosion allowances for the various coil materials. The following corrosion allowances shall be used as a minimum:

Material	Inches
Carbon steel through C-1/2Mo	0.125
Low alloys through 5Cr-1/2Mo	0.100
Above 7 Cr-1/2 Mo through austenitic steels	0.050

Calculations made to determine tube wall thickness for coils shall include considerations for erosion and corrosion allowances for the various coil materials. The following corrosion allowances shall be used as a minimum:

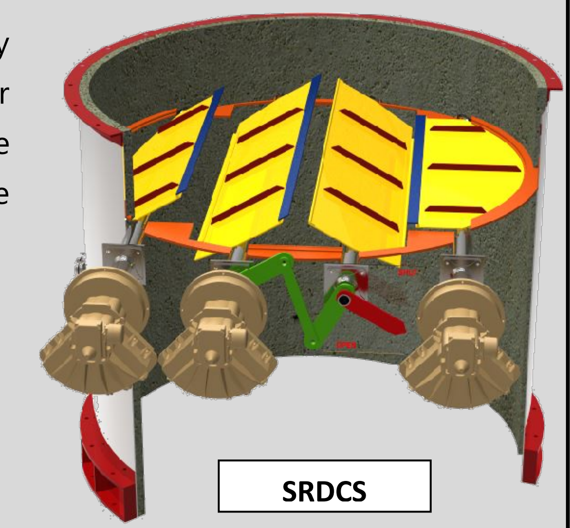
Material	Inches
Carbon steel through C-1/2 Mo	0.125
Low alloys through 9Cr-1Mo	0.080
Above 9Cr-1Mo through austenitic steels	0.040

Safe and Reliable Draft Control System

Conventional

Fired heaters are major consumers of energy in the Refining and Petrochemical Industries. Almost 40 to 70% of the total energy consumption in a refinery or petrochemical plants is in fired heaters. Refineries in the USA spend upward of $2.5 Billion per year on the fuel bill. While most of the plant operators and engineers are aware of the importance of controlling Excess Oxygen in the fired heaters, the draft control in fired heaters is often over looked. Most of the heaters are operating with very high draft. The average draft in the fired heaters maintained is at almost 3-4 times the value recommended.

We have developed a new type of damper operation for controlling draft in the fired heaters. Our patent pending damper design has multiple pneumatic operators for controlling the damper. Typically, two operators will cover most of the range but in some very large dampers, we may recommend installing 3 operators. By installing multiple operators, we can change the control characteristics of the damper itself and damper can work smoothly from 50 % to 115% load without any issues. It is possible to save substantial amount of energy by improving the controls. We can take care of tramp air by operating the heater at correct draft. We have developed a Safe and Reliable Damper Control System which can be used by itself or can be integrated with draft control system.


SRDCS

All tubes shall be seamless, preferably in single continuous lengths. Electric flash welding is not permitted for intermediate welds. Tubes furnished to an average wall thickness shall be in accordance with ASTM tolerances so that the required minimum wall thickness is provided.

All tubes shall be seamless. Tubes shall not be circumferentially welded to obtain the required tube length, unless approved by the purchaser, in which case the location of welds shall be agreed by purchaser. Electric flash welding shall not be used for intermediate welds. Tubes furnished to an average wall

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
			thickness shall be in accordance with suitable tolerances so that the required minimum wall thickness is provided.	
Tubes, when projected into header box housings, shall extend a minimum of 150 millimetres (6 inches) (in the cold position) beyond the face of the end tube sheet of which 100 millimetres (4 inches) must be bare. When rolled plug headers are used, the tube length shall include a bare tube projection equal to two times the tube seat dimension, plus 50 mm (2 inches)			Tubes, if projected into header box housings, shall extend at least 150 mm (6 in.), in the cold position, beyond the face of the end-tube sheet, of which 100 mm (4 in.) shall be bare.	
The extended surface in convection sections may be studded, where each stud is attached to the tube by arc or resistance welding process or the finned type, where helically wound fins are continuously welded to the tube.			The extended surface in convection sections may be studded (where each stud is attached to the tube by arc or resistance welding) or finned (where helically wound fins are high-frequency, continuously welded to the tube). The purchaser shall specify or agree the type of extended surface to be provided. In the case of finning, the purchaser shall specify or agree whether the fins shall be solid or segmented (serrated).	
In Table 4, Tube material and ASTM Specification, for Cast 25Cr-20Ni A608 Gr tubes specification is not mentioned			In Table 3, Tube material and ASTM Specification, for Cast 25Cr-20Ni A608 Gr material tubes specification: A213 TP 310H is included	
Section 4- Headers				
When plug headers are specified to permit mechanical cleaning of coked or fouled tubes, they shall consist of the two-hole type. Single-hole, 180-degree, plug headers may be installed only for tube inspection and draining.		When plug headers are specified to permit mechanical cleaning of coked or fouled tubes, they shall consist of the two-hole type. Single-hole, 180-degree, plug headers may be installed only for tube inspection and draining. When pigging is the mechanical cleaning method, contoured plugs are required. The contoured plug top must be clearly marked to assure proper orientation.		If plug headers are specified to permit mechanical cleaning of coked or fouled tubes, they shall consist of the two-hole type. Single-hole, 180-degree, plug headers may be installed only for tube inspection and draining.
The Table 5: Tube centre to centre dimensions for headers contains details for minimum rolling distances			Table 4: Tube centre to centre dimensions for headers, is modified. The entire details for header centre to centre dimension for minimum rolling are deleted.	
Dimensions of the tube seat shall conform to details shown in Table 1 for tube wall thickness within the limits shown. Dimensions for tube wall thinner or thicker than shown in Table 1 are not within the scope of this standard.			**Deleted**	

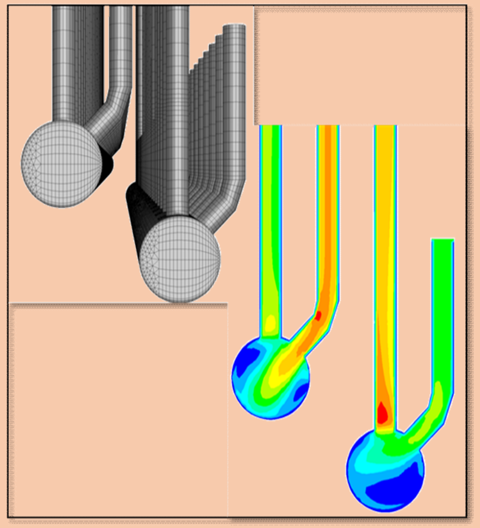
1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Table 1: Tube seat dimensions: For 4" O.D pipe the dimension 'B' is 1.5" and minimum tube wall is 0.1875".		Table 1: Tube seat dimensions: For 4" O.D pipe the dimension 'B' is 1.625"and minimum tube wall is 0.0625".	Table 1: Tube Seat Dimensions- Deleted	
Return bends are preferred for the following conditions: **Added**		Return bends are preferred for the following conditions: d. When pigging is the mechanical cleaning method.		

CFD Modeling

At Furnace Improvements, we utilize CFD modeling to analyze problems and provide solutions. This tool enables us to study the existing design and operating conditions of heaters and determine recommendations for solving any difficulties. CFD gives a competitive edge over other analyses due to its visual presentation of the observed conditions and proposed modifications. The following are a few areas where FIS has used this tool effectively:

- Flow maldistribution
- Mixing (ammonia injection grid & flue gas
- recirculation mix box design)
- Combustion (burner & heater design)
- Tube failures
- Heat transfer

However, the CFD applications are not limited to these items. FIS is making every effort to explore its varied applications and use this powerful tool if and when it is required.



CFD Modeling of Flow Distribution in an

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Table 6—Plug Header and Return Bend Materials			Table 5—Plug Header and Return Bend Materials is modified. Following materials are added in the table: 1. 9 Cr-1Mo-V; 2. 18 Cr-8 Ni Type 304L; 3. 16 Cr-12 Ni-2 Mo Type 316L; 4. 18 Cr-10 Ni- 3 Mo Type 317; 5. 18Cr-10Ni-3Mo Type 317L. The material specification for 7 Cr - 1/2 Mo is deleted.	

Section 5- Piping Terminals and Manifolds

Added in 2nd Edition	Manifolds and external piping shall be located so as not to block access for the removal of single tubes or hairpins.

<table>
<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td>Added in 2nd Edition</td><td colspan="4">Manifolds inside a header box shall be selected for the same design pressure as the connecting tubes and for a design temperature equal to the maximum fluid operating temperature at that location plus a minimum of 50°F.</td></tr>
<tr><td>Added in 2nd Edition</td><td></td><td colspan="3">
<table>
<tr><th colspan="7">Table 7: Allowable Movements</th></tr>
<tr><th></th><th colspan="3">Horizontal tubes</th><th colspan="3">Vertical Tubes</th></tr>
<tr><th></th><th>Δx</th><th>Δy</th><th>Δz</th><th>Δx</th><th>Δy</th><th>Δz</th></tr>
<tr><td>Radiant Terminals</td><td>0</td><td>+1</td><td>±1</td><td>0</td><td>±1</td><td>±1</td></tr>
<tr><td>Convection Terminals</td><td>0</td><td>+0.5</td><td>±0.5</td><td>-</td><td>-</td><td>-</td></tr>
</table>
</td></tr>
<tr><td colspan="2">The crossover piping shall be the same metallurgy as the preceding convection tube</td><td colspan="3">When external, the crossover piping shall be the same metallurgy as the preceding convection tube, but when internal it shall be of the metallurgy used for the radiant tubes.</td></tr>
<tr><td colspan="3">Table 6—Allowable Forces and Movements for Tubes</td><td colspan="2">Deleted</td></tr>
<tr><td colspan="3">Table 7—Allowable forces and movements (tubes only)</td><td colspan="2">Table 7—Allowable Movements for Tubes, is modified and changes are made in the Δx direction, from a value of 0, it is now required to be specified by the vendor</td></tr>
<tr><td colspan="3">Added in 4th Edition</td><td colspan="2">Figure 5—Diagram of Forces for Manifolds</td></tr>
<tr><td colspan="3">Added in 4th Edition</td><td colspan="2">Table 8—Allowable Forces and Moments for Manifolds</td></tr>
<tr><td colspan="3">Added in 4th Edition</td><td colspan="2">Table 9—Allowable Movements for Manifolds</td></tr>
<tr><td colspan="5">Section 6 Tube Supports</td></tr>
<tr><td>For the convection section, the temperature of the flue gas in contact with the support plus 100°F.</td><td>For the convection section, the temperature of the flue gas in contact with the support plus 100°F for gas firing or plus 200°F for oil firing</td><td colspan="3">For the convection section, the temperature of the flue gases in contact with the support plus 55°C (100°F)</td></tr>
<tr><td colspan="2">The minimum corrosion allowance for all exposed surfaces of each tube support and guide contacting flue gases shall be 1.3 millimeters (0.05 inch) for austenitic materials and 2.5 millimeters (0.10 inch) for ferritic-materials.</td><td colspan="3">The minimum corrosion allowance each side for all exposed surfaces of each tube support and guide contacting flue gases shall be 1.3 millimeters (0.05 inch) for austenitic materials and 2.5 millimeters (0.10 inch) for ferritic-materials.</td></tr>
</table>

<table>
<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td>Type 304 stainless steel anchors shall be used</td><td colspan="4">As a minimum, Type 304 stainless steel anchors shall be used</td></tr>
<tr><td>The sleeve material shall be the same as the end tube sheet.</td><td colspan="4">The sleeve material shall be Type 304 stainless steel.</td></tr>
<tr><td>The vendor shall specify the source for allowable stress data</td><td colspan="4">Stress data are presented in appendix D</td></tr>
<tr><td>Added in 2nd Edition</td><td colspan="4">
<table>
<tr><th colspan="4">Table 8: Maximum Design Temperature for Tube Support Materials</th></tr>
<tr><th>Temperature (°F)</th><th>Material</th><th>Casting</th><th>Plate</th></tr>
<tr><td>1200</td><td>2.25Cr-1Mo</td><td>A217 Gr WC9</td><td>A387 Gr 22, C1.1</td></tr>
<tr><td>1600</td><td>25Cr-12Ni</td><td>-</td><td>A240 Type 309H</td></tr>
<tr><td>1600</td><td>25Cr-20Ni</td><td>-</td><td>A240 Type 309H</td></tr>
<tr><td>1800</td><td>50Cr-50Ni-Cb</td><td>A560 Gr 50Cr-50Ni-Cb</td><td>-</td></tr>
</table>
</td></tr>
<tr><td colspan="3">Added in 4th Edition</td><td colspan="2">For design temperature for supports and guides exposed to flue gas- Where the radiant tube-support castings are shielded behind a row of tubes, the bridgewall temperature may be used.</td></tr>
<tr><td colspan="3">If the tube support design temperature exceeds 1200 F and the fuel contains more than 100 parts per million total vanadium and sodium, the support shall be one of the following:
1. Covered with 50 millimeters (2 inches) of castable refractory having a minimum density of 2,081 kilograms per cubic meter (130 pounds per cubic foot).</td><td colspan="2">If the tube support design temperature exceeds 1200 F and the fuel contains more than 100 parts per million total vanadium and sodium, the support shall be one of the following:
b) For radiant or accessible supports only, covered with 50 mm (2 in) of castable refractory having a minimum density of 2,080 kg/m^3 (130 lb/ft^3).</td></tr>
<tr><td colspan="5">Section 7 Refractories and Insulation</td></tr>
<tr><td>Added in 2nd Edition</td><td colspan="4">Radiant floors shall not exceed 195°F</td></tr>
<tr><td colspan="4">Walls, arches and floors shall be designed to allow for proper expansion of all parts. Where multilayer or multi-component linings are used, joints shall not be continuous through the lining.</td><td>Deleted</td></tr>
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1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Platformer Heater Capacity Improvement Project

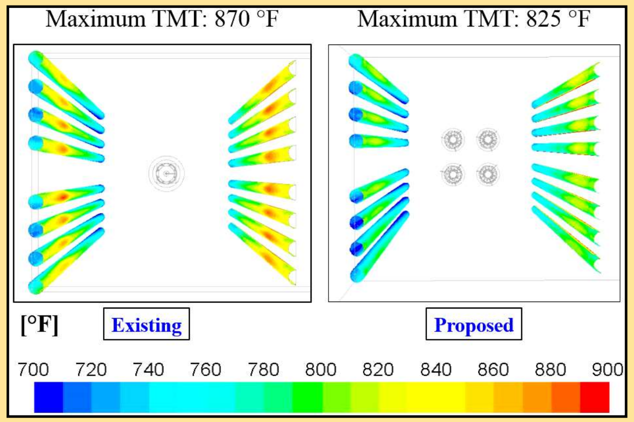
Furnace Improvements (FIS) was employed by a refinery in California to perform a capacity improvement on a Platformer Heater (H-70-01/02/03). The heater was originally built in 1979. It was designed for 12 MBPD and rated for 135.58 MMBtu/hr. of heat duty and 84.03 MMBtu/hr. of process heat duty. The heater was running at 13,000 to 15,000 BPD charge rate. The refinery was seeking to revamp the heater for 18 MBPD and total process heat duty of 113.01 MMBtu/hr and 160.86 MMBtu/hr of the total heat duty. The design thermal efficiency of the heater was ~88% and was operating at 80-81%. The stack temperature was higher by almost 300°F than design.

The conventional revamp option was to extend the existing radiant cells. Extending the radiant cells has the disadvantages: Space limitation, Higher firing rates, very high cost (requires radiant tubes and new manifolds). FIS' recommended increasing the capacity of the heater using our patented "*Split Flow Technology*".

The overall heater efficiency was improved 9%. There was an increased heat duty by 28.08 MMBtu/hr., about 33% more than the original design values. The firing rate was well within the original firing rate. FIS carried out the entire scope of activities from conceptualization to commissioning of this heater revamp. The heater was successfully commissioned in February 2008.

The floor hot surface shall be 2.5" thick course of high duty fireclay or castable of equivalent density and temperature rating.	The floor hot surface shall be 2.5" thick layer of high duty fireclay or a 3" thick layer of castable of 2500ºF service temperature and minimum cold crush strength of 500 pounds per square inch after drying at 230ºF			
Burners blocks shall have a minimum service temperature of 2700ºF	Burner blocks shall be suitable for a service temperature of at least 1650 °C (3000°F).			**Deleted**
Added in 2nd Edition	Target walls with flame impingement on both sides shall be constructed of high-duty firebrick of at least 2800ºF rating. Bricks shall be laid dry or with mortared joints. Expansion joints shall be packed with ceramic fiber strips having a service temperature rating equal to or greater than the brick. Target walls with flame impingement on one side may be of brick or plastic refractory of equivalent maximum service temperature. Either may be backed by a castable or ceramic fiber board.		Target walls with flame impingement on both sides shall be constructed of high-duty firebrick with at least a 1540°C (2800°F) rating. Bricks shall be laid dry or with mortared joints. Expansion joints shall be packed with ceramic fiber strips having a rated temperature not less than 1540°C (2800°F).	Target walls with flame impingement on both sides (free-standing) shall be constructed of super-duty fireclay bricks with at least a 1540 °C (2800 °F) rating. Super-duty fireclay bricks shall be laid with mortared joints. Expansion joints shall be packed with RCF strips rated for 1430°C (2600°F), minimum.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	Refractory anchors are not mandatory for floor castable, unless required for shipping considerations.			**Deleted**
Target walls with flame impingement on one side shall be of brick or of plastic refractory with a rated temperature of at least 1540°C (2800°F). Either may be backed by a castable or ceramic fiberboard.				**Deleted**

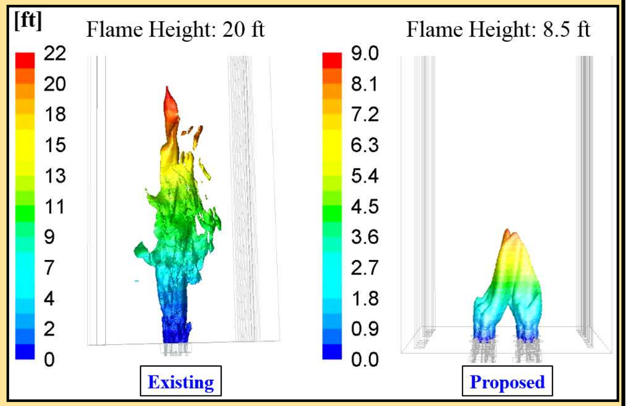


CFD Modeling to Improve Flame Profiles in Crude Heater

The Heater had frequent decoking requirement every 2.5 years. The flames were impinging on the radiant tubes.

The objective here was to increase the run length to 5 years and increase charge rate by 10%. CFD simulations were carried out using a single burner to understand flame characteristics, flue gas circulation pattern and radiant tube metal temperatures.

Each existing large burner was replaced by four smaller inclined burners. This helped in reducing high temperature zones in the heater and high flue gas temperature around the radiant tubes.



Flame length was reduced by over 50% for the proposed case and There was a significant reduction in radiant tube metal temperature.

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Added in 2nd Edition	Table 9: Maximum temperatures for anchor tips			
	Table 9: Maximum temperature of anchor tips for carbon steel is 800°F		Table 10: Maximum temperature of anchor tips for carbon steel is 850°F	
Added in 2nd Edition	Recommended refractory dry out procedure shall be provided by the heater vendor.		**Deleted**	
Added in 2nd Edition	Brick construction can be used for gravity walls, floors, or as hot face layers.			
Added in 5th Edition				At the Owner's option, when using a monolithic refractory, the outside casing temp. may be increased up to 212°F if this allows the use of a single layer lining system with the understanding this will increase the rate of heat loss.
Added in 5th Edition				For the hot-face layer the maximum

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				continuous use temperature quoted on the manufacturer's product data sheet shall be greater than the design hot-face temperature.
Added in 5th Edition				If one or more backup layers are used, the maximum continuous use temperature quoted on the manufacturer's product data sheet shall be greater than the design interface temperatures.
Added in 5th Edition				Back up insulation shall not be water soluble (e.g. organically bound insulating block and fiber materials).
Added in 2nd Edition	Gravity walls shall be of mortared construction. The mortar shall be non-slagging, air-setting, and chemically compatible with adjacent refractory, including the rated temperature of the brick.			
Added in 2nd Edition	Vertical expansion joints shall be provided at gravity wall ends and required intermediate locations. All expansion joints shall be kept open and free to move. If the joint is formed with lapped brick no mortar shall be used, that is, a dry joint.			
Added in 2nd Edition	Floor brick shall not be mortared. 0.5" gap for expansion shall be provided with fibrous refractory material in strip, not loose bulk, form.			
Added in 2nd Edition	Minimum service temperature for a hot face brick layer shall be 1427°C (2600°F) on walls with the expected flame impingement and 1260°C (2300°F) for other exposed wall applications. Minimum service temperature for shielded walls shall be 2000°F.			**Deleted**
Added in 5th Edition				Figure—6 Illustration of Gravity Wall Dimensional Requirements

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Alky Heater (H-2) NOx Reduction and Efficiency Improvement Project

Furnace Improvements (FIS) was contacted to perform a NO_x Reduction Study for Alky Unit Heater (H-2) in November 2005. The target NO_x emission rate was 0.035 lb./MMBtu (HHV).

The Alky Heater is a vertical cylindrical heater with a design heat duty of 55 MMBtu/hr. Heater was operating at an average of 41.37 MM Btu/hr. heat duty. The heater efficiency was very low. Excess oxygen in the firebox and convection section was very high. The existing floor was in bad shape. The heater did not have any damper and draft control.

Based on the heater analysis and to meet the NOx emissions level, FIS recommended:

- Modification of the existing floor
- Installation of 8 new ULNB burners
- Installation of stack damper, stack oxygen and temperature indicators
- Installation of a new stack with connected ladders and platforms.

Parameter	Before Revamp	After Revamp
Duty (MMBtu/hr)	55	60
Efficiency (%)	66	86.2
Firing Rate (MMBtu/hr)	83.3	69.6
Energy savings ($/year)	-	782,093
Payback Period (Years)	-	1.72

After the revamp, the efficiency increased by 20%. The total cost of the project for the design services, engineering services, fabrication and installation was $1,560,000. The project payout was estimated to be less than 2 years. This heater was successfully commissioned in March 2008.

Added in 5th Edition	Figure—7 Typical Stud Layout for Overlap Blanket System
Added in 5th Edition	Figure—8 Typical Layered fibre Lining Anchoring System
Added in 5th Edition	Figure—9 Examples of Modular fibre Systems
Added in 5th Edition	Figure—10 Hardware Span Required for Overhead Section Modules
Added in 5th Edition	Figure—11 Typical Module Orientations
Added in 5th Edition	Figure—12 Typical Blanket Lining Repair of Hot-face Layer

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 5th Edition				Figure—13 Typical Blanket Lining Repair of Multiple Layers
Added in 5th Edition				Figure—14 Typical Repair of Modular fibre Linings
All brick linings on vertical flat casing shall be tied back to and supported by the structural steel framing members. All supporting shelves and tie members shall be austenitic chrome-nickel alloy material, except that pipe-type supports located in the layer insulating block may be carbon steel, provided that the metal temperature does not exceed 500°F. A minimum of 10% of the bricks shall be tied back.	All brick linings on vertical flat casing shall be tied back to, and supported by, the structural steel framing members. All tie members shall be austenitic alloy material, except that pipe supports located in the backup layer may be carbon steel. At least 15% of the bricks shall be tied back. It is not necessary for the brick lining on the cylindrical casing to be tied back if the radius of curvature of the casing keys the bricks.			When firebrick linings are selected for use in radiant sidewall, they shall be held against the wall and supported using shelf supports and/or tie-backs. These anchoring types shall be detailed in the furnace design information as follows. a) Horizontal shelf supports shall not support more than 10 times the firebrick load weight and shall have a shelf width which supports 50 % of the hot-face lining thickness. b) Support shelves shall be regularly spaced on vertical centers typically 1.8 m (6 ft.) high, but not to exceed 3 m (10 ft.), based on calculated loads and thermal expansions. c) Support shelves shall be slotted to provide for differential thermal expansion. Shelf material is defined by the calculated service temperature at the hottest portion of the shelf. e) Tie-backs shall extend into at least 1/3 the thickness of the hot-face brick layer.
Added in 2nd Edition	Brick linings shall be supported by metal support shelves attached to the casing on vertical centers not to exceed 6′. Support shelves shall be slotted to provide for differential thermal expansion. Shelf material will be defined by the calculated service temperature; carbon steel is satisfactory up to 700°F.			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	Expansion joints shall be provided in both vertical and horizontal directions of the walls, at wall edges, and about burner tiles, doors, and sleeved penetrations.			Expansion joints shall be provided in both vertical and horizontal directions of the walls, at wall edges and around burner tiles, doors and sleeved penetrations. These joints shall be filled with AES/RCF fiber, compressed sufficiently to stay in place, but still allow for the required thermal movement.

Capacity Improvement for FRE-APS and FRE-VPS Heaters (31/32-F-01)

FIS carried out a Crude Heater Capacity Improvement project for an Indian Refinery in Mumbai. The Client wanted to increase the heater capacity by 15% with a thermal efficiency of more than 90%.

FIS proposed addition of a small convection section on top of the existing heater convection section and addition of burners to the heater. The convection section had a coil for vacuum heater as well and the capacity of vacuum heater was increased by 15% too.

The study was carried out in 2 weeks and the detail engineering was carried out in 8 weeks. The heater was successfully commissioned on May 2010.

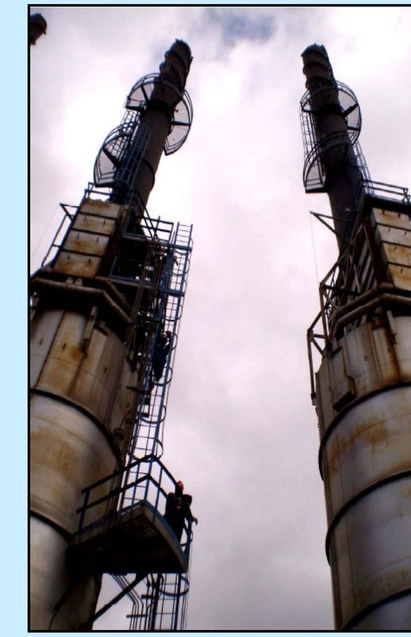
1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Monolithic floor, wall, and arch construction shall be a 1:2:4 volumetric mix of lumnite-haydite-vermiculite. This mixture shall be limited to a maximum service temperature of 1900ºF. Wall and arches shall utilize Type 304 SS anchors.	Hydraulic-setting castable are suitable as lining for all parts of fired heaters. Minimum castable construction is a 1:2:4 volumetric mix of lumnite-haydite-vermiculite. This mixture shall be limited to a maximum service temperature of 1900ºF and clean fuel applications. This castable shall be limited to 8" maximum thickness on arches and walls.			
For dual layer castable construction, the hot face layer shall be a minimum of 3" thick. The anchors or anchoring systems shall provide support for each layer.	For dual layer castable construction, the hot face layer shall be a minimum of 3" thick. The anchors or anchoring systems shall provide support for each layer when in arch or overhead position.			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Anchor penetration shall not be less than 70% of the individual layer being anchored. The anchor shall not be closer than 0.5" from the hot face.	Anchor penetration shall not be less than 70% of the individual layer being anchored for castable thickness greater than 2". The anchor shall not be closer than 0.5" from the hot face.			
The anchor spacing shall be a maximum of twice the total lining thickness but shall not exceed 12" on a square pattern for walls and 9" on a square pattern for the arches. The anchor orientation shall be varied to avoid shear planes	The anchor spacing shall be a maximum of thrice the total lining thickness but shall not exceed 12" on a square pattern for walls and 9" on a square pattern for the arches. The anchor orientation shall be varied to avoid creating continuous shear planes			When monolithic refractory is used, anchors and anchor spacing/pitch shall be as follows. a) For adiant/convection section roofs (not including breeching), anchor spacing/pitch shall be a maximum of 1.5 times the lining thickness with 300 mm (12 in.), maximum (center-to-center). b) For walls and breeching, anchor spacing/pitch shall be a maximum of 2 times the lining thickness with 300 mm (12 in.), maximum (center-to-center).
Added in 2nd Edition	Anchors for total castable thickness up to 6" shall be a minimum of 3/16" diameter. Greater thickness required a minimum of 0.25" diameter anchors.			For linings greater than or equal to 75 mm (3 in.) in thickness, anchors shall be at least 6.0 mm (1/4 in.) in diameter.
Added in 2nd Edition	Castable linings in header boxes, breechings and lined flue gas ducts and stacks shall not be less than 2" thick.			
Added in 5th Edition				For dual layer linings, "Y" anchors shall be installed to hold the hot-face in place. Spacing for the "Y" anchor on the hot-face shall be the same as that above for single layer linings based on the hot-face lining thickness. Additional anchoring may be used to hold the backup insulating layer during installation.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 5th Edition				All individual anchors shall be subject to 100 % visual inspection and hammer test and/or bend test per Table 13 to confirm they are fully welded with proper spacing and configuration.
Added in 5th Edition				Anchor welding requirements are as follows- a) At the start of each shift, sample test welds shall be performed by each welder. A sample test shall entail stud welding five anchors on a clean scrap metal plate. The hammer and bend test shall be performed for each sample to ensure a sound full weld. The bend test shall involve bending the anchor tine 15 degrees from vertical and back without cracking. b) All equipment settings shall be noted and checked after each work break.
Added in 5th Edition				Table 13—Minimum Hammer/Bend Test Frequency
11.6 Materials (Full Section)				**Deleted**
Added in 5th Edition				Responsibilities (Full Section)

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Capacity Increase Revamp of H-102 and H-205 Reboilers, Alon US



FIS was employed by a Texan Refinery to develop a NOx reduction study for De-Pantanizer Reboilers (H-102 and H-205). Client wished to reduce the NOx emissions from their heaters by installing Ultra Low NOx Burners. The targeted NOx emissions from these heaters are 0.035 lb./MMBtu (HHV basis).

Both heaters are vertical cylindrical heaters with horizontal convection section and a top mounted stack. They are design for an absorbed heat duty of 33 and 46 MMBtu/hr. FIS performed the study and found out that the convection sections were fouled. FIS suggest revamping the heaters with patented “Split Flow Technology” to increase capacity by 10%. FIS also suggest installing the ULNB with patented “inclined firing system” to eliminate fouling problems.

FIS replaced existing burners with ULN Burners. FIS installed the burners using inclined firing system technology to prevent flame impingement on tubes. The increase in capacity of the heaters after revamp was 10%. FIS scope of work included design, detail engineering, procurement, fabrication and supply of new convection section, new plenum and revamp of floor, arch and stack damper.

The heaters were revamped and commissioned in June 2011. Client is extremely happy with both heaters after revamp.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Addition in 2nd Edition	Anchors in 2" thick castable linings shall be held in place by 10-gauge minimum, bare carbon steel chain link fencing, wire mesh, or linear anchors anchored to the steel.		In castable linings up to 50 mm (2 in) thick, fencing or wire mesh shall be used for anchoring the lining. The purchaser shall specify or agree if carbon steel material is acceptable.	**Deleted**
Addition in 4th Edition		Castables with low iron content, or heavy-weight castables, shall be used on exposed hot-face walls if the total heavy-metals content, including sodium, within the fuel exceeds 250 mg/kg (250 ppm by mass). Heavyweight castables shall have a minimum density of 1 800 kg/m^3 (110 lb/ft^3) with an Al_2O_3 content of not less than 40 %. In aggregate, the Al_2O_3 content shall be not less than 40% and the SiO_2 content shall not exceed 35%.		**Deleted**
Addition in 2nd Edition	Expansion joints shall be provided around burner blocks, brick, and pre-fired shapes.			**Deleted**
Addition in 4th Edition			Maintenance/Repair: The mechanical function of supports, tie-backs and expansion joints shall be taken into consideration when repairing firebrick	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
			linings. Repairs are generally made by replacing or refurbishing entire structural units, such as the entire lift of firebricks on a support from expansion joint to expansion joint and/or several courses of firebricks at the top of a lift.	
Added in 5th Edition				Firebrick and mortar types shall be specified by the owner or equipment manufacturer.
Added in 2nd Edition	Metallic fibre may be added for reinforcement only in castables of density 880 kg/m³ (55 lb./ft³) or higher. Metallic fibres shall be limited to no more than 3% mass fraction of the dry mixture.			**Deleted**
Added in 3rd Edition		Hydraulic-setting castables, in particular light-weight and medium-weight insulating castables are susceptible to the development of alkaline hydrolysis (carbonization) placed under high ambient temperatures and/or high humidity conditions shortly after placement. See 16.5.8 regarding placement & curing.		**Deleted**
Added in 2nd Edition	Low iron content (max. 1.5% mass fraction) materials shall be used when the total heavy metals content of the fuel exceeds 100 mg/kg (100 ppm by mass).			**Deleted**
Added in 2nd Edition	Ceramic fibre in layered or modular construction may be used in all heater areas except stacks, ducts, and floors			
The hot face of layered ceramic fiber blanket installations shall be a minimum of 1" thick, 8 pounds per cubic foot density, needled material. Backup layers of ceramic fiber shall be a minimum of 1" thick, 4 pounds per cubic feet, needled material.	The hot face of layered ceramic fiber blanket installations shall be a minimum of 1" thick, 8 pounds per cubic foot density, needled material. Ceramic fiber board, when applied as a hot face layer, shall not be less than 1.5" thick nor less than 14 pounds per cubic foot density. Backup layers of ceramic fiber blanket shall be a minimum of 6 pounds per cubic feet density, needled material. Ceramic fiber board size, when used as hot face layer, shall be limited to a maximum of 24"X 24" when temperatures are below 2000°F and 18"X 18" when temperatures exceed 2000°F.			
Added in 2nd Edition	Any layer of ceramic fibre shall be suitable for a service temperature of at least 500°F above its calculated hot face temperature.			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
The anchor spacing for walls shall not exceed the following rectangular pattern: 6 inches by 9 inches for 12 inch wide blankets; 9 inches by 9 inches for 24-inch wide blankets; 9 inches by 10 inches for 36 inch wide blankets; and 9 inches by 10.5 inches for 48-inch wide blankets.		The anchor spacing for walls shall not exceed the following rectangular pattern: 6 inches by 9 inches for 12 inches wide blankets; 9 inches by 12 inches for 24-inch wide blankets; 10.5-inches by 12 inches for 48-inch wide blankets.		Anchor spacing shall be as follows: a) Vertical walls—Spacing across the blanket width shall be on 254 mm (10 in.) centers. Spacing along the blanket length shall be 254 mm to 305 mm (10 in. to 12 in.). In more extreme conditions (vibration or other), tighter centers of less than 254 mm (10 in.) are acceptable and advisable.
Added in 2nd Edition	Metallic anchor parts that are not shielded by tubes shall be completely wrapped with ceramic fibre patches or be protected by ceramic retainer cups filled with moldable ceramic fibre.			**Deleted**

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Where velocities in excess of 40 feet per second are encountered, rigidizers or wet-pack type blankets should be considered to improve resistance to shredding.	Ceramic fiber blanket is unacceptable to be used as the hot face layer when flue gas velocities are in excess of 40 ft/sec. Wet blanket, ceramic fiber board, or ceramic f fiber modules shall be used on hot face layers with velocities greater than 40 ft/sec but less than 80 ft/sec. Hot face refractory with velocities greater than 80 ft/sec require castable or external lining.			
Added in 2nd Edition	Ceramic fiber blanket shall be installed with its longest dimension in the direction of gas flow. The hot face layer of blanket shall be constructed with all joints over-lapped. Overlaps shall be in direction of gas flow. Hot face layers of ceramic fiber board shall be constructed with tight butt joints			
Added in 2nd Edition	Ceramic fiber blanket used in backup layers shall be installed with butt joints with at least 1"compression on the joints. All joints in successive layers of blanket shall be staggered.			11.4.10 Fibre blanket used in backup layers shall be installed with butt joints with at least 13 mm (1/2 in.) compression on the joints.
Added in 2nd Edition	Ceramic fiber blanket modules shall be installed in solider course (with batten strips) patterns.	Ceramic fiber blanket modules shall be installed in soldier course (with batten strips) patterns. Parquet patterns are acceptable in arch areas only.		
Added in 2nd Edition	Module systems shall be installed so that joints at each edge are compressed to avoid gaps due to shrinkage.			
Added in 2nd Edition	Module applied in arches shall be designed such that anchorage is provided over at least 80% of the module width.			
Added in 2nd Edition	Anchors shall be attached to the casing before modules are installed.			
Added in 2nd Edition	Anchor assembly shall be located in module at a maximum distance of 2" from the module cold face.			**Deleted**
Added in 2nd Edition	Module internal hardware shall be Type 304 SS as a minimum.		Module internal hardware shall be austenitic stainless steel or nickel alloy (see Table 11).	Internal hardware and anchors shall comply with the maximum tip temperature defined for studs in Table 12, based on the highest calculated temperature for each of the components.
The size of the ceramic fiberboard, if used as hot-face layer, shall be limited to maximum dimensions of 600 mm × 600 mm (24 in × 24 in) if temperatures of the flue gases are below 1100°C (2000 °F) and 450 mm × 450 mm (18 in × 18 in) if temperatures of the flue gases exceed 1100°C (2000 °F).				Maximum dimensions for fibre board used on the hot-face shall be: a) 600 mm x 600 mm (24 in. x 24 in.),

1st Edition	**2nd Edition**	**3rd Edition**	**4th Edition**	**5th Edition**
				maximum, if the design hot-face temperature is below 1100°C (2000°F) on sidewalls. b) 450 mm x 450 mm (18 in. x 18 in.), maximum, if the design hot-face temperature exceeds 1100°C (2000°F), or if used on the roof at any temperature.
Any layer of ceramic fiber shall be suitable for a service temperature at least 280°C (500°F) above its calculated hot-face temperature.				**Deleted**
The hot-face layer of a ceramic-fiber blanket system shall be anchored at a maximum distance of 75 mm (3 in) from all edges.				**Deleted**
Added in 5th Edition		The hot face blanket layer shall be overlap design [typically 100 mm (4 in.)], as shown in Figure 7, and shall only use a fiber blanket size of 610 mm (24 in.) wide x 25 mm (1 in.) thick. Anchor retaining clips shall be installed with 12 mm to 25 mm (1/2 in. to 1 in.) compression.		
The anchor spacing for arches shall not exceed the following rectangular pattern: 6 in × 9 in for 12 in wide blankets; 9 in × 9 in for 24 in wide blankets; 9 in × 10 in for 36 in wide blankets; and 9 in × 10.5 in for 48 in wide blankets.				Overhead (arch, hip roof, etc.)—Spacing across the blanket width shall be on 254 mm (10 in.) centers. Spacing along the blanket length shall be 225 mm to 250 mm (9 in. to 10 in.). In more extreme conditions (vibration or other), tighter centres of less than 225 mm (9 in.) are acceptable and advisable.
Wet-blanket, ceramic fiberboard, or ceramic-fiber modules shall be used on hot-face layers with velocities greater than 40 ft/s but less than 80 ft/s.				Wet blanket, fiberboard, or modules shall not be used as hot-face layers when velocities are greater than 30 m/s (100 ft/s).

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Platformer Heaters Capacity Improvement and NOx Reduction Project

Furnace Improvements (FIS) was employed to re-rate Heater process using Low NOx Burners and increase the capacity on Platformer Heaters (H-4/5). The heaters were originally built in 1959. The heaters were changed to forced draft in 1977. Common air pre-heater, induced draft and forced draft fan were added to pre-heat the combustion air. Process fluid is heated in radiant sections. Convection section is used for steam generation.

Heaters design capacity is 32 MBPD. The client wanted to revamp the heaters for a higher capacity of 40 MBPD. The conventional revamp option had the following disadvantages:

- Very high cost
- Requires large size manifolds and piping
- Total pressure drop was very high

Heater Section	Design Heat Duty	Revamp Heat Duty	Extra Duty Required
Process Duty	MMBtu/hr		
H-4	73.8	82.7	8.9
H-5	72.0	80.5	8.5
H-6	37.5	42.1	4.6
Total	183.3	205.3	22.0
Steam Generation	80.5	51.4	-
Firing Rate	292.2	283.7	(-)8.5

Advantages of revamped design based on split flow (using "*Split Flow technology*") are as follows:

- Lower heat flux
- Lower firing rates
- Lower pressure drop
- No radiant section modification

The process heat duty increased by 22.0 MMBtu/hr. The revamp heaters firing rate shall be 8.5 MMBtu/hr lower than existing design. The new design reduces the air preheat temperature to 270°F from operating temperature of 600-700°F.

1st–4th Edition	5th Edition
Hot-face refractory with velocities greater than 24 m/s (80 ft/s) shall have castable or external lining.	**Deleted**
Added in 5th Edition	Full thickness fiber linings shall not be used for the lining of floors where maintenance traffic and scaffolding construction are anticipated.
Added in 5th Edition	Typical patch repairs [i.e. less than 0.465 m^2 (5 ft^2)] are shown in Figure 12 and Figure13 for blanket lining systems, and Figure 14 for a modular system.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	When ceramic fiber construction is used with fuels having a sulfur content exceeding 10 parts per million, the casing shall have an internal protective coating to prevent corrosion. The protective coating shall be rated for 350ºF service temperature.			If block, IFB or fiber is used against the casing, the following applies. a) For fuels having a Sulphur content exceeding 200 mg/kg (200 ppm by mass), the casing and carbon steel anchor components that will be operating below acid dew-point temperature shall be coated to prevent corrosion. The protective coating shall have a maximum continuous use temperature of 175°C (350 °F) or greater and it shall be applied after the anchors are welded to the casing.
Added in 2nd Edition	A vapor barrier of Type 304 SS foil shall be provided when the fuel Sulphur content exceeds 500 parts per million. The vapor barrier must be located so that the exposure temperature is at least 100ºF above the calculated acid dew point for all operating cases. Vapor barrier edges shall be overlapped; edges and punctures shall be sealed.		A vapour barrier of austenitic stainless steel foil shall be provided if the fuel sulphur content exceeds 500 mg/kg (500 ppm by mass). The vapour barrier shall be located so that the exposure temperature is at least 55°C (100°F) above the calculated acid dew point for all operating cases. Vapour-barrier edges shall be overlapped by at least 175 mm (7 in); edges and punctures shall be sealed.	For fuels having a Sulphur content exceeding 500 mg/kg (500 ppm by mass), a 2 mil (50 micron) vapor barrier of austenitic stainless steel foil shall be provided in addition to coating. The vapor barrier shall be installed in soldier course and located so that the exposed temperature is at least 55°C (100°F) above the calculated acid dew point for all operating cases. Vapor barrier edges shall be overlapped by at least 175 mm (7 in.). Edges and punctures shall be overlapped and sealed with sodium silicate or colloidal silica. Mineral wool block shall not be used against the casing.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 5th Edition				In layered construction, blanket shall have a maximum width of 600 mm (24 in.) and be applied using an approved anchoring system.

Hydrogen Heater Capacity Improvement Project

Furnace Improvements (FIS) carried out a Hydrogen Heater (77-H-001) revamp project. The Hydrogen Heater is a vertical cylindrical heater, built in 1990. The heater was operating at an efficiency of 78% and an absorbed duty of 11.6 MMBtu/hr. The revamp heater design heat duty is 14.77 MMBtu/hr.

Operating data analysis indicated the following:

- Convection section fins are burned out/ fouled, resulting in higher flue gas temperature leaving the convection section.
- Flue gas temperature leaving the convection section increases continuously with time. Currently, it is around 100ºF higher than the clean conditions flue gas temperature.

The conventional revamp scheme (to preheat the feed in the convection section) resulted in very high fluid pressure drop. High fluid pressure drop was not feasible.

FIS redesigned the convection section with FIS patented **"Split Flow Technology"**. In this scheme, the feed was heated parallel in the convection and radiant section. The pressure drop across the heater reduced even at higher capacity, due to this parallel processing.

FIS carried out the entire scope of activities from conceptualization to commissioning of this heater revamp. The heater was successfully commissioned in May 2009. After revamp, the thermal efficiency of this heater increased from 78% to 86%.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	Ceramic-fibre systems shall not be applied for services where the total heavy-metals content in the fuel exceeds 100 mg/kg (100 ppm by mass).			Ceramic fibre shall not be used as the hot face layer if the design hot-face temperature exceeds 700°C (1300°F) when the fuel's combined sodium and vanadium content exceed 100 parts per million (weight basis) in the fuel being fired.
Where soot blowers or steam lances are provided, unprotected ceramic fiber shall not be used in convection sections.	Ceramic fiber shall not be used in convection sections where soot blowers or steam lances are provided,			
Added in 2nd Edition	Anchors shall be installed before applying protection coating to the casing. The coating shall cover the anchors so that uncoated parts are above the acid dew point temperature.			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	Castable layers shall be a minimum of 3 inches thick.			
Added in 2nd Edition	The anchoring system shall provider retention and support for each component layer.			
Added in 2nd Edition	Brick may be used for hot face service or as a backup layer if the hot face layer is brick.			
Added in 5th Edition				For installation of castable refractory refer to API 936.
Added in 5th Edition				Design (minimum mechanical requirements subject to additional process considerations such as thermal design). d) Burner block: Pre-cast shapes or pneumatic air rammed refractory suitable for service. e) Bull nose: Single or dual component with each castable layer thickness 75 mm (3 in.), minimum. i) Corbelling: Constructed integral with the hot-face layer and containing anchors consistent with the taller height of the corbelling).
The following shall apply to castables: a) The surfaces to which castable is applied shall be kept above 45°F and below 100°F during installation and curing b) For pneumatic application, the lining shall be applied in horizontal strips working upward from the bottom. It shall proceed continuously to the required thickness in a given area. If the installation is interrupted, the lining shall be cut back immediately to the casing surface. This cut shall be full depth at a 90° angle to the casing surface. c) Rebound materials shall not be re-used in applying linings. d) Scoring of the castable surfaces shall be in accordance with the vendor's specifications. e) Each layer of the castable shall be properly air-cured after installation. To reduce the tendency for hydraulic setting castables to develop alkaline hydrolysis, an application of an impervious organic coating shall be applied to the hot-face layer immediately after placement and the same coating shall be reapplied shortly after				Alkali hydrolysis in insulating castable refractory materials [less than 1600 kg/m^3 (100 lb/ft^3)]. a) To reduce the possibility of alkali hydrolysis, linings with castable hot faces shall be dried out to a minimum of 260 °C (500 °F) hot-face temperature (heating from hot-face) for 8 hours within 45 days of installation. Heating/

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<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td colspan="4">the 24-h cure. The use of forced drying by air movement or low temperature to remove a percentage of the mechanical water prior to the application of the impervious coating can further reduce the possibility of development of alkaline hydrolysis. Alkaline hydrolysis is a naturally occurring phenomenon, such that the use of either or both of the above procedures might not entirely prevent the formation thereof. In instances where alkaline hydrolysis has occurred, the loss in refractory thickness is usually less than 10 mm (0,375 inch). When this occurs, the loose material shall be brushed off and an impervious organic coating applied.
f) Shop-installed castable shall not be handled or tested for 72 h after installation.</td><td>cooling rates for this dry out shall be 55 °C/hour (100 °F/hour), maximum.
b) Before dry out, castable linings shall be inspected for alkali hydrolysis. Affected material shall be removed and replaced prior to the dry out. Alternate methods for minimizing alkali hydrolysis and remediation shall be approved by the owner.
c) Once dried out, linings shall be protected from moisture and mechanical damage. 11.5.4 A significant advantage of monolithic refractories is their ability to be maintained by localized repairs. For cement bonded materials, patching should be made for the full lining or hot-face layer thickness. Overlay repairs are subject to owner’s approval.
11.5.5 Dry out and heat-up/cool-down rate requirements are as follows:
a) lining systems with a monolithic hot-face and/or layer shall be dried out as agreed and approved by owner
c) neither firebrick nor fiber linings require dry out on initial heating.</td></tr>
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CDHDS Reboiler Heater (H-60) Efficiency Improvement Project

Furnace Improvements (FIS) was employed to develop an efficiency improvement scheme for CDHDS reboiler heater (H-60).

The CDHDS reboiler heater is a vertical cylindrical natural draft heater built in 2002. The CDHDS reboiler heater (H-60) was designed for a process duty of 72 MMBtu/hr, with a design efficiency of 81%. The heater was operating at an efficiency of 79%, with the flue gas stack temperature of 780°F. FIS reviewed the design and proposed the following changes to improve the efficiency:

- Addition of 6 rows of steam generation coil in convection section
- New Stack transition cone
- 25 ft. Stack extension

The total heat duty of the heater was increased to 82 MMBtu/hr. The extra 10 MMBtu/hr is absorbed in steam generation coil. Flue gas temperature leaving the stack was reduced at 400°F. The efficiency of the heater was increased to 90%, which brought energy savings of approximately USD $ 590,550 per year. The payback period is 1 year 3 months.

</td></tr>
<tr><td colspan="4">Block insulation shall be made of calcium silicate or mineral-wool fiber, with a minimum service temperature rating of 938°C (1800°F). Block insulation shall be used only as a backup material, but shall not be used if the fuel Sulphur content exceeds 1 % mass fraction in liquid fuel or 100 mg/kg hydrogen sulfide in gas fuel. Block insulation shall not be used as backup material in floor construction.</td><td>**Deleted**</td></tr>
<tr><td colspan="4">The mortar joints in firebrick construction shall be as thin as possible. In applying the mortar, the brick shall be dipped or troweled on two edges. Expansion joints shall be mortar-free. Brick should be placed against the mating surface and tapped gently to ensure uniform joints no more than 1.5 mm (1/16 in) wide.</td><td>Mortar joints shall cover all contact surfaces and be 3 mm (1/8 in.) thick, maximum.</td></tr>
<tr><td colspan="4">**Added in 5th Edition**</td><td>Table 11—Lining System Decision Matrix Guidelines</td></tr>
<tr><td>Block insulation shall be used only as a backup material for refractories exposed to products of combustion. Block insulation shall not be used for brick or ceramic fiber when the fuel contains more than 1% by weight Sulphur in fuel oil 1.5% by volume hydrogen sulphide in fuel gas.</td><td colspan="4">Block insulation shall be calcium silicate or mineral wool fiber with a minimum service temperature rating of 1800°F. Block insulation shall be used only as a backup material, but shall not be used when the fuel Sulphur content exceeds 1% by weight in liquid fuel or 100 parts per million hydrogen sulphide in gas fuel. Block insulation shall not be used as backup material in floor construction.</td></tr>
</table>

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
When block insulation is used with brick or ceramic fibre, the casing plates shall have an internal protective coating to prevent corrosion	When insulating block or ceramic fiber is used as backup insulation, the casing shall have a protective coating if the fuel Sulphur content exceeds 10 parts per million. The protective coating shall be rated for 300°F service temperature.	7.5.7 When insulating block or ceramic fiber is used as backup insulation, the casing shall have a protective coating if the fuel Sulphur content exceeds 10 ppm. The protective coating shall be rated for 350°F service temperature.		
Added in 2nd Edition	Minimum density of mineral wool block and ceramic fibre used as backup material shall be 8 pounds per cubic foot.		The minimum density of insulating block and ceramic-fibre blanket used as backup materials shall be 8 lb/ft^3.	Fibre board, fibre block, insulating block and insulating firebrick (IFB) used as back up insulation shall have 15 lb/ft^3 density and shall be sealed to prevent water migration when a water-containing monolithic refractory is applied on the hot face.
Added in 5th Edition				When castable is used against the casing, no additional corrosion protection is required.
Fireclay brick, ASTM C 27	Fireclay brick, ASTM C 64			
Materials shall conform to following ASTM specifications- 1. Castable refractory, ASTM C401, Class O, P, or Q 2. Insulating block (mineral slag wool, neutral pH), ASTM C612 CL3	Materials shall conform to following ASTM specifications- 1. Castable refractory, ASTM C401, Class N, O, P, Q, or R 2. Insulating block (mineral slag wool, neutral pH), ASTM C612 CL5			

<table>
<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td colspan="5">

Hot Oil Heater

FIS submitted the design and was awarded a contract for the turnkey supply of new Hot Oil Heater for their BEU unit. The BEU Heater (H-3) is a natural draft, vertical cylindrical heater with a radiant section, convection section and stack. The heater is used to heat hot oil. The heater is designed for a total heat duty of 165 MMBtu/hr.

FIS executed the heater process, mechanical design, structural analysis, material procurement and fabrication of this hot oil heater. The client requested an expedited delivery for this heater to meet their turnaround schedule. This heater was delivered to the site within 9 months of receipt of order.

The fabrication was done to such an extent that there were no structural welds at the site. All the connections were designed to be bolted connections. This is a 6-pass heater and radiant panels were designed for each pass to fit in each radiant panel. The stack outside diameter is 11'-3 5/8" and the height is 97'-2". This stack was shipped in two pieces, which were bolted at the site. This heater was successfully commissioned in May 2009.

</td></tr>
<tr><td>Materials shall have a composition as shown:
- Lumnite or alumina cement, 40 percent Al_2O_3
- Ceramic fiber, 52 percent Al_2O_3; 46-53 percent SiO_3</td><td>Materials shall have a composition as shown:
- Lumnite or calcium aluminate cement, 35 percent Al_2O_3 or better
- Ceramic fiber, at least 45 percent Al_2O_3; remainder primarily SiO_3 and ZrO_2</td><td colspan="3">Materials shall have a composition as shown:
a. Lumnite or calcium aluminate cement, 35 percent Al_2O_3 or better.
b. Ceramic fiber, at least 43 percent combined total of Al_2O_3 + Zirconia or at least 43 percent combined total of Al_2O_3 + Chromia remainder primarily SiO_3 or ZrO_2.</td></tr>
<tr><td colspan="2">**Added in 5th Edition**</td><td colspan="3">11.6.1 The anchor material shall be selected based on the maximum temperature an anchor and/or component tip will be exposed to and selection criteria listed in Table 12 for maximum temperatures of anchor tips.
11.6.2 Weld metal shall be compatible with anchor and base metal.
11.6.3 All weld procedures and welders shall be approved by heater supplier and, if required, by the contractor and/or owner.
11.6.4 Anchor shall be welded to a clean surface per SSPC SP-6 or SSPC SP-3 (for spot cleaning).
11.6.5 For all floors, anchors are not required unless the refractory is shop installed.</td></tr>
<tr><td colspan="5">**Section 8 Structures and Appurtenances**</td></tr>
<tr><td>**Added in 2nd Edition**</td><td colspan="4">The effect of elevated design temperature on yield strength and modulus of elasticity shall be modified in accordance with the minimum yield strength and modulus of elasticity for structural steel shall be listed in table 10</td></tr>
</table>

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Flat arches shall have the casing sloped and all structural members arranged to allow unobstructed runoff of rain water. When pitched roofs are provided for weather protection, eaves and gables shall prevent the entry of windblown rain	Flat roof design shall allow for runoff of rain water. This can be accomplished by arrangement of structural members and drain openings, by sloping the roof or with a secondary roof for weather protection. When pitched roofs are provided for weather protection, eaves and gables shall prevent the entry of windblown rain			
Added in 2nd Edition	Duct structural system shall support duct work independent of expansion joints during operation, when idle or with duct sections removed.			
Added in 4th Edition			The casing shall be reinforced at the burner mounting to maintain the burner alignment during operation. Gaskets shall be provided at each bolted burner mounting flange connection to the heater.	
Added in 2nd Edition	When specified by the purchaser, to minimize flue gas bypassing, horizontal partitions shall be provided in convection section header boxes on a spacing not to exceed 5 feet.	When header boxes are greater than 1.5 meters (5 feet) in length or when specified by purchaser, horizontal partitions shall be provided in convection header boxes. The maximum spacing is 1.5 meters (5 feet).		
Added in 4th Edition			Gaskets shall be used in all header-box joints to achieve airtightness. Where terminals and crossovers protrude through the header box, the opening around the coil shall be sealed to minimize leakage.	
Added in 2nd Edition	A bolted and gasketed access door shall also be provided in any air plenum below the floor access way.	One access door having a minimum clear opening of 450 millimeters by 450 millimeters (18 inches by 18 inches) shall be provided in the floor for vertical cylindrical heaters. A bolted and gasketed access door shall also be provided in any air plenum below the floor access way. Where space is not available, access via a burner port is acceptable.		
Observation doors and ports shall be provided for viewing all radiant tubes, radiant tube supports, the bottom row of shield tubes, and all burner flames for proper operation and light off	Observation doors and ports shall be provided for viewing all radiant tubes and all burner flames for proper operation and light off			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	Access doors shall be provided to ducts, plenums and at all duct connections to air preheaters and control dampers.	Access doors having a minimum clear opening of 600 millimeters by 600 millimeters (24 inches by 24 inches) shall be provided to ducts, plenums and at all duct connections to air preheaters and control dampers.		

Capacity Improvement for Reactor Charge Heater (080-H-001)

Furnace Improvements (FIS) was employed to carry out a capacity improvement of the Reactor Charge Heater (080-H-001). The client wanted to increase the process heat duty from 29.95 MMBtu/hr. to 37 MMBtu/hr. The maximum firing rate limitation was 54 MMBtu/hr.

This heater was originally built in 1965 as a natural draft all radiant heater. The heater was operating at 85% efficiency.

The revamp options to increase the capacity of the heater were:

- Replace existing radiant coil and put in a new convection to preheat the process feed.
- Revamp using FIS Split Flow Technology. In this option, the process feed is split and heated parallel in radiant and convections sections. The two parallel streams are then combined at the outlet.

FIS revamped the heater, for increasing the processing capacity, using *"Split Flow Technology."*

Parameter	Units	Design	Operating	Revamp
Total Absorbed Duty	**MMBtu/hr**	**47.63**	**55.48**	**42.4**
Process Duty (Total)	**MMBtu/hr**	**29.99**	**37.68**	**37.01**
Process Radiant Duty	**MMBtu/hr**	**29.99**	**37.68**	**25.01**
Process Convection Duty	**MMBtu/hr**	**-**	**-**	**12**
Total Fuel Firing Rate	**MMBtu/hr**	**53.47**	**64.83**	**49.87**
Firebox Temperature	**°F**	**1,540**	**1,630**	**1,511**
Radiant Average Heat Flux	**Btu/hr/ft^2**	**11,820**	**14,850**	**11,480**

Advantages of the revamped design based on Split Flow are as follows:

a) No radiant section modification
b) Existing tubes and supports can be used
c) Steam generation system can be reused with minimum modifications
d) Lowest cost & Shortest turn-around time

1st Edition	2nd – 5th Edition
Platforms shall be provided, at all observation doors and ports	Platforms shall be provided, at all observation doors and ports not accessible from grade
Platforms shall be provided, at auxiliary equipment such as fans, drivers, and air preheaters, for operating purposes	Platforms shall be provided, at auxiliary equipment such as steam drums, fans, drivers, and air preheaters, for operating purposes

<table>
<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td colspan="3">Ladders shall be caged from a point 2.3 m (7.5 ft) above grade or any platform. A self-closing safety closing gate shall be provided for all ladders serving platforms or landings.</td><td colspan="2">Ladders shall be caged from a point 2.3 m (7.5 ft) above grade or any platform. A self-closing safety gate shall be provided for all ladders serving platforms and landings. Ladders shall be arranged for side step-off; step through ladders shall not be used unless specified or agreed by the purchaser.</td></tr>
<tr><td colspan="4">Added in 5th Edition</td><td>Stack service temperature shall be defined as maximum predicted stack flue gas temperature plus 140°C (250°F).</td></tr>
<tr><td>Added in 2nd Edition</td><td colspan="4">Handrails, ladders and platforms shall be arranged so as not to interfere with tube handling. Where interference exists, provide removable sections.</td></tr>
<tr><td colspan="3">1. Connections considered as accessible from a platform shall be no more than 2.1 m (7 feet) above the floor of the platform.
2. Connections considered as accessible from grade shall be no more than 3 m (10 feet) above grade.</td><td colspan="2">Thermocouple connections considered as accessible from a platform or grade shall be no more than 2 m (6.5 ft) above the floor of the platform or the grade. Flue-gas sampling connections shall be no more than 1.2 m (4 ft) above the floor of the platform or the grade.</td></tr>
<tr><td colspan="2">Materials used in the fabrication of fired heaters shall conform to the following specifications or purchaser’s approved equivalent specifications:
a. Structural shapes, ASTM A 36;
b. Plate, ASTM A 36, A 283 Grade C or A 285 Grade C;
c. Structural bolts, ASTM A 307, unfinished.;
d. High-strength bolts, ASTM A 325 or ASTM A 490;
e. Pipe for columns and davits, ASTM A 53 Grade B.</td><td>Materials used in the fabrication of fired heaters shall conform to the following specifications or purchaser’s approved equivalent specifications:a. Structural shapes, ASTM A 36, A 242, A 572; b. Plate, ASTM A 36, A 283 Grade C, A 242, or A 572.; c. Structural bolts, ASTM A 307, unfinished; d. High-strength bolts, ASTM A 325 or ASTM A 490; e. Pipe for columns and davits, ASTM A 53 Grade B.</td><td colspan="2">For metal temperatures, lower than 425°C (800°F), stacks, ducts, and breeching shall be constructed from one of the following structural grades of steel: EN 10025-2:2004, Annex A (grades Fe360, Fe430, Fe510), ASTM (A36, A242, A572), or their equivalent.

If metal temperatures exceed 425 °C (800 °F), stainless or alloy steels shall be used.

The mechanical properties of the steels at temperatures between 20 °C (70 °F) and 425 °C (800 °F) shall be determined according to the values given in Table 14.

If the minimum service temperature is –18 °C (0 °F) or higher, bolting material shall be in accordance with ASTM A307, ASTM A325, ASTM A193-B7, or equivalent. Below –18 °C (0 °F), A193-B7 bolts with ASTM A194-2H nuts, ASTM A320-L7 bolting, or equivalent shall be used. No welding is permitted on A320-L7 or A193-B7 materials.</td></tr>
</table>

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Materials for service at design ambient temperatures below −29 °C (−20 °F) shall be as specified by the purchaser			Materials for service at design ambient temperatures below −30°C (−20°F) shall be as specified by the purchaser. For ambient temperatures below −20°C (−5°F), special low-temperature steels shall be considered.	
Added in 4th Edition			The mechanical properties and the chemical composition of structural, alloy, or stainless steels shall comply with API requirements or their equivalent.	
Section 9 Stack, Ducts & Breeching				
Stacks, breeching and ducts shall be of welded construction.		Stacks shall be of all welded construction. Field splice joints in stacks shall require full penetration welding. Breeching and ducting may be of welded or bolted construction.		
The top of stack linings shall be protected to prevent water penetration between the stack shell plate and the lining.			A corrosion-resistant metal cap should be provided at the top of the stack lining refractory to protect its horizontal surface from the weather.	
Added in 2nd Edition	When critical wind velocities exceed 97 kilometers per hour (60 miles per hour), dynamic loads resulting from wind need not be included in the design load. Stacks located closer than 8 diameters may be subject to increased wind loads.		A dynamic analysis shall be made to determine the stack's response to wind and earthquake action. If no specific requirements are given by the purchaser, the methods given in Annex H should be adopted for the dynamics due to wind.	
The minimum stack shell plate thickness shall be 6 millimeters (1/4-inch) including corrosion allowance. The minimum corrosion allowance on stacks shall be 1.6 millimeters (1/16 inch).		The minimum stack shell plate thickness shall be 6 millimeters (1/4-inch) including corrosion allowance. The minimum corrosion allowance on stacks shall be 1.6 millimeters (1/16 inch) for lined stacks and 3 millimeters (1/8 inch) for unlined stack.		
Added in 4th Edition			Linings can be required in steel stacks for one or more of the following purposes: a) fire protection, b) to protect structural steel from gases of excessively high temperature, c) corrosion protection, d) to maintain the flue gas temperature at least 20 °C (35 °F) above the acid dew point, e) to reduce potential for aerodynamic instability.	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Capacity Increase and Efficiency Improvement in Naphtha Stabilizer Reboiler Texan Refinery requested FIS to rerate the NSR for new process conditions. The natural draft heater is a vertical cylindrical with convection section and mounted stack. It had a heat duty of 8.6 MMBtu/hr with an efficiency of 83%. FIS observed that the firebox was small and volumetric heat release was high. The proposed process conditions weren't feasible with the existing radiant section. Convection section temperatures were high and the stack height was limiting with the new firing conditions. FIS approach was to extend the radiant section and install a new radiant coil with 50% more radiant area. The heat duty increase to 10.8 MMBtu/hr and the efficiency went up to 88% giving fuel savings of US$270,000 per year. FIS worked on the design, detail engineering, fabrication and supply of the new convection section, stack and radiant coils. This project was completed in a fast track and it was successfully commissioned on September 2009. 				
Added in 4th Edition			The suitability of specialty linings other than refractory should be discussed with the manufacturer, but consideration should be given to their strength, flexibility, thermal properties, and resistance to chemical attack.	
Added in 4th Edition			Castable linings shall be secured to stacks, ducts, and breeching by suitable anchorage.	
Added in 2nd Edition	Louver dampers shall have a minimum of one blade for every 1.2 square meters (13 square feet) of internal cross sectional area in the stack or duct. Each blade shall have approximately equal surface area. Blades shall have opposed movement.		Louvre dampers shall have a minimum of one blade for every 1.2 m^2 (13 ft^2) of internal cross-sectional area in the stack or duct. The blades shall have approximately equal surface areas. Blades shall have opposed movement unless they are located at the fan suction, in which case there will be parallel closing movement opposite to the fan rotation.	
Added in 2nd Edition	Bearings shall be aligning, self-lubricating graphite bearings mounted in bearing manufacturer's standard housing.			
Added in 3rd Edition	The use of unlined stacks shall be the decision of the owner considering location and fuel composition. When unlined stacks are specified the flue gas temperature shall not be less than 204°C (400°F) nor greater than 371°C (700°F).		**Deleted**	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
The tensile stress on anchors bolts shall not exceed 21,000 pounds per square inch on the AISC tensile area for ASTM A 307 material and 33,000 pounds per square inch for ASTM A 193 B7 or A 320 L7 material.	The tensile stress on anchor bolts shall not exceed 138 mega pascals (20,000 pounds per square inch) on the AISC tensile area for ASTM A 307 material and 227 mega pascals (33,000 pounds per square inch) for A 320 L7 material.		**Deleted**	
The tensile stress on structural bolts shall not exceed 26,000 pounds per square inch on the AISC tensile area for ASTM A 325 material and 33,000 pounds per square inch for ASTM A 193 B7 or A 320 L7 material.	The tensile stress on structural bolts shall not exceed 303 mega pascals (44,000 pounds per square inch) on the AISC nominal area for ASTM A 325 and 227 mega pascals (33,000 pounds per square inch) for ASTM A 193 B7 or A 320 L7 material.		**Deleted**	
Added in 4th Edition			Apertures in the stack shell plates, other than flue inlets, shall have the corners radiused to a minimum of 10 times the plate thickness.	
For single openings in cylindrical stacks the chord shall not exceed the radius. For two openings, opposite each other, each chord shall not exceed 0.75 radius.	For single openings in cylindrical stacks the chord shall not exceed the 1.4 times radius. For two openings, opposite each other, each chord shall not exceed the radius.			
Added in 4th Edition			Ring stiffeners provided to carry wind pressure should be designed for the circumferential bending moments.	
Added in 4th Edition			Circumferential bending moments due to wind pressure may be neglected in unstiffened cylindrical shells if the ratio $R/t \leq 160$, where R is the radius and t is the corroded thickness of the shell.	
Stack deflection due to static wind loads shall not exceed-150 millimeters (6 inches) per 30 meters (100 feet) of stack height, based on the shell plate thickness less 50 percent of the corrosion allowance.		Stack deflection due to static wind loads shall not exceed 1 in 200 of stack height, based on the shell plate thickness less 50 % of the corrosion allowance and without considering the presence of a lining.		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Capacity Improvement for FRE-APS and FRE-VPS Heaters (31/32-F-01)

FIS carried out a Crude Heater Capacity Improvement project for an Indian Refinery in Mumbai. The Client wanted to increase the heater capacity by 15% with a thermal efficiency of more than 90%.

FIS proposed addition of a small convection section on top of the existing heater convection section and addition of burners to the heater. The convection section had a coil for vacuum heater as well and the capacity of vacuum heater was increased by 15% too.

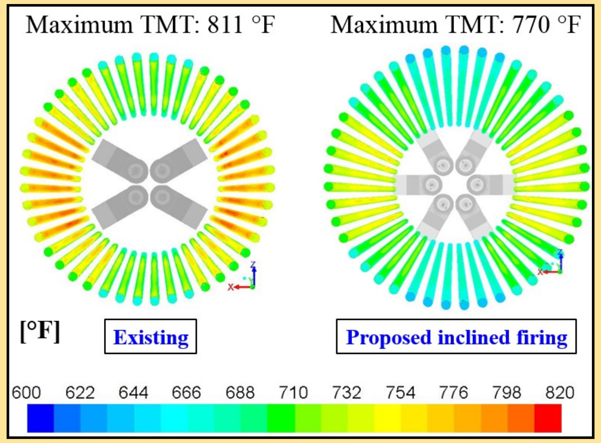
The study was carried out in 2 weeks and the detail engineering was carried out in 8 weeks. The heater was successfully commissioned on May 2010.

Added in 4th Edition			The permitted deviation (execution tolerance), δ, from the vertical of the steel shell at any level above the base of the erected stack shall be determined from Equation (3) in meters or Eq. (4) in feet: $\delta = h /(1000((1 + 50 / h)^{1/2}))$ (3) or $\delta = h /(1000((1 + 50 / h)^{1/2}))$ (4) where, h is the stack height, expressed in meters (ft).	
Added in 5th Edition				Refractory QA/QC, Examination, and Testing (Full Section - Except 17.5.5 Inspection and testing of monolithic refractories section.)
Added in 5th Edition				Table 18—Documentation Required for Refractory Type Selected
Added in 5th Edition				Table 19—Acceptance/Rejection Criteria for Defective Firebricks in Lot
Added in 5th Edition				Table 20—Tolerance Requirements for Brick
Added in 4th Edition			If the critical wind speed for the first mode of vibration of the stack is 1.25 times higher than the maximum (hourly mean) design wind speed (evaluated at the top of the stack), dynamic loads resulting from cross-wind response need not be included in the design load.	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 4th Edition			If analysis indicates that excessive vibrations due to cross-winds are possible, one of the following methods to reduce vortex-induced amplitudes shall be used. a) Increase mass and structural damping characteristics (e.g. use of refractory lining). b) Use a mass damper (e.g. tuned pendulum damper). c) Use aerodynamic devices (e.g. helical or vertical strakes as described in 13.5.4 and 13.5.5 or staggered vertical plates as described in 13.5.6), the choice of which shall be specified or agreed by the purchaser. Annex H gives recommendations regarding the application of spoilers or strakes. d) Modify stack length and/or diameter until acceptable vibration characteristics are achieved.	
13.4 meters per second (44 feet per second or 30 miles per hour) £ Vc < 26.8 meters (88 feet per second or 60 miles per hour): Not acceptable		13.4 meters per second (44 feet per second or 30 miles per hour) £ Vc < 26.8 meters (88 feet per second or 60 miles per hour): Not acceptable, unless the manufacturer can demonstrate to the satisfaction of the owner and/or purchaser the validity of the stack design in this range.		
Staggered vertical plates not less than 6 millimeters (1/4 inch) thick and not more than 1.5 meters (5 feet) long. Four strakes shall be spaced at 90 degrees around the stack and shall project 0.10 diameter from the outside surface of the stack. Adjacent levels of strakes shall be staggered 45 degrees from each other.		Staggered vertical plates not less than 6 millimeters (1/4 inch) thick and not more than 1.5 meters (5 feet) long. Three strakes shall be spaced at 120 degrees around the stack and shall project 0.10 diameter from the outside surface of the stack. Adjacent levels of strakes shall be staggered 30 degrees from each other.		

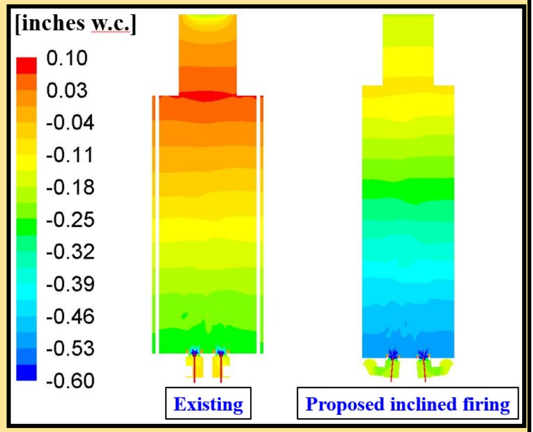
1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Heater Capacity Improvement and TMT Reduction study using CFD Modeling



Existing heater operation was limiting on draft with positive pressure of 0.1 inches WC at arch. Also, it was required to increase the heater duty by 40%.
CFD analysis for the existing burner and heater configuration was carried out to match the field observations and predict positive pressure at arch.

FIS recommended to increase the height of radiant section, to address the heater operation issue and install six burners to increase the heater capacity. Proposed configuration is designed for a draft of 0.1 inches WC. Also, greater draft is available at heater floor which is utilized in burners to have higher pressure drop and improve the flame patterns and flue gas recirculation in the heater. Flames for the proposed case are shorter and away from radiant tubes. Maximum TMT values have been reduced by 40ºF.



Added in 4th Edition				If a stack is positioned within proximity of other tall structures, consideration should be given to the possibility of buffeting effects.
Added in 4th Edition				If a stack is positioned adjacent to another stack or tall cylindrical vessel, the minimum recommended spacing between centers is 4d, where d is the largest diameter of the adjacent structures. Interference effects may be neglected for spacing between centers of greater than 15d.
Added in 4th Edition				For a stack downwind of an adjacent stack or a tall vessel, interference effects shall be accounted for by an increase in wind load.
Stacks, ducts, and breeching shall be constructed of materials confirming to ASTM A 36 or A 242.	Stacks, ducts, and breeching shall be constructed of materials confirming to ASTM A 36 or A 242. Alternative materials may be selected when approved by purchaser.			
Added in 3rd Edition		ISO 13705 Annex H or ASME STS-1 are acceptable alternate design criteria without owner or purchaser approval.		
Section 10 Burners and Auxiliary Equipment				
Added in 2nd Edition	Burners shall be designed in accordance with all local and national mandatory statues and regulations			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Table 12: Minimum clearance for natural draft operation			Table 13: Minimum clearance for natural draft operation are modified. The burner clearances are increased substantially.	
Added in 4th Edition			The number and size of burners shall ensure that the visible flame length is a maximum of two-thirds of the radiant section height. For floor-fired heaters, the CO content at the bridge wall shall be a maximum of 40 ppm, by volume for gas-fired heaters, 80 ppm, by volume for oil-fired heaters, at maximum design firing conditions. For horizontal opposed firing, the minimum visible clearance between opposed firing flame tip shall be 4 ft.	
All burners shall be sized for a maximum heat release at the design excess air based on the following: a) Five or fewer burners: 125% of normal heat release at design conditions b) six or seven burners: 115% of normal heat release at design conditions c) eight or more burners: 110% of normal heat release at design conditions.			All burners shall be sized for a maximum heat release at the design excess air based on the following: a) five or fewer burners: 120% of normal heat release at design conditions; b) six or seven burners: 115% of normal heat release at design conditions; c) eight or more burners: 110% of normal heat release at design conditions.	
Added in 2nd Edition	1. Pilot shall have a minimum heat release of 75000 Btu/hr. The minimum heat release must be approved by the purchaser, when accompanying a high intensity burner whose heat release is 15 MMBTU/hr or greater 2. The pilot burner shall be provided with a continuous supply of air, under all operating conditions. This includes operations with main burner out of service. 3. The pilot burner shall remain stable over the full firing range of the main burner. It shall also remain stable upon loss of main burner fuel, minimum draft, and all combustion air rates and for all operating conditions.			
Added in 2nd Edition	Burner tiles shall be pre-fired to no less than 500°F	Burner tiles shall be supplied pre-dried, as required to allow for full firing after installation without further treatment. Burner tiles fabricated from water-based and hydrous materials shall be pre-dried to no less than 260°C (500°F).		
Added in 2nd Edition	The material used for construction of a burner shall be chosen for strength, as well as temperature and corrosion resistance, for anticipated service conditions. Burner components shall be designed in accordance with minimum requirements as shown in table 13.			
The burner shall have a turndown capability to at least 40 percent of the normal heat release without adjusting the air controls		**Deleted**		
Added in 2nd Edition	The burner shall be selected to use no less than 90% of the maximum draft available for the maximum specified heat release.			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 4th Edition			Table 14—Minimum Clearances for Forced-draft Operation	

Convection Section Modification in CO (CCU-1 & CCU-2) Heater for SCR Installation

A Refinery has CO heater (CCU/2) in their FCC unit. The client was installing a new SCR unit downstream of the CO Heater as a part of the consent decree agreement to reduce the NOx emissions. The new SCR requires a specific flue gas inlet temperature, which will require reconfiguring the heat transfer surface in the convection section.

FIS modeled the convection section for 5 proposed cases and provided a revised design. The proposed cases were so extreme in nature that it was very difficult to meet the flue gas temperature requirement for all the 5 cases for one design. So, FIS designed the last coil as a trim coil. The last coil will be use in service when the flue gas temperature exceeds the higher limit and it will be run dry when the flue gas temperature drops below the lower limit.

FIS also provided a revised configuration for the oil preheat coil to limit the oil outlet temperature below 730°F to prevent coking.
The client wanted the superheated steam temperature to be close to the design so FIS reconfigured the super heater surface and provided a revised design. The client approved FIS design to revamp the convection section.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 4th Edition			-The pilot shall be positioned and sized to ensure that it is capable of lighting any of the main burner fuels. The purchaser shall specify the minimum main fuel flow rate during cold-burner light-off. -The pilot shall be capable of relighting an individual main burner over the full range of fuels. The combustion air flow rate might need to be reduced for satisfactory re ignition, particularly for forced-draft and low-NOx burners.	
Added in 2nd Edition	When natural draft burners are used in forced draft service, the purchaser shall specify the required heater capacity during natural draft operation, if required.	Natural draft oil burner shall be of a double block design to maintain flame stability when firing heavy fuels such as vacuum or atmospheric reduced crude oils, tars, or other high viscosity fuels requiring preheat.	**Deleted**	
Added in 4th Edition			The burner shall maintain flame stability when operating at no less than 33% of the maximum heat release settings without adjusting the air controls.	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	Oil burners shall be designed to operate on a maximum oil viscosity of 43 CS (200 SSU).		Oil burners should be designed to operate at a normal kinematic viscosity of 15 mm^2/s (15 cSt) to 20 mm^2/s (20 cSt). The maximum shall not exceed 40 mm^2/s (40 cSt).	
Added in 2nd Edition	Atomize steam shall be supplied dry at the burner, or with slight superheat.			
Burners and gas rings or tips and oil guns shall be removable while heater is in operation.	Gas manifolds and oil guns shall be removable while heater is in operation. Purchaser must specify whether they require removal of the diffuser or the complete burner assembly			
Soot blowers shall be either of the following types: 1. Automatic retractable type. 2. Fixed position rotary type, automatic or manually operated.	Unless otherwise specified, soot blowers shall be automatic, sequential, and fully retractable.			
Soot blowers spacing for staggered tube banks shall be based on the following: 1. Retractable type: Maximum horizontal or vertical coverage shall be 4 ft. from lance or 4 tube rows, whichever is less. 2. Rotary type- Maximum horizontal or vertical coverage shall be 3ft. from the lance or 3 tube rows, whichever is less.	Spacing of retractable soot blowers shall be based upon a maximum horizontal and vertical coverage of 4 ft. from lance centerline or five tube row whichever is less. The first row if shield tubes may be neglected from the soot blowers coverage.			
Provide erosion protection of convection section walls located within the soot blower zones using erosion protection consisting of 0.1-inch minimum thickness stainless steel shrouds, either high duty fireclay brick or castable refractory with a minimum density of 125 pounds per cubic feet.	Provide erosion protection of convection section walls located within the soot blower zones using either high duty fireclay brick or castable refractory with a minimum density of 125 pounds per cubic feet.			
Added in 2nd Edition	The damper controller shall provide positive action to translate the damper blade in either an open or closed direction.			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Table 11- Minimum Clearance for natural draft operation	For Low NOx gas burners, an increase in longitudinal clearance must be provided. This is achieved by multiplying dimensions in column A by a factor of 1.3 and D by a factor of 1.5. Low NOx burners are those which incorporate design features with the specific intent to reduce the formation of NOx below levels normally produced by conventional burners. For intermediate firing rates, the required clearances may be achieved by linear interpolation			
Added in 4th Edition			Stack and flue gas duct dampers shall have blades of minimum thickness of 6 mm (0.25 in.).	

CO Boiler Convection Replacement

An Illinois refinery had a CO boiler in their Fluid Catalytic Cracking (FCC) Unit. The CO boiler was more than 40 years old. The CO boiler's convection section is used to preheat the FCC charge and generate superheated steam at 600 psig and 710°F.

The boiler had three main problems: Low economizer tube metal temperatures reaching dew point levels, high super-heated steam temperature and problems with tube supports in the hottest zone.

The refinery approached Furnace Improvements (FIS) to provide a new thermal design for replacing the convection section of the CO boiler. FIS conducted a detailed operation analysis of the existing CO boiler and built a model of the existing design. With the model built, we were able to simulate the current operating conditions and predict the heater performance for the future operating conditions.

We developed a better design overcoming the drawbacks in the existing CO heater. The convection section was redesigned to:

1. Increase FCC feed flow
2. Improve CO Boiler efficiency
3. Prevent cold end corrosion of economizer
1. Eliminate flow distribution problems

The new design was developed retaining the existing soot blower locations and platform elevations. It was estimated to save the client almost $550,000 per year.

CO Boiler Convection Section Replacement

Item	Units	Before Revamp	After Revamp
Process Heat Duty	MMBtu/hr	81.55	104.91
Steam Heat Duty	MMBtu/hr	100.90	115.92
Process Flow	BPC	41,995	48,000
Stack Temp.	°F	636	577
Efficiency	%	68.0	72.6
Fuel Savings	$ / annum	0.55 Million* [$3.0/MMBtu]	

Section 11 Instrument and Auxiliary Connections

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Provide one flue gas temperature connection in the flue gas exit of each radiant section for each 30 feet of radiant box length or diameter. Provide a minimum of two connections		Provide a minimum of two uniformly spaced flue gas temperature connections for each radiant section in the flue gas	One flue gas temperature connection shall be provided in the flue-gas exit of each radiant section for each 9 m (30 ft) of radiant box length or diameter. At least two connections shall be provided.	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
		exit.		
Provide a flue gas temperature connection in the convection section immediately after each process or utility coil for each 9.15 meters (30 feet) of convection tube length.-Provide a minimum of two connections after the last convection coil		One flue gas temperature connection shall be provided in the convection section immediately after each process or utility coil for each 9.15 meters (30 feet) of convection tube length.	One flue gas temperature connection shall be provided in the convection section immediately after each process or utility coil for each 9 m (30 ft) of convection tube length. A minimum of two connections shall be provided after the last convection coil	
Provide flue gas temperature connections in each stack and each off-take to stack		Provide flue gas temperature connections in each stack	Flue gas temperature Connections shall be provided in each stack and each take-off to a stack.	
Provide flue gas pressure connection a connection downstream of any air balancing damper in the combustion air distribution ducting.			A flue gas pressure connection of at least DN 15 (½ NPS) shall be provided at a suitable location downstream of any combustion air-control damper in the burner wind box or plenum.	
The flue gas pressure connections furnished shall be 11/2-inch NPS 3000-pound screwed forged steel couplings welded to the casing plate. When refractory lining exceeds 3 inches in thickness, the opening shall be lined with a stainless steel pipe, Schedule 80, Type 304. A hex-head forged steel screwed plug shall be furnished with each coupling.		The flue gas pressure connections furnished shall be 11/2-inch NPS 3000-pound screwed forged steel couplings welded to the casing plate. The opening in the refractory shall be lined with a Schedule 80 pipe of material suitable for the operating temperature. A hex-head forged steel screwed plug shall be furnished with each coupling. The connection and pipe sleeve shall be sloped to be self-draining.	The flue gas pressure connections furnished shall be DN 40 (1½ NPS), 20 MPa (3 000 lb) screwed forged-steel couplings welded to the outside casing plate. If the refractory lining exceeds 75 mm (3 in) in thickness, the opening shall be lined with austenitic stainless steel pipe (schedule 80). A hex-head forged-steel screwed plug shall be furnished with each coupling.	
Added in 4th Edition			Connections shall be provided in each stack and each take-off to a stack in compliance with environmental air-quality monitoring requirements as specified by the appropriate regulatory body. Sampling-point locations shall be determined according to environmental requirements regarding upstream and downstream flow disturbances.	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
The connections shall be 4 inch NPS, Schedule 80 pipe with a 150-pound raised face flange. The pipe shall be welded to the outside casing plate and project 203 millimeters (8 inches) to the face of the flange. A 150 pound class blind flange shall be furnished by the heater vendor for each connection, with appropriate gaskets for the temperature and corrosive conditions of the flue gas. The pipe shall extend into the heater to within 38 millimeters (11/2 inches) of the hot face of the refractory lining.		The connections shall be flanged nozzles with size and rating specified by the Purchaser. The pipe shall be welded to the outside casing plate and project 203 millimeters (8 inches) to the face of the flange. A blind flange shall be furnished for each connection, with appropriate gaskets for the temperature and corrosive conditions of the flue gas. The pipe shall extend into the heater to within 38 millimeters (11/2 inches) of the hot face of the refractory lining.	The connections shall be DN 100 (4 NPS) schedule 80 pipe with a class PN 20 (ASME class 150) raised-face flange. The pipe shall be welded to the outside casing plate and project 200 mm (8 in) to the face of the flange. The heater vendor shall furnish for each connection a class PN 20 (ASME class 150) blind flange with appropriate gaskets for the temperature and corrosive conditions of the flue gas. The pipe shall extend 38 mm (1.5 in) into the heater from the hot-face of the refractory lining.	

Vacuum Heater Capacity Increase Project

Furnace Improvements (FIS) was employed to conduct an engineering study for a refinery vacuum heater (200-H4) in Indiana.

As part of their expansion project, the refinery needed to increase the capacity of a cabin vacuum heater. This heater was originally installed in 1949.

FIS developed four modification options to increase the capacity of the vacuum heater. The client opted for :

1. Revamping the radiant section coil
2. New burners
3. New stack.

With these modifications, the capacity of the heater was increased from 8,200 to 9,500 BPD. The Heater was successfully commissioned and is working with increased capacity since May 2008

When process outlet thermos-well connections are specified and individual outlets are provided by the heater vendor, the thermos-well connections shall be furnished as part of the outlet piping system. When an outlet manifold is furnished by the vendor, the individual coil outlet thermos-well connections shall be provided by the heater vendor, if specified.		When an outlet manifold is furnished by the vendor, the individual coil outlet thermos-well connections shall be provided by the heater vendor, if specified.	If process-outlet thermos well connections are specified by the purchaser and individual outlets are provided by the heater vendor, the thermos well connections shall be furnished as part of the outlet piping system. If an outlet manifold is furnished, the specified thermos well connections shall be provided by the heater vendor.	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Process fluid thermo-well connection size and rating shall be 1.5 inch raised face flanges with a rating adequate for the fluid design pressure and temperature. The material shall be the same as the tube or pipe to which it is connected.		Process fluid thermo-well connection size and rating shall be specified by the Purchaser. The material shall be the same as the tube or pipe to which it is connected.	Process-fluid thermos-well connections shall be DN 40 (1 1/2 NPS) raised face flanges with a rating adequate for the fluid-design pressure and temperature. The material shall be the same as the tube or pipe to which it is connected.	
Added in 2nd Edition	11.3.1 Purge steam connection can be used as snuffing steam connections			
A minimum of two purge connections shall be provided for each firebox. The connections shall be 11/2- or 2-inch NPS, 3000-pound screwed forged steel pipe couplings, and welded to the outside casing plate. The openings through the refractory shall be lined with a Schedule 80 stainless steel pipe, Type 304.			A minimum of two purge connections shall be provided of minimum size DN 20 (3/4 NPS) and minimum rating 20 MPa (3 000 lb) for each firebox. The connections shall be DN 40 (1 1/2 NPS) or DN 50 (2 NPS), 20 MPa (3 000 lb) screwed forged-steel pipe couplings, welded to the outside casing plate. Flanged connections may also be used. The openings through the refractory shall be lined with a schedule 80 austenitic stainless steel pipe.	
Purge connections shall be provided in each radiant section and in header boxes that contain flanged or plug type fittings, provided that the process fluid being heated is considered flammable. Sufficient connections shall be furnished to provide 2 pounds per hour of steam per cubic foot of combustion volume	A minimum of two purge connections shall be provided for each firebox. Purge connections shall provide a minimum of three firebox volume changes within 15 minutes.			
Added in 2nd Edition	For forced draft systems, the forced draft fan can be used to purge the firebox in lieu of purge steam			
Tube skin thermocouples, when specified, shall be welded to a tube within a 60-degree arc on the tube wall, directly facing the flame envelope. Lead wire, insulators, and protective sheaths shall be designed to accommodate all anticipated tube movement. Protective sheaths shall be made gas tight and constructed of type 310 stainless steel (as minimum). Such sheaths are to be attached to the heater tubes by welded clips or bands. All thermocouple assemblies shall terminate on the exterior shell of the fired heater with a thermocouple head.		Quantity and location of tube-skin thermocouple connections shall be specified by Purchaser. The casing connection shall be an 11/2-inch NPS 3000-pound screwed forged steel coupling welded to the casing plate. The opening in the refractory shall be	The quantity and location of tube-skin thermocouple connections shall be specified by the purchaser. Lead wire, insulators and protective sheaths shall be designed to accommodate all anticipated tube movement. Protective sheaths shall be made gas-tight and constructed of type 310 stainless steel or other alloy suitable for the operating conditions. Such sheaths shall be attached to the heater tubes by welded clips or bands. All thermocouple assemblies shall terminate on the exterior shell of the fired heater with a thermocouple head.	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
		lined with schedule 80 pipe of material suitable for the operating temperature. A hex-head forged steel screwed plug shall be furnished with each coupling.		

Section 12 Shop Fabrication and Field Erection

Performance Improvement Project on 3 Platform Heaters

A Wyoming Refinery approached Furnace Improvements (FIS) to carry out an engineering study for a capacity increase of 3 platformer heaters. The middle heater (#1 Re-heater) has a common convection and stack for all three heaters. These heaters were draft limiting and were not able to achieve the desired throughput.

FIS analysed the existing design data and drawings of these Heaters (H-1003/4/5). The observations were that the existing heaters are deficient in design. The Arch pressure was positive on all three heaters at design conditions. The arch pressure was (+) 0.603 in WC, (+) 0.103 in WC and (+) 0.123 in WC for H-1003, H-1004 & H-1005 heaters respectively.

In this study, FIS proposed 5 recommendations for the revamp of Charge Heater (H-1003), #1 Reheater (H-1004) and #2 Reheater (H-1005). The recommendations were based on improving the draft in all the three heaters. FIS also proposed a recommendation for increasing the capacity of the heaters to the target capacity.

Client chose the stack modification as a revamp option. The existing stack and transition cone were replaced and the new stack will be wider and have new dampers (4 blades) and platforms.

1st Edition	2nd–5th Edition
The minimum size of bolts shall be ¾ inch in diameter, except where flange width prohibits its use. In no case shall the bolts be less than 5/8 inch in diameter.	The minimum size of bolts shall be 5/8 inch in diameter, except where flange width prohibits use of 5/8 inch bolts. In no case shall the bolts be less than ½ inch in diameter. Checkered plate flooring shall be furnished with one 1/2 inch in diameter
Heater steel shall power tool cleaned to SSPC SP-3 and primed with one coat of red iron oxide pigmented alkyl-type paint to a minimum dry film thickness of 1.5 mils. Surfaces shall not be painted during wet, damp, or foggy weather or when the ambient temperature is below 40ºF or above 110ºF	Heater steel shall be sand blasted to SSPC SP-6 and primed with one coat of inorganic zinc primer to a minimum dry film thickness of 3 mils. Surfaces shall be painted in accordance with manufacturer's recommendations on temperature and relative humidity.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	Platforms, handrails and toe-boards, grating, stairways, fasteners, ladders, and attendant light structural supports shall be hot-dipped galvanized.	Unless otherwise specified, platforms, handrails and toe boards, grating, stairways, fasteners, ladders, and attendant light structural supports shall be hot-dipped galvanized. Galvanizing shall conform to the applicable sections of ASTM A123, A143, A153, A384, and A385. Bolts joining galvanized sections shall be galvanized per ASTM A153 or zinc coated per ASTM A164, Type LS coating.		
Added in 3rd Edition		Internal coatings shall be applied according to the manufacturers recommended practices including surface preparation and atmospheric conditions.		
Added in 2nd Edition	Materials shall be stored in original containers, if possible and shall be protected from moisture and from atmospheric and foreign contaminants. They shall be kept completely dry and at manufacturer's recommended storage temperature until used. Bricks shall be free of cracks, chips, spalling, or other defects.			
Added in 5th Edition				For packaging and protecting of monolithic refractory, refer to API 936.
Added in 5th Edition				The refractory installer shall be responsible for all repairs to refractory linings which are damaged while within his control.
Bricks should be placed against the material surface and tapped gently to ensure uniform joints.	Bricks should be placed against the material surface and tapped gently to ensure uniform joints, no more than 1/16 inch wide			
Added in 2nd Edition	Expansion joints shall be mortar free			
Added in 2nd Edition	Anchors with circular bases shall be welded all around. Other anchors shall be welded to casing along both sides.			
Each layer of the castable shall be properly cured after installation. A resin based membrane curing compound shall be applied immediately after the initial set, with a curing period of at least 24	The castable shall be properly cured after installation. Curing may be performed by air drying, by using a light spray of potable water, or by the application of a resin base membrane curing compound. When water spray is used, the curing shall continue without interruption for at least 24 hours			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
hours. Shop installed castable shall not be handled or tested for 72 hours after installation				
Added in 2nd Edition	Chain link fence anchoring shall be pulled out and held in place after welding, and prior to castable application, to ensure proper position in the castable layer			
Added in 2nd Edition	Each layer of castable shall be properly cured after installation. A resin base membrane curing compound shall be applied immediately after the initial set, with a curing period of at least 24 hours. Shop installed castable shall not be handled or tested for 72 hours after installation.			
Added in 2nd Edition	Castable lined panels shall be handled to avoid excessive cracking or separation of the refractory from the steel.			
Care shall be taken to avoid refractory and insulation damage due to weather. Protection shall include but not be limited to the provision of arch drainage, covering of openings, proper fit and tightening of doors and header boxes, and provision of adequate door lap bars.	Take care to avoid refractory damage due to weather. Standing water or saturation of the refractory shall be prevented. Protection shall include cover to avoid rain impingement and shall allow drainage, proper fit, and tightening of doors and header boxes.			
Added in 3rd Edition		For shop lined castable refractory sections, to minimize the tendency for alkali hydrolysis to occur, the sections shall be prepared for shipment in a way to allow good air circulation during the entire shipping and storage periods. The use of shrink wrap (air tight packaging) coverings shall be avoided.		
Added in 3rd Edition		For shop lined fiber refractory sections, shrink wrapping of lined sections is required.		
Added in 3rd Edition		The vendor shall identify the maximum number of shop lined sections that can be stacked and orientation of sections for shipping and storage purposes on the drawings.		
Added in 3rd Edition		All openings shall be suitably protected to prevent damage and the possible entry of water and other foreign material.		
Added in 3rd Edition		All flange gasket surfaces shall be coated with an easily removable rust preventative and shall be protected by suitably attached durable covers such as wood, plastic or gasketed steel.		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 3rd Edition		All threaded connections shall be protected by metal plugs or caps of compatible material.		
Added in 3rd Edition		Connections that are beveled for welding shall be suitably covered to protect the bevel from damage.		
Added in 3rd Edition		All exposed ferrous surfaces not otherwise coated shall be given one coat of manufacturer's standard shop primer. Any additional painting requirements shall be specified by the purchaser.		
Added in 3rd Edition		The item number, shipping weight and purchaser's order number shall be painted on the heater and loose components. 13.6.10 All boxes, crates or packages shall be identified with the purchaser's order number and the equipment item number		
Added in 3rd Edition		Stencil "DO NOT WELD" (in two places 180 degrees apart, as a minimum) on equipment that has been post weld heat-treated.		
Added in 3rd Edition		All liquids used for cleaning or testing shall be drained from units before shipment.		
Added in 3rd Edition		Tubes shall be free of foreign material prior to shipment.		
Added in 3rd Edition		The vendor shall advise the purchaser if any pieces are temporarily fixed for shipping purposes. Transit and erection clips or fasteners shall be clearly identified on the equipment and the field assembly drawings to ensure removal before commissioning of the heater.		
Added in 3rd Edition		The extent of skidding, boxing, crating or coating for export shipment shall be specified by the purchaser.		
Added in 3rd Edition		Any long-term storage requirements shall be specified by the purchaser.		
Added in 2nd Edition	Sections where refractory edges are exposed shall be protected against cracking of edges and corners. Avoid external blows to the steel casing.			
Added in 2nd Edition	Field joints between panels shall be sealed in accordance with the heater vendor's requirements.			
Added in 2nd Edition	Construction joints, resulting from panel or modular construction shall have continuous refractory cover to the full thickness of the adjacent refractory.			
Table 17 — Welding Filler Materials			Deleted	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Capacity Increase for Naphtha Splitter Reboiler Service

Furnace Improvements (FIS) was employed by a Refinery in Indiana to carry out a heat duty increase project for the Naphtha Splitter Reboiler service. Operating heat duty was around 11.74 MMBtu/hr. This was being supplied by Naphtha Splitter Reboiler Heater and by Platformer Heater Convection Coil. Naphtha Splitter Reboiler service heat duty needs to be increased by 5 MMBtu/hr.

FIS reviewed the design and operating data for Platformer Heater (300-H1/H2/H3). Any heat duty increase in this heater was not viable. In this heater, there are 3 radiant cells and a common convection section. It was possible to shift part of the #1 Inter Heater duty to the radiant cell of the heater and use part of this convection coil to provide heat duty of Naphtha Splitter service. This would require an increase in the firing rate of the Inter Heater cell and need new burners of a higher capacity.

FIS revamped the old Platformer Charge Heater adding a new radiant section with tubes and hangers and a small convection section. The stack was reused. The capacity was increased from 8.38 MMBtu/hr (Naphtha Splitter Reboiler) to 20.12 MMBtu/hr (old Platform Charge Heater).

Section 13 Inspection and Testing

Added in 2nd Edition	Consistent with ASME B31.3 definitions, inspection applies to functions performed for the owner's inspector or the inspector's delegates. Examination applies to quality control functions performed by the manufacturer (for components only), fabricator and erector.
Added in 2nd Edition	Pre-inspection meetings between purchaser and fabricator shall be held before start of fabrication.
Added in 2nd Edition	All radiographs shall show 2% sensitivity.
13.2.2.1 The root passes of 10% of all austenitic welds shall be liquid-penetrant inspected.	The root passes of 10% of all austenitic welds for each welder shall be liquid-penetrant examined following weld surface penetration per ASME Boiler and Pressure vessel code, section V, Article 6. When the required examination identifies a defect, progressive examination shall be required as per ASME B31.3, Para 341.3.4
13.2.2.3 Carbon steel welds shall be fully radiographed to the extent of 10% of all welds.	10% of all carbon steel welds by each welder shall be 100% radiographed. When the required examination identifies a defect, progressive examination shall be required as per ASME B31.3, Para 341.3.4. For each weld found to be defective, radiographs shall be made promptly on welds made by the same welder that produced defective welds

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 2nd Edition	Acceptance criteria of welds shall be per ASME B31.3, table 341.2A for normal fluid service. Radiography requirement apply also to coils fabricated to the ASME Boiler and Pressure Vessel Code.			
All longitudinal seam welds in carbon steel or alloy materials shall be fully radiographed and dye penetrant examined	All longitudinal seam welds on manifolds shall be 100% radiographed. In addition, these welds shall be liquid-penetrant examined for austenitic materials or magnetic particle examined for ferritic materials.			
In cases radiographic examination is difficult to interpret, such as nozzle (fillet) welds, dye penetrant or magnetic particle examination may be substituted.	In cases where weld or material configuration makes radiographic examination difficult to interpret or impossible to perform, such as nozzle (fillet) welds, ultrasonic examination may be substituted. When ultrasonic examination is impractical. Liquid penetrant (for austenitic materials) or magnetic particle examination (for ferritic materials) may be substituted.			
When post weld heat treatment is required, radiographic examination shall be performed upon completion of heat treatment.	Post-weld heat treatment shall be performed in accordance with ASME B31.3, Paragraph 331.3, unless otherwise agreed to by the purchaser. Radiographic examination shall be performed upon completion of heat treatment. Hardness testing of the materials accessible to measuring equipment shall be performed in accordance with ASME B31.3, Paragraph 331.1.7.		Post-weld heat treatment shall be performed in accordance with the pressure design code. Any required radiographic examination shall be performed after completion of heat treatment.	
Added in 2nd Edition	Proposed welding procedures, procedure qualification records, and welding rod specifications for all pressure retaining welds shall be in accordance with ASME IX and shall be submitted by fabricator for review, comment or approval by the purchaser.			
Added in 2nd Edition	Welder qualifications and applicable manufacturer's reports shall be maintained. Examples include certified material mill test reports, AWS classification and manufacturer of electrode or filler material, welding specifications and procedures, positive materials identification documentation of alloy materials, and non-destructive examination procedures and results. Unless otherwise specified by the engineering design, records of examination procedures and examination personnel qualifications shall be retained for at least five years after the record is generated for the project.			
Added in 2nd Edition	Material conformance shall be verified by review of chemical and physical test results submitted by the manufacturer. Positive materials identification may be requested to verify these results.			

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<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
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H-28 Vacuum Heater Performance Improvement Study

A refinery was facing coking problems in their Vacuum Heater. In addition, they also wanted to revamp the heater to handle Canadian Crude and reduce NOx emissions. FIS did the process study and because of the study, the client decided to build a new Vacuum heater with an existing heater foundation.

The new heater is 4 ft. wider. This vacuum heater is a horizontal tube box with a convection section. It is designed for a heat duty of 43 MMBtu/hr. FIS's scope involves design, engineering, structural analysis and supply of this heater to the site. The heater has an efficiency of 90%. It was successfully commissioned in March 2009. The heater was delivered within 7 months of starting the job. A few months after the start up, FIS received the following feedback from the client.

".. we talked about the performance of the VF4 H28 heater since startup. It has been fantastic! The stack temperature is 370-380°F and the fuel gas usage has dropped about 40% from the old heater. This is one of the most efficient heaters in the refinery. The NOx stack testing came back 0.026 lb NOx/MMBtu, which is also outstanding. They are even trying to reduce the O2 even lower, from 4% to 3%. It's a lot different when you have a tight firebox. Great job!!!" -Client

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<tr><td>Tube supports shall be sand and grid blasted and subjected to 100% liquid penetrant examination. Unacceptable surface defects and discontinuities shall be removed and their removal verified by liquid –penetrant examination. Defects shall be considered major when the depth of the cavity, after preparation for repair, exceeds 20% of the section thickness or when the cavity exceeds 10"in length. All other defects shall be considered minor. Minor defects shall be repaired by welding and the repair verified by liquid penetration examination. Repairs of major defects shall be verified by radiographic examination</td><td colspan="4">Tube supports shall be visually inspected (MSS SP-55) and dimensionally checked. Tube supports shall be adequately cleaned to facilitate examination of all surfaces. Intersections of all reinforcing ribs with the main member shall be 100% liquid-penetrant examined (austenitic) or magnetic particle examined (ferritic). Testing shall be performed according to ASTM E 165 and ASTM A407, respectively. Acceptance levels shall be specified per E433 for type and class. Unacceptable surface defects and linear discontinuities exceeding the requirements specified in ASME Boiler and Pressure vessel code, section VII, Div. 1, Appendix 7, shall be removed and their removal verified by liquid –penetrant examination. Defects shall be considered major when the depth of the cavity, after preparation for repair, exceeds 20% of the section thickness or when the cavity exceeds 10" in length. All other defects shall be considered minor. Minor defects shall be repaired by welding and the repair verified by liquid penetration examination. Repairs of major defects shall be verified by radiographic examination.</td></tr>
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1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Radiographic examination of critical sections shall specified by the purchaser	Radiographic examination of critical sections shall be performed and specified by the purchaser with testing and acceptance criteria as per ASME Boiler and Pressure Vessel code, Section VII.			
Liquid penetrant examination shall be performed according to ASME E 165 with ASTM E 433 as the referenced standard. Radiographic examination shall be in accordance with ASTM E 446 or ASTM E 186, to severity level 3 in all categories Weld repairs shall be made using welding procedures and operators qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.	All repairs shall be verified by liquid penetrant examination. Liquid penetrant examination shall be performed according to ASME E 165 with ASTM E 433 as the referenced standard. In accordance with ASTM E 433, the purchase shall specify acceptability criteria for type, class, and length that is maximum dimensions and quantity of indications per unit area. Major repairs shall be verified by radiography. Radiographic examination shall be in accordance with ASTM E 446 or ASTM E 186, to severity level 2, except for cracks and hot tears which shall be Level 0. Weld repairs shall be made using welding procedures and operators qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.			
Cast radiant tube supports, hangers, or guides shall be visually examined for surface imperfections to ascertain whether the casting surface has any discontinuities. Defects shall be marked for removal or repair, or to warrant complete replacement of the casting.	Cast radiant tube supports, hangers, or guides shall be visually examined for surface imperfections using MSS SP-55 as a reference for categories and degree of severity. Defects shall be marked for removal or repair, or to warrant complete replacement of the casting. Dimensions shall be verified with checks based on an agreed sampling plan. Repairs shall be verified by liquid penetrant examination.			
Added in 2nd Edition	All Cast return bends and pressure fittings shall be visually examined as per ASME B31.3, Para 344.2 and MSS SP-55 for imperfections and to confirm dimensions in accordance with reference drawings and the agreed upon sampling plan. Examination shall confirm proper and complete identification as specified in the purchase order.			
Added in 2nd Edition	All surfaces shall be suitably prepared for liquid penetrant examination (austenitic) or magnetic particle examination with ASTM specifications E 165 and E 433, and evaluated per agreed upon acceptance levels per MSS Sp-93 and MSS SP-53, Table 1, respectively.			

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Cast return bends and fittings shall be given a radiographic examination of their entire surface in accordance with ANSI B31.3. Radiographic quality shall be in accordance with ASTME 446, Security level 3 for each category defect.	Radiographic examination of cast return bends and fittings shall be in accordance with ASME B31.3. Radiographic quality shall be in accordance with ASTM E446, Security level 2 as minimum, for each category defect. Sampling quantities and coverage degree shall be specified by purchaser in addition to levels of acceptability for six categories listed.			
Added in 2nd Edition	Machined weld bevels shall be checked with liquid penetrant and examined for indications. Degrees of acceptability shall be set by purchaser.			
Refractory linings shall be examined throughout for thickness variations during application and for cracks after curing. Thickness variations are limited to a range of minus 6 mm (1/4 inch) to plus 13 millimeters (1/2 inch). Cracks which are 1/8 inch or greater in width and penetrate more than 50% of the castable thickness shall be repaired. Repairs shall be made by chipping out the unsound refractory to the backup layer interface and exposing a minimum of one tieback anchor or to the sound metal, making a joint between sound refractory that is perpendicular to the base metal, and then gunning, casting, or hand packing the area to be repaired.			Refractory linings shall be examined throughout for thickness variations during application and for cracks after curing. Thickness tolerance is limited to a range of minus 1/4 in to plus 1/2 in. Cracks which are 1/8 in or greater in width and penetrate more than 50 % of the castable thickness shall be repaired. Repairs shall be made by chipping out the unsound refractory to the backup layer interface or casing and exposing a minimum of three tieback anchors, or to the sound metal, making a joint between sound refractory that has a minimum slope of 1 in to the base metal (dove-tail construction) and then gunning, casting or hand-packing the area to be repaired.	
Finned extended surface shall be inspected to ensure fins are perpendicular to the tube within 15 degrees. The maximum discontinuity of the resistance weld shall be 2.5″ in 100″ of weld.	Finned extended surface shall be inspected to ensure fins are perpendicular to the tube within 15 degrees. The maximum discontinuity of the resistance weld shall be 2.5″ in 100″ of weld. The attachment weld shall provide a cross sectional area of not less than 90% of the cross-sectional area of the root of the fin. Cross sectional area is the product of the fin width and the peripheral length.			
Added in 2nd Edition	For rolled joint fittings, the fitting tube hole inner diameter, the tube outer diameter and the tube inner diameter (before and after rolling) shall be measured and recorded in accordance with the fitting location drawings. These measurements shall be supplied to the purchaser.			
Added in 2nd Edition	Fabricated supports include both plate-fabricated and multicast techniques. Fabricated convection tube inter-mediate supports shall have support lug welds radiographed. Warping of the completed support shall be within AISC standards.			
Added in 3rd Edition		The test pressure shall not exceed 9.75 times the design pressure.	**Deleted**	
Added in 2nd Edition	A bubble surfactant will be applied to weld seams to aid visual leak detection.			

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<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
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Capacity Increase and Efficiency Improvement in Naphtha Stabilizer Reboiler

A Texan Refinery requested FIS to rerate the NSR for new process conditions. The natural draft heater was a vertical cylindrical with convection section and mounted stack. It had a heat duty of 8.6 MMBtu/hr with an efficiency of 83%.

FIS observed that the firebox was small and volumetric heat release was high. The proposed process conditions weren't feasible with the existing radiant section. Convection section temperatures were high and the stack height was limiting with the new firing conditions.

FIS approach was to extend the radiant section and install a new radiant coil with 50% more radiant area. The heat duty was increased to 10.8 MMBtu/hr and the efficiency went up to 88% giving fuel savings of US$270,000 per year.

</td></tr>
<tr><td colspan="4">**Added in 5th Edition**</td><td>Refractory QA/QC, Examination, and Testing (Full Section - Except 17.5.5 Inspection and testing of monolithic refractories section.)</td></tr>
<tr><td colspan="4">**Added in 5th Edition**</td><td>Table 18—Documentation Required for Refractory Type Selected</td></tr>
<tr><td colspan="4">**Added in 5th Edition**</td><td>Table 19—Acceptance/Rejection Criteria for Defective Firebricks in Lot</td></tr>
<tr><td colspan="4">**Added in 5th Edition**</td><td>Table 20—Tolerance Requirements for Brick</td></tr>
</table>

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
If hydrostatic testing of pressure parts is not considered practical by agreement between the purchaser and the vendor, then pneumatic leak testing shall be substituted, using a non-flammable gas. The pneumatic test pressure shall be 414 kilopascals (60 pounds per square inch gauge) or 15% of the maximum allowable design pressure, whichever is less. The pneumatic test pressure shall be maintained for a length of time sufficient to examine for leaks, but in no case for less than 15 minutes. A bubble surfactant will be applied to weld seams to aid visual leak detection.			If hydrostatic testing or pneumatic pressure-testing of pressure parts is not considered practical, by agreement between the purchaser and the vendor, 100 % radiography shall be performed on all welds and pneumatic leak-testing shall be performed using air or a non-toxic, non-flammable gas. The pneumatic leak test pressure shall be 430 kPa (60 psi) gauge or 15 % of the maximum allowable design pressure, whichever is less. The pneumatic test pressure shall be maintained for a length of time sufficient to examine for leaks, but in no case for less than 15 min. A bubble surfactant shall be applied to weld seams to aid visual leak detection.	
Except when the test fluid is the process fluid, the test fluid shall be removed from all heater components upon completion of hydrostatic testing.		Except when the test fluid is the process fluid, the test fluid shall be removed from all heater components upon completion of hydrostatic testing. Heating shall never be used to evaporate water from austenitic stainless steel tubes.		
Added in 2nd Edition	Positive material identification (PMI) is a procedure to ensure that specified metallic alloy materials are properly identified by their true elemental composition.			
Added in 2nd Edition	PMI program methods, degree of examination, PMI testing instruments, and tester qualification shall be agreed upon between the purchaser and the vendor prior to manufacturing.		PMI program methods, degree of examination, PMI testing instruments, and tester qualifications shall be agreed upon between the purchaser and the vendor prior to manufacturing. PMI shall not be required for burner components, unless specified by the purchaser.	
Added in 2nd Edition	Unless superseded by the purchaser's requirement, 10% of all alloy components shall be PMI tested. If random testing is done. PMI shall be made on components from different heat numbers. The purchaser may alternatively chose to specify that a PMI test be made on each component.			
Added in 2nd Edition	Tabulation of tested items shall be included within all final data books, keyed to weld maps on as built drawings and mill certification document stampings. Tested items shall be immediately marked.			
Appendix A				
Appendix A: Fired Heater Data Sheet	Appendix A: Equipment Data Sheets			
	Modification	1. Molecular weight added in other types of fuels 2. Fuel entry deleted from pilot data 3. Stress to rupture basis in tube and coils details changed to design life 4. Number of tubes changed to number of tubes/Number of tube rows		

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<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td></td><td></td><td colspan="3">5. In tube spacing, additional row for vertical spacing in tube layout is added
6. Additional entry for type of plenum
7. In stacks, corrosion allowance label is changed to thickness
8. Additional row for type of access doors
9. CO/NOx analyzer removed</td></tr>
<tr><td colspan="5">Appendix B</td></tr>
<tr><td>Added in 2nd Edition</td><td colspan="4">Order of precedence of standards and specifications</td></tr>
<tr><td rowspan="14"></td><td colspan="4">Editions of reference publications applicable to this project</td></tr>
<tr><td colspan="4">Special requirements or exceptions to API standard 560</td></tr>
<tr><td colspan="4">Special requirements or exceptions to API standard 560</td></tr>
<tr><td colspan="4">Design excess air to be used as basis for calculated efficiencies</td></tr>
<tr><td colspan="4">Soot blowers to be provided</td></tr>
<tr><td colspan="4">Alternative basis for burner sizing.</td></tr>
<tr><td colspan="4">Required heater capacity during forced draft outage and continued operation on natural draft.</td></tr>
<tr><td colspan="4">On-stream removal of complete burner assembly is required.</td></tr>
<tr><td colspan="4">Pre-inspection meetings required prior to the start of fabrication</td></tr>
<tr><td colspan="4">Acceptance criteria for machined weld bevels</td></tr>
<tr><td colspan="4">Positive materials identification requirements.</td></tr>
<tr><td colspan="4">Electrical area classification for fired heater equipment/system</td></tr>
<tr><td colspan="4">Weather and environmental requirements for outdoor installation</td></tr>
</table>

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
	Alternative requirement for air intake height above grade			
	Corrosion allowance required for fan scroll and housing			
	Corrosion-resistant shaft sleeves required for I.D fans.			
	Rotor response analysis required.			
	Mechanical run test required. Other tests?			
	Environmental conditions of flue gas and air affecting fan material selections,			
	Fan driver type and sizing basis			
	Fan vendor is required to review overall control system for compatibility			
	Fan vendor to state maximum expected leakage through closed damper and vanes			
	Shop fit-up and assembly of fan, drivers and other auxiliaries required prior to shipment. Hardness testing?			
	Equipment shall be special prepared for six months of outdoor storage			
Appendix D				
Added in 2nd Edition	Appendix D- Stress curves for use to design tube support elements			
Appendix E				
Added in 5th Edition				**Table E.1 – Driver Trip Speeds**
Added in 3rd Edition		The purchaser shall specify all other accessories to be supplied by the fan vendor.		
Added in 3rd Edition		Service factors for the driver shall be determined using Table 15.		
Added in 3rd Edition		Control dampers shall be designed to move to the position specified by the Purchaser, in the event of damper control signal failure or motive force failure.		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Reactor Charge Heater (B-301) Capacity Increase Project

A Port Arthur Refinery has a reactor charge heater in the GFU Unit. The charge heater is a vertical cylindrical heater built in 1981 with an air preheating system. It was designed for a total heat duty of 60 MM Btu/hr.

Furnace Improvements (FIS) was employed in March 2005 to rerate the heater. The rerating was to be done with new process conditions to minimize the pressure drop. FIS rerated the heater for new process conditions using our patented “Split Flow Technology”. FIS also utilized the convectional series flow technology to minimize the pressure drop and hardware changes, therefore, overall minimizing project cost.

FIS recommended rearrangement of the number of passes or the replacement of the radiant and convection sections. FIS carried out the entire scope of activities from conceptualization to commissioning of this heater revamp. The heater was successfully revamped in December 2006 and restarted operation in January 2007. The client is very pleased with the heater performance.

Appendix F

Added in 3rd Edition	Appendix F- Air preheater systems for fired process heaters			
F.2.1.3 b) increased NO*x* production (resulting from higher flame temperatures);				Potential change in NOx production (new burners may mitigate increased NOx resulting from higher flame temperatures);
Added in 5th Edition				Cost of running fans.
Factors affecting air preheat system choice Modified		System Selection Considerations c. The heater’s fuel(s) and corresponding cleaning requirements. d. The APH system’s design flue gas temperatures. g. The negative effects of air leakage into the flue gas stream: corrosion of downstream equipment, increased hydraulic horsepower consumption, and reduced combustion air flow (which could cause a reduction in the heater’s firing rate). h. The ability to provide uniform radiant flux via proper burner location and arrangement. i. The potential constraints of an exchanger’s maximum exposure temperatures k. The system’s controls requirements and degree of automation. l. The negative effects of heat transfer fluid leakage.		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Process Design Modified		Process Design In some cases, the efficiency of an existing heater is so low that the addition of an air preheat system would generate other problems. Examples of such problems are: a. The hot air temperature must be limited to control NOx emissions. b. The hot air temperature must be limited to control high radiant flux rates (i.e., high tube metal temperatures). c. The hot air temperature must be limited to control tube support and/or guide temperatures. d. The air preheater selected cannot tolerate the high flue gas temperatures leaving the heater. In many applications, any/all of the above problems may be solved by adding convection section surface area, thus reducing the outlet flue gas temperature to an acceptable level.		
Added in 4th Edition			Process design General In order to properly design a fired heater that incorporates an APH system, it is necessary to understand the process effects that an APH system imposes on the heater and account for these within the heater's design. The primary variable interactions are as follows.	
Added in 4th Edition			Firebox temperatures increase with increasing combustion-air temperatures.	Firebox temperatures increase with increasing combustion air temperatures and reduced excess air;
Added in 4th Edition			Radiant duty, flux rates and coil temperatures increase with increasing combustion-air temperatures.	
Added in 4th Edition			Radiant refractory and coil-support temperatures increase with increasing combustion-air temperatures.	
Added in 4th Edition			Radiant-process film temperatures increase with increasing combustion-air temperatures.	
Added in 4th Edition			Convection duty, flux rates and coil temperatures decrease with increasing combustion-air temperatures.	Convection duty, flux rates, and coil temperatures decrease with reduced flue gas flow rates;

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 4th Edition			Convection-process film temperatures decrease with increasing combustion-air temperatures.	Convection-process film temperatures decrease with reduced flue gas flow rates;

N 744 Boiler NOx Reduction Project

Furnace Improvements (FIS) was approached to convert a CO boiler in Unit 40 to be a standalone refinery fuel gas fired boiler, and reduce NOx emissions. The existing boiler was revamped into a fuel gas fired boiler with a maximum capacity of 400,000 lb/hr of steam @ 625 psig, 750 °F and reduced the NOx emissions down to 0.02 lb/MMBTU (16 ppm).

FIS developed a heat transfer model of the boiler. Analyzed the performance of the boiler with NOx reduction and provided the client with various options for NOx reduction. They selected the option of ultra low NOx burners with external flue gas recirculation and steam injection into the burners. FIS scope of services included the following:

1. Replace existing burners with new Ultra-Low NOx Burners and FGR Fan
2. Provide new Economizer: FIS installed a new economizer which increased the efficiency of the boiler by 3%.
3. Steam Super Heater Modifications: The existing heat transfer surface was inadequate and steam temperature was to drop to about 680 °F after the revamp. FIS put additional heat transfer surface in the super heater to raise the temperature to 810 °F.
4. Firebox Modifications: FIS maximized the heat transfer surface in the firebox by sealing the CO ports with water wall panels, and removing the refractory from the floor and the roof.
5. New Attemperator: FIS installed a new attemperator to maintain a constant super heat temperature at all boiler loads.

Description	Before Revamp	After Revamp
Stack Temperature	460°F	310°F
Boiler Efficiency (LHV)	87%	90%
Steam Temperature Out of Boiler	700-730°F	730-810°F
Steam Temperature after Attemperator	Not Working	730-750°F
NOx	-	<0.02 Lb/MMBtu (HHV)

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 4th Edition			Flue-gas mass flows decrease with increasing combustion-air temperatures. In short, because of the above functionalities, the operation of an APH system increases the radiant duty and decreases the convection duty in a fired heater. This small duty shift between the radiant and convection sections shall be expected and quantified (i.e. modelled) in order to properly design both heater sections. It is the proper quantification of the noted duty shifts and proper adjustment in radiant-surface area that enable a heater to achieve design duty without exceeding its allowable average radiant-heat flux and all directly related parameters during APH operations.	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Linings and Heat Loss Modified		Setting Losses To accurately reflect the additional surface area of the APH system's hot ducts, it is usually appropriate to increase the heater's setting losses by 0.50 to 1.00%, to a total of 2.0 to 2.5%. **REFRACTORY DESIGN AND SETTING LOSSES** Because air preheat systems are usually justified on fuel savings, heat losses should be identified and minimized. The addition of ducts, fans, and the air preheater increases the surface area from which heat losses will occur. The heat losses through linings should be modeled to confirm that the combined heater and air preheat system setting losses are within acceptable limits. Heaters with balanced draft air preheat systems, and a design basis of 82°C casing temperature @ 27°C and 0 km/hr wind velocity (180°F @ 80°F and 0 mph), will typically yield slightly less than 2.5% setting losses. Because most ducts have design velocities in excess of ceramic fiber's maximum use velocity, the most common duct refractory is low density castable. Weight savings can be realized through the use of ceramic fiber blanket refractory, but such fiber will require a protective shrouding whenever the gas velocity exceeds ceramic fiber blanket's maximum design velocity of 12 m/s (40 ft/sec). Existing heater and ducting refractories should be checked for mechanical integrity, repaired as required, since reducing heat losses also improves efficiency and reduces costs.		
F.3.5 Convection Section	Modified	**High Air Temperature Considerations** High flue gas temperatures will often result in high combustion air temperatures. If the air preheater will generate high air temperatures, the burners and similar components downstream of the APH exchanger may need to be constructed of higher chrome alloys and/or have enhanced designs. The increased combustion air temperatures will increase the burners' flame temperatures, consequently increasing the burners' thermal NOx production. If a NOx emissions target cannot be achieved at the current design conditions, one or more of the following solutions must be considered: a. Change the burner design. b. Reduce the combustion air temperature. c. Reduce the firebox temperature (i.e., bridgewall temperature). d. Change the fuel(s) compositions to achieve lower temperature flames. e. Retrofit a post-combustion NOx reduction (e.g., SCR or SNCR) system to the heater.		
Added in 3rd Edition		Spare Fan Assemblies		
Added in 3rd Edition		Natural Draft Capability		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Common air-preheater materials cannot tolerate the heater's high flue-gas temperatures; it is necessary to upgrade the preheater metallurgy to accommodate the temperatures of the incoming flue-gas.				**Deleted**
In most retrofit applications, any or all of the above constraints can be avoided by increasing the convection section's duty. The incremental convection duty increases the heater's duty and efficiency and reduces the outlet flue-gas temperature, the APH exchanger duty, the hot combustion-air temperature and NOx emissions.				In some retrofit applications, the above constraints can be mitigated by adding convection section surface area to increase the convection section duty.
Natural-draught burners Typical excess-air levels are the following: a) fuel-gas fired, natural-draught operation 15%; b) fuel-gas fired, forced-/balanced-draught operation 10%; c) fuel-oil fired, natural-draught operation 20%; d) fuel-oil fired, forced-/balanced-draught operation 15%. Forced-draught burners Typical excess-air levels are the following: a) fuel-gas fired, forced-/balanced-draught operation 10% b) fuel-oil fired, forced-/balanced-draught operation 15%				Burners Up to 100 mm (4 in.) H2O Pressure Drop Typical excess-air levels are as follows: a) fuel-gas fired, natural-draft operation: 15% to 20%; b) fuel-gas fired, forced-/balanced-draft operation: 10% to 15%; c) fuel-oil fired, natural-draft operation: 20% to 25%; d) fuel-oil fired, forced-/balanced-draft operation: 15% to 20%. Burners Above 100 mm (4 in.) H2O Pressure Drop Typical excess-air levels are as follows: a) fuel-gas fired, forced-/balanced-draft operation: 10%; b) fuel-oil fired, forced-/balanced-draft operation: 15%.
Spare fan assemblies: Another common practice used to keep a heater on-stream in the event of a mechanical fan failure is the provision of spare fan assemblies or spare fan drivers, with "on-line" switching capability. The choice of whether to back up either the FD fan or the ID fan, or both, depends upon the user's experience and equipment failure probability.				Spare Fan Assemblies— Another common practice used to keep a heater on-stream in the event of a mechanical fan failure is the provision of spare fan assemblies or spare fan drivers, with "on-

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				line" switching capability. The choice of whether to back up either the FD fan or the ID fan, or both, depends upon the user's experience and equipment failure probability. An alternative is to have two fans running at 60 %, which avoids start-up time in the event of a single fan failure.

Convection Section Modification in CO (CCU-1 & CCU-2) Heater for SCR Installation

A Refinery has CO heater (CCU/2) in their FCC unit. It is used to combust the FCC off gas (mainly CO gas) from the spent catalyst regenerator unit. The hot flue gases generated from combustion of FCC off gas are used to preheat the oil and generate super-heated steam.

The client was installing a new SCR unit downstream of the CO Heater as a part of the consent decree agreement to reduce the NOx emissions. The new SCR requires a specific flue gas inlet temperature, which will require reconfiguring the heat transfer surface in the convection section.

FIS modelled the convection section for 5 proposed cases and provided a revised design. The proposed cases were so extreme in nature that it was very difficult to meet the flue gas temperature requirement for all the 5 cases for one design. So,

FIS designed the last coil as a trim coil. The last coil will be use in service when the flue gas temperature exceeds the higher limit and it will be run dry when the flue gas temperature drops below the lower limit. FIS also provided a revised configuration for the oil pre-heat coil to limit the oil outlet temperature below 730 Deg. F to prevent coking. The client wanted the superheated steam temperature to be close to the design so FIS reconfigured the super heater surface and provided a revised design. The client approved FIS design to revamp the convection section. The project was successfully commissioned in August 2009.

1st–4th Edition	5th Edition
Added in 5th Edition	General- Flue Gas Acid Dew Point Temperature
Added in 5th Edition	Calculation of Flue Gas Acid Dew Point Temperature
Added in 5th Edition	Measurement of flue gas acid dew point temperature

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Figure F.4- Recommended minimum metal temperature versus sulfur content				Illustrations of Sulphuric Acid FGADP temperature
Added in 5th Edition				Authoritative Design Guidelines
Added in 5th Edition				Effects of Operations
Added in 5th Edition		In moderate temperature climates where the ambient temperature never drops below freezing, this method allows the cold-end surface temperatures to be maintained above the dew point, as necessary, while other conditions change. This corrosion avoidance method is less capable than either external preheating or hot air recirculation methods because of the following system characteristics. a) The air-side heat transfer coefficient is not directly proportional to mass flow; for example, a 50 % drop in air flow yields only a 39 % reduction in the air-side coefficient. b) Low ambient air temperatures increase the cold-end temperature differential; as the ambient temperatures decrease, the cold-end temperature differential increases and heat transfer increases proportionally (thus reducing the benefit of cold air bypassing). Because of this method's inherent limitations, cold air bypass systems are often used in conjunction with one or more of the following more capable methods: external preheating and/or hot air recirculation. Both of the following methods increase the temperature of the combustion air flowing into the APH, thereby reducing the effect of thermal shock on the APH caused by low ambient air temperature.		
Added in 5th Edition		External preheat of cold air: — the minimization of corrosion, air pocketing, condensate build up, and drainage problems. This method does reduce the thermal shock on the exchanger caused by low temperature ambient air and does provide improved cold-end temperature control capability in comparison to the cold air bypass method.		
This type of cold-end control recycles heated combustion air to the FD-fan suction to obtain a mixed-air temperature that is high enough to keep the exchanger cold-end above the dew point temperature. This method provides improved cold-end temperature-control capability in comparison with the cold-air bypass method but requires the purchase and operation of an oversized forced-draught fan to accommodate the additional combustion-air flow.				This type of cold-end temperature control recycles a fraction of the heated combustion air stream to some point upstream of the APH to obtain a hotter mixed air temperature and maintain the APH's cold-end metal temperatures above the FGADP temperature. Systems that recycle heated air to the FD fan

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				suction will require the purchase and operation of a moderately larger FD fan to accommodate the larger volumetric flow rates required to support this method. Systems that recycle heated air directly to the APH will require the purchase and cold-weather operation of a booster fan (that operates in parallel to the FD fan) to recycle the heated air to the exchanger's air inlet. This method provides improved cold-end temperature control capability in comparison to the cold air by-pass method.
Added in 5th Edition				Comparison of Temperature Monitoring Strategies
Added in 3rd Edition		Spare Fan Assemblies		
		Natural Draft Capability		
		Draft generation for alternative operations		
Cold End Temperature Control Modified		**Exchanger Cold-End Temperature Control** In order to achieve the design life of the air preheat exchanger, it is important for the system to have the capability to maintain the exchanger cold-end temperatures above the acid dew point under any/all operating conditions. Even when existing design conditions do not indicate a need for such a requirement, cold-end temperature control should be provided to accommodate future operations. Following are a few future operating cases that could require the use of cold-end temperature control: a. Reduced firing rates; will produce lower flue gas temperatures (i.e., higher efficiencies). b. Lower ambient temperatures; will produce lower flue gas temperatures. c. Changes in combustion conditions; with regard to heater fouling, excess air, and duty.		

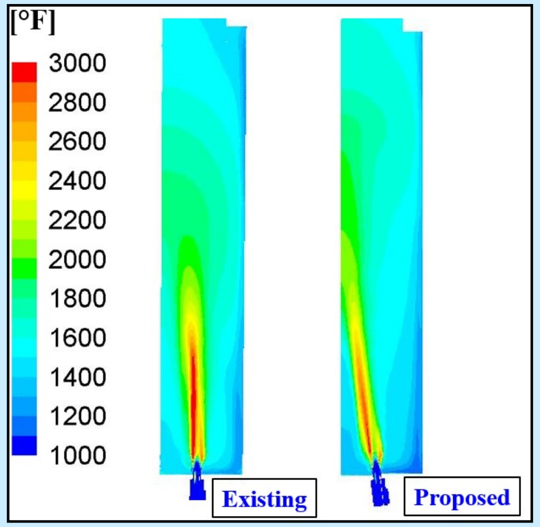
1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
		d. Changes in fuel composition; may increase the flue gas dew point. Note that any combination of the above conditions could result in the situation where the exchanger's cold-end surfaces are cooled below the acid dew point. In order to achieve the design life of the exchanger, the subject temperature control system must have the capability to keep the exchanger's cold-end surfaces above the acid dew point under any possible operating condition. Because the exchanger cold-end surfaces are the coolest flue gas wetted surfaces, the system downstream of the exchanger will remain above the dew point if the exchanger's cold-end surfaces are maintained above the dew point. Note that if the control of cold-end temperatures results in a flue gas discharge temperature that is higher than the design discharge temperature, such control is achieved at the expense of system efficiency.		

Combustion Modeling of Heater using CFD

Existing burner configuration had issues of flames leaning towards the radiant tubes and impingement of hot flue gases on radiant tubes.

CFD analysis was done for the existing and proposed configurations. It was proposed to install burners with higher air side pressure drop and inclining towards the centre of the heater.

Proposed simulation results showed reduction in tube metal temperatures and improved flue gas flow pattern. Smaller size of burners with increased air side pressure drop, and burners inclined towards the centre of heater. The proposed configuration improved flue gas flow patterns and reduced radiant tube metal temperatures significantly.



Stack Temperature Control Modified		Stack Temperature Control The design, maintenance and operation of an APH system should minimize cold air leakage, insulation voids, and other sources of localized cooling that could result in localized corrosion in the cold flue gas section of the system.		
Added in 2nd Edition	Flue gas due point monitoring	**Deleted**		
Excess Air The following minimum design burner excess air quantities are recommended for negative pressure fired heaters: a. Natural draft burners designed to operate with forced draft hot/cold air/ and/or natural draft ambient air. 1. Fuel gas fired, 10 percent 2. Fuel oil fired, 15 percent		Following are expected design excess air levels for general service "air tight" fired heaters. **Natural Draft Burners** a. Fuel gas fired, Natural Draft Operation; 15% b. Fuel gas fired, Forced/Balanced Draft Operation; 10% c. Fuel oil fired, Natural Draft Operation; 20% d. Fuel oil fired, Forced/Balanced Draft Operation; 15% **Forced Draft Burners** a. Fuel gas fired, Forced/Balanced Draft Operation; 10%		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
b. Forced draft/ high intensity burners 1. Fuel gas fired, 5 percent 2. Fuel oil fired, 10 percent Note that these are minimum suggested values. Fired heater operation at lower excess air is not recommended without special control instrumentation or design features. Where operating or user experience dictates. Fired heaters may be designed to operate at higher excess air values. Design efficiencies of fired heaters should be at excess air quantities stated in 2.2.2		b. Fuel oil fired, Forced/Balanced Draft Operation; 15% The above percentages are desired operating excess air levels. Where the heater design and/or user experience dictates, otherwise, it will be appropriate to design the system to operate at different excess air levels. **Design Excess Air Percentages** An important consideration in maximizing a fired heater's efficiency is the control of combustion air flow rates such that design excess air (or excess O2) levels are maintained, while sustaining complete combustion, stable and well defined flames, and stable heater operation. Forced and balanced draft APH systems are able to operate at excess air levels lower than natural draft systems. Typically, during forced/balanced draft operation, a system can safely operate with 5% less excess air than during natural draft operation. This excess air reduction is the result of the improved combustion air control provided by the typical forced draft fan and supporting instrumentation. The design excess air percentages are usually slightly reduced in retrofit applications. This reflects the superior air/ fuel ratio control provided by the forced draft system. However, excess air levels for retrofit efforts on "existing" heaters that suffer from significant air infiltration, should not be minimized. Care should be exercised in such applications to estimate the burner excess air by subtracting the estimated air leakage percentage from the measured heater excess air percentage. A superior alternative is to repair, fill and caulk leaking areas. It is a common oversight to overlook the leakage air. It is inappropriate to assume that the excess air concentration measured at the arch/roof is the actual burner excess air concentration. Following are expected design excess air levels for general service "air tight" fired heaters.		
F.3.2 Burners F.6.4.3 Burner design F.9.8 Burner Modified		**COMBUSTION DESIGN** Burner Performance The following objectives should be considered in the selection of burners for systems with, and without, APH systems. a. Maximum combustion performance throughout the entire operating range (inclusive of turndown) for all specified fuels. b. Maximum flux uniformity; identical heat release rates, identical flame shape/size, identical excess air percentages through each and every burner. c. Maximum burner-to-tube spacing (i.e., in excess of that required to avoid flame impingement). d. Minimum flue gas (NOx, CO, UHC, VOC, SPM) emissions. e. Minimum noise emissions. Note that the above selection criteria are applicable for both natural draft and balanced/forced/induced draft (as applicable) operations.		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Burner Selection The following general comments are meant to provide only an overview of the different burner designs commonly used in fired heater applications. For a complete review of this topic, refer to API Publication 535; Burners for Fired Heaters in General Refinery Services. Burners are broadly categorized by draft and/or by combustion process. By draft, the two types are natural draft and forced draft. By combustion process, the most common burner types are premix, raw gas/oil, staged air, staged fuel, and internal recirculation. Because forced draft burners are dependent upon a fan to provide a pressurized combustion air stream, the most common burner type is natural draft. Natural draft burners have low draft loss (< 20 mm H_2O or 0.8 in. H_2O) requirements, and are designed to operate with the draft created by the stack and heater proper. Because of the increased air side pressure drop and enhanced mixing, forced draft burners generally provide combustion performance that is superior to natural draft burner performance. Compared to natural draft burners, forced draft burners operate at reduced excess air levels, provide more stable flames and more defined flames. The selection of burner type, by combustion process, depends on many factors. For a thorough discussion on these many factors, the reader should refer to the aforementioned API Publication 535.			**Burner selection** In general, the application of an APH system to a fired heater does not alter the burner performance selection criteria. Application of an APH system does, however, elevate the operating temperatures of the burners, and it is necessary to meet the burner's performance criteria at these higher operating temperatures. Thus, a successful combustion design considers the following: a) Burner performance during "air-preheat" operations (e.g., heat release, flue-gas emissions, noise emissions, etc.); b) burner performance during "natural-draught" operations; c) means to achieve equal and uniform air flow to each burner under all operating conditions; d) Since the application of an APH typically requires FD fans, for new furnace designs, the use of high pressure drop FD burners may be considered. This generally leads to fewer burners and an improved distribution of combustion air over the burners. This feature basically eliminates the possibility of operating without FD fans. For a thorough review of burner technology and selection criteria, refer to API RP 535.	
Design Excess Air Percentages An important consideration in maximizing a fired heater's efficiency is the control of combustion air flow rates such that design excess air (or excess O2) levels are maintained, while sustaining complete combustion, stable and well defined flames, and stable heater operation. Forced and balanced draft APH systems are able to operate at excess air levels lower than natural draft systems. Typically, during forced/balanced draft operation, a system can safely operate with 5% less excess air than during natural draft operation. This excess air reduction is the result of the improved combustion air control provided by the typical forced draft fan and supporting instrumentation. The design excess air percentages are usually slightly reduced in retrofit applications. This reflects the superior air/ fuel ratio control provided by the forced draft system. However, excess air levels for retrofit efforts on "existing" heaters that suffer from significant air infiltration, should not be minimized. Care should be exercised in such applications to estimate the burner excess air by subtracting the estimated air leakage percentage from the measured heater excess air percentage.			**Design excess air- General** An important consideration in maximizing a fired heater's efficiency is the consistent control of combustion-air flow rates such that design excess-air (or excess-oxygen) levels are maintained, while sustaining complete combustion, stable and well-defined flames and stable heater operation. Because of the improved combustion-air flow control provided by a forced-draught fan and its supporting instrumentation, forced- and balanced-draught APH systems are able to consistently operate at excess-air levels lower than natural-draught systems. However, excess-air levels for "old" heaters, which suffer from significant air infiltration, should not be minimized. Care should be exercised in such retrofit applications to maintain sufficient excess-air flow through the burners and avoid sub-stoichiometric combustion at the burner. The flue-gas O2 levels at the arch/roof areas include O2 from both sources: burner excess air and infiltration air. The most common practice of estimating the burner excess	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
A superior alternative is to repair, fill and caulk leaking areas. It is a common oversight to overlook the leakage air. It is inappropriate to assume that the excess air concentration measured at the arch/roof is the actual burner excess air concentration. Following are expected design excess air levels for general service "air tight" fired heaters.			O2 is to subtract the radiant section's estimated air leakage (as percentage O2) from the arch/bridgewall measured excess percentage O2. As a point of reference, most seal-welded (i.e. airtight) fired heaters with airtight observation doors have less than a 1.0 % increase in O2 from the arch to floor. F.3.2.2.2 and F.3.2.2.3 are typical design excess-air levels for general-service "airtight" fired heaters. Where the heater design and/or user experience dictates, it is appropriate to design the system to operate at different excess-air levels.	
Added in 4th Edition			F.3.2.3 Post-combustion NOx-reduction considerations	
High Air Temperature Considerations			**Deleted**	
REFRACTORY DESIGN AND SETTING LOSSES Because air preheat systems are usually justified on fuel savings, heat losses should be identified and minimized. The addition of ducts, fans, and the air preheater increases the surface area from which heat losses will occur. The heat losses through linings should be modeled to confirm that the combined heater and air preheat system setting losses are within acceptable limits. Heaters with balanced draft air preheat systems, and a design basis of a 82°C casing temperature @ 27°C and 0 km/hr wind velocity (180°F @ 80°F and 0 mph), will typically yield slightly less than 2.5% setting losses. Because most ducts have design velocities in excess of ceramic fiber's maximum use velocity, the most common duct refractory is low density castable. Weight savings can be realized through the use of ceramic fiber blanket refractory, but such fiber will require a protective shrouding whenever the gas velocity exceeds ceramic fiber blanket's maximum design velocity of 12 m/s (40 ft/sec). Existing heater and ducting refractories should be checked for mechanical integrity, repaired as required, since reducing heat losses also improves efficiency and reduces costs.			**Refractory design and setting losses** The addition of ducts, fans and an air preheater significantly increases the surface area from which heat losses occur. The heat losses through these surfaces should be modelled to confirm that the combined heater and APH system setting losses are within acceptable limits. To reflect the additional heat losses of the APH system, it is common practice to increase the heater's setting losses by 0.5% to 1.0%, to a total of 2.0 % to 2.5 % of design heat release. Heaters with balanced-draught APH systems and a design basis of an 82 °C (180 °F) casing with 27 °C (80 °F) and 0 km/h (0 mph) ambient conditions typically yield slightly less than 2.5% setting losses. External insulation may be applied on the hot-air ducts. Because most ducts have design velocities in excess of ceramic fibre's maximum-use velocity, the most common duct refractory is low-density insulating castable. If needed, refractory mass savings can be realized through the use of ceramic-fibre blanket or board. However, ceramic-fibre blanket requires a protective shrouding whenever the air/gas velocity exceeds ceramic-fibre blanket's maximum design velocity of 12 m/s (40 ft/s).	

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

CDHDS Reboiler Heater (H-60) Efficiency Improvement Project

Furnace Improvements (FIS) was employed to develop an efficiency improvement scheme for CDHDS reboiler heater (H-60).

The CDHDS reboiler heater is a vertical cylindrical natural draft heater built in 2002. The CDHDS reboiler heater (H-60) was designed for a process duty of 72 MMBtu/hr, with a design efficiency of 81%. The heater was operating at an efficiency of 79%, with the flue gas stack temperature of 780°F.

FIS reviewed the design and proposed the following changes to improve the efficiency:

- Adding six rows of steam generation coil in convection section
- New stack transition cone
- 25 ft of stack extension

In this scheme, 71,000 lb/hr of 450 # steam condensate is flashed to 150 # 2 phase, vapor-liquid stream. Flashing is completed before it enters the convection section. The total heat duty of the heater was increased to 82 MMBtu/hr. The extra 10 MMBtu/hr is absorbed in steam generation coil. Flue gas temperature leaving the stack was reduced at 400°F. The efficiency of the heater was increased to 90%, which brought energy savings of approximately USD $ 590,550 per year. The payback period is 1 year 3 months.

<table>
<tr><td colspan="3">Stack temperature control</td><td colspan="2">Deleted</td></tr>
<tr><td colspan="4">Regenerative air preheaters
The heat-transfer surfaces of a regenerative air-preheat exchanger are not required to serve as pressure parts confining a fluid and are designed to tolerate moderate corrosion. As a result, regenerative air-preheat exchangers can operate at lower metal temperatures than most other types of air preheaters. However, it is necessary to consider the effects on downstream equipment of the inherent air leakage and the periodic removal of acidic soot particles during soot blowing. Regenerative air preheaters are commercially available in standard combinations of carbon-steel, low-alloy-steel and corrosion-resistant enamelled-steel construction. The manufacturer should be consulted for recommended cold-end temperature limits.</td><td>Regenerative APH
Regenerative APHs operate at lower metal temperatures than most other types of APHs. Therefore, they may use combinations of carbon-steel, low-alloy-steel, and corrosion-resistant enamelled-steel construction. The manufacturer should be consulted for the appropriate material of construction based on the cold-end temperature.</td></tr>
<tr><td colspan="4">General considerations in the application of an APH system are presented in F.2. In contrast, F.4 provides a more detailed review of each system’s characteristics, which can be used as an aid in the understanding of strengths and weaknesses of each system. The following factors should be considered in the determination of the most appropriate APH system design and the selection of a preheater (APH-exchanger) type:</td><td>The following factors should be considered when determining the most appropriate APH system design and</td></tr>
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<table>
<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td colspan="4">a) the heater's natural-draught operating requirements;
b) the heater's fuels and corresponding cleaning requirements;
c) the APH system's available plot area;
d) the APH system's design flue-gas temperatures;
e) the ability to clean the preheater (i.e. APH exchanger) with minimal impact on the heater's operations;
f) the ability to service the APH system with minimal impact on the heater's operations;
g) the negative effects of air leakage into the flue-gas stream: corrosion of downstream equipment, increased hydraulic-power consumption and reduced combustion-air flow (which can cause a reduction in the heater's firing rate);
h) the ability to provide uniform radiant flux via proper burner location and arrangement;
i) the potential constraints of an exchanger's maximum exposure temperatures;
j) the potential for, and the methods available to minimize, cold-end corrosion;
k) the system's controls requirements and degree of automation;
l) the negative effects of heat-transfer-fluid leakage;
m) the effect of process terminal temperatures on the available system efficiency;
n) the effect of burner type (forced versus natural draught);
o) the feasibility of enlarging the APH system capacity to handle future increases in process requirements</td><td>selection:
a) the heater's natural-draft operating requirements;
b) fuel type and quality and corresponding cleaning requirements and the type of refractory in flue gas ductwork;
c) available plot area;
d) the APH system's design flue gas temperatures;
e) the ability to meet required turndown conditions based on the ambient temperature range;
f) the ability to clean the preheater (i.e. APH exchanger) with minimal impact on the heater's operations;
g) the ability to service the APH system with minimal impact on the heater's operations;
h) the negative effects of air leakage into the flue gas stream: corrosion of downstream equipment, increased hydraulic-power consumption, and reduced combustion air flow (which can cause a reduction in the heater's firing rate);
i) increased radiant heat flux rates;
j) the potential for, and the methods available to minimize, cold-end corrosion;
k) the system's controls requirements</td></tr>
</table>

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				and degree of automation; l) the negative effects of heat-transfer-fluid leakage; m) the effect of burner type (forced versus natural draft); n) the feasibility of enlarging the APH system capacity to handle future increases in process requirements; o) presence of SCR before APH

Modified	Centrifugal Fan Selection Guidelines

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Fouling and Clean-ability Air preheat systems on fuel oil fired heaters should use exchanger designs that can be soot blown on-line, or water washed off-line. Most finned tubular recuperative exchangers, most regenerative exchangers, and tubular indirect exchangers can be designed to permit on-line soot blowing. Most cast iron recuperative exchangers may be cleaned via off-line warm water washing. Heat transfer surface designs that minimize fouling are available. Fouling of the heat transfer surface affects thermal performance and results in an increase in pressure drop across the unit. When fuels other than clean gas are fired, soot blowing and water washing facilities should be provided. Consistent on-line soot blowing is recommended whenever liquid fuels are fired.			Fouling and clean-ability APH systems on fuel-oil-fired heaters should use exchanger designs that can be soot-blown on-line or water-washed off-line. Most recuperative exchangers, most regenerative exchangers and most tubular indirect exchangers can be designed to permit on-line soot-blowing. Similarly, most cast-iron recuperative exchangers can be designed to facilitate cleaning via off-line warm-water washing.	
Centrifugal Fan Natural Draft Capability Most heaters will require some degree of natural draft operation; usually from 80 to 100% of design duty. If natural draft operating capability is required, the system must have low draft loss burners, an independently located air preheat exchanger, the appropriate ducts and dampers to bypass the air preheat exchanger and provide adequate combustion air, and a stack capable of maintaining 2.5 mm H2O (0.10 in. H2O) of draft at the arch during natural draft operation.			**Centrifugal Fan Natural-draught capability** Most heaters require some degree of natural-draught operation, usually from 75 % to 100% of design duty. If natural-draught operating capability is required, the system shall have low-draught-loss burners, an independently located APH exchanger and the appropriate ducts and dampers to bypass the APH exchanger, and shall provide adequate combustion air and a stack capable of maintaining a draught of 2,5 mm H2O (0,10 in H2O) at the arch during natural-draught operation. An alternative to low-draught-loss burners is to apply high-pressure-drop burners, whereby it is accepted that the furnace can only be operated in forced-draught mode; however, it can be necessary to bypass the APH system and ID fan.	
Burner Location and Arrangement			**Deleted**	
Burners			**Deleted**	
Acid Condensate Corrosion: If the application of one or more of the above techniques is not practical, the following practices are recommended. – The design should maintain the bulk cold flue-gas temperature above the dew point. – Appropriate corrosion-resistant materials should be used in the heat-exchanger cold end. – A low-point drain should be provided to permit removal of the corrosive condensate.				Acid Condensate Corrosion If the techniques in F.3.5 are not practical, the following practices are recommended. — The design should maintain the bulk cold flue gas temperature above the dew point. — Appropriate corrosion-resistant

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				materials should be used in the heat-exchanger cold end. — A low-point drain should be provided to permit removal of the corrosive condensate. — A replaceable cold-end section.

NOx Reduction and Capacity Increase of H-102 and H-205 Heaters

FIS was employed by a Texan Refinery to develop a NOx reduction study for Depantanizer Reboilers (H-102 and H-205). Client wished to reduce the NOx emissions from their heaters by installing Ultra Low NOx Burners. The targeted NOx emissions from these heaters are 0.035 lb/MMBtu (HHV basis).
Both heaters are vertical cylindrical heaters with horizontal convection section and a top mounted stack. They are designed for an absorbed heat duty of 33 and 46 MMBtu/hr.

FIS performed the study and found out that the convection sections were fouled. FIS suggested to revamp the heaters with patented "**Split Flow Technology**" to increase capacity by 10%. FIS also suggested to install the ULNB with patented **"inclined firing system"** to eliminate fouling problems.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 5th Edition		APH systems shall be designed with provisions for the following: a) normal start-up; b) normal shutdown; c) emergency shutdown; d) emergency transition to natural draft, for heaters designed with natural draft capability; e) emergency transition to spare FD or ID fan, for systems with spare fans; f) emergency transition to FD fan only or ID fan only, for systems design for such operation		
Added in 5th Edition		**Fans Lockout System** A lockable energy isolating device shall be provided for all fans and motors for the purpose of shutting off and disabling the fans and motors whenever maintenance or servicing is performed. The isolating device shall prevent unexpected energy release or movement and as a minimum shall disconnect all electrical sources.		
The flow element for measuring combustion air flow should be located so that only the combustion air to the burners is measured. No leakage air should be included in the measurement. If the fired heater is to be fired over a wide operating range,			In order to provide the means to effectively monitor and operate an APH system, the following design features (as applicable) are recommended.	

1st Edition / 2nd Edition / 3rd Edition	4th Edition / 5th Edition
the use of a variable speed or multispeed fan driver should be considered. These drivers can provide improved control, reduce noise, and conserve power. When forced draft burners are used, operation on natural draft may not be possible. Personnel should be alerted to this operating limitation. Cleaning facilities should be provided at the air preheater whenever liquid fuels are fired. Online cleaning of the induced daft fan may also be desirable. E.5.4 PERFORMANCE CHECKS The following APH system features are recommended: a. Temperature and pressure measuring connections in all flue gas and air streams entering and leaving the air preheater (to monitor performance and fouling), b. Pressure measuring connections at locations upstream and downstream of the fan(s), c. Flue gas analyzer connections—for continuous gas analysis— upstream of the exchanger, unless such connections would be redundant, d. Flue gas sample connections—for occasional use—immediately upstream and immediately downstream of the air preheat exchanger (to monitor leakage), e. Pitot Tube ports immediately upstream of the APH exchanger in the flue gas and air streams to allow the measurement and troubleshooting of the air and flue gas flow profiles entering the exchanger. APH system performance will be adversely affected by air and/or gas maldistribution.	a) Pressure and temperature connections should be provided upstream and downstream of the APH exchanger in both the combustion-air and flue-gas ducting; such can be used for exchanger-performance monitoring, foulant monitoring/water-wash scheduling and engineering reviews/system troubleshooting. b) Composition connections should be provided upstream and downstream of the APH exchanger in the flue gas ducting; these can be used for exchanger leak detection, system mass balances and engineering reviews/system troubleshooting. c) Pressure connections should be provided upstream and downstream of the fan(s). d) Combustion-air flow element(s) should be located such that only the combustion air to the burners is measured (i.e. any preheater air leakage is excluded from the measurement). e) Parallel fireboxes/cells should be designed and instrumented to be individually controlled. f) Parallel fireboxes/cells should have their own oxygen analyzers to ensure that each firebox has adequate excess air. g) Combustion-air ducting to parallel fireboxes/cells should be hydraulically similar. h) Combustion-air ducting to parallel fireboxes/cells should contain a flow-control damper that permits O2 control for each cell over the APH system's operating range. i) Flue-gas ducting from parallel fireboxes/cells should be hydraulically similar. j) Flue-gas ducting from parallel fireboxes/cells should contain a flow-control damper that permits arch/roof draught control for each cell over the APH system's operating range. k) Variable speed or multi-speed fan drivers should be considered for applications with large operating ranges and/or significant time periods of turndown operations. These drivers provide improved control, reduced noise and reduced power consumption.

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<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td colspan="5">

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<tr><td colspan="3">The most desirable location for duct blinds and dampers is near grade to limit work on or over an operating fired heater. When locating the fans and the air preheater, accessibility for maintenance should be considered.</td><td colspan="2">The most desirable location for duct blinds and dampers is near grade to limit work on or over an operating fired heater. When locating the fans and the air preheater, accessibility for maintenance should be considered. Cleaning facilities are typically provided for air preheaters in heavy-fuel-oil-fired applications. Online cleaning provisions for the induced-draft fan can also be desirable. Refractory systems in existing heaters and ductwork should be inspected periodically for mechanical integrity, and repaired as required.</td></tr>
<tr><td colspan="3">Exchanger performance guidelines
The common design objective of most air preheat systems is to maximize the fired heater's efficiency consistent with the system's capital, operating, and maintenance costs. To achieve this objective, it is important to select a cold-end design (flue gas) temperature that maximizes flue gas heat recovery and minimizes fouling and corrosion. The flue gas temperature at which corrosion and fouling become excessive is affected by:</td><td colspan="2">Exchanger performance guidelines
The common design objective of most APH systems is to maximize the fired-heater's efficiency consistent with the system's capital, operating and maintenance costs. To achieve this objective, it is important to select a cold end design (flue-gas) temperature that maximizes flue-gas heat recovery and</td></tr>
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<tr><td colspan="3">a. Fuel sulfur or other contaminant content.
b. Fuel or flue gas additives.
c. Flue gas oxygen and moisture content.
d. Combustion temperature.
e. Furnace cleanliness.
f. Burner design.
g. Air preheater design.
h. Ash content from heavy residual oils.</td><td colspan="2">minimizes fouling and corrosion.
The flue-gas temperature at which corrosion and fouling become excessive is affected by the following:
a) concentration in the fuel of sulfur, ash and other contaminants;
b) fuel or flue-gas additives;
c) flue-gas oxygen and moisture content;
d) air-preheater design.</td></tr>
<tr><td colspan="4">APH System Recommended Minimum Metal Temperatures
Corrosion of air-preheater cold-end surfaces is generally caused by the condensation of sulfuric acid vapor formed from the products of combustion of a sulfur-laden fuel. The acidic deposits also provide a moist surface that is ideal for collecting solid particles that foul the APH’s heat-transfer surface. Consequently, to obtain the preheater design life, it is imperative to measure and control the APH’s cold-end surfaces above the acid-dew-point temperature.</td><td>APH Recommended Minimum Metal Temperatures
Corrosion of air-preheater cold-end surfaces is generally caused by the condensation of sulfuric acid vapor formed from the products of combustion of a sulfur-laden fuel. The acidic deposits also provide a moist surface that is ideal for collecting solid particles that foul the APH’s heat-transfer surface. Consequently, to obtain the preheater design life, it is imperative to measure and control the APH’s cold-end surfaces above the acid-dew-point temperature. Thermally aggressive APH Systems (i.e. those with metal temperatures at or below the FGADP temperatures) should mitigate such risks via the adoption of one or more of the following practices.
a) Separate the exchanger into a hot and cold module, and make the cold module “easily replaceable.”</td></tr>
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1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				b) Use corrosion resistant materials: glass tubes, glass coated tubes, glass coated plates, coated tubes, stainless steel, or some other special corrosion resistant material. NOTE 1 Glass tubes can break, which will reduce the efficiency gain from these tubes (most designs permit individual replacement of tubes). NOTE 2 Glass coatings can become porous and the tube/plate substrate will corrode (however, these tubes can be individually replaced). NOTE 3 Tube coatings are typically soft and subject to erosion. c) Use thicker tubes and/or plates to provide additional corrosion allowance. NOTE Forecasting or calculating the corrosion rate(s) for the several acid and cold-end material combinations is beyond the scope of this annex. Refer to the bibliography for additional sources of information on corrosion rates and acid condensation rates, and/or consult an authoritative source for application specific guidance.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Crude Heater NOx Reduction Project

A refinery has a Crude Heater (191-H-1) in its Atmospheric Vacuum Unit AVU-191. The heater was built in 1969 and designed for 160,000 BPD at a total heat duty of 490.7 MMBtu/hr. The heater was later revamped to process 178,500 BPD of crude and 31,500 BPD of slip stream at total heat duty of 612.4 MMBtu/hr.

Furnace Improvements (FIS) was approached to modify the existing Crude Heater (191-H-1) to enable it to be retrofitted with a selective Catalytic Reduction Unit (SCR) to reduce NOx emissions to less than 0.010 lb/MMBtu. A new SCR and Waste Heat Recovery (WHR) was installed to accomplish these changes. FIS also performed the CFD analysis to ensure there is proper mixing of Ammonia with flue gases in the SCR unit and there is uniform distribution of flue gases over the catalyst bed.

In the proposed option, FIS designed the heater for 260,000 BPD at a firing rate of 727 MMBtu/hr (LHV). Crude feed to 191-H-1 is split into two streams: A hot stream (main crude charge) at 215,000 BPD, 456° F and a cold stream (slip crude stream) at 45,000 BPD, 240° F. The total absorbed heat duty of the Crude Heater is 672.2 MMBtu/hr.

The WHR section is designed to reduce the flue gas temperature to 300°F as opposed to the current 350°F to 385°F. FIS's scope included providing engineering services, designing equipment and supplying materials needed to modify the existing Crude Heater and auxiliary equipment. FIS's scope included the supply of a new waste heat recovery unit, modify the existing heater convection, and upgrade of the FD and ID Fans. The new waste heat recovery is installed and connected to the new SCR and existing Crude Heater.

Description	Before Revamp	After Revamp
Total Heat Duty, MMBtu/hr	612.4	672.2
Heater Efficiency (LHV), %	91	92.4
Stack Temperature, °F	350-385	300
NOx, lb/MMBtu	-	<0.01 lb/MMBtu

The total cost of the project for design, engineering, fabrication and supply was $7 Million. Erection has been completed and the heater was commissioned in February 2009.

Selecting hot-end temperature for APH Systems

The hot flue gas temperature is a direct outcome of the heater design. Current heater designs will usually provide the following "process inlet-to-exit flue gas" approach differentials:

a. For A106 B « T11/P11 materials: 40–80°C (75–150°F)

b. For T22/P22 « T91/P91 materials: 70–110°C (125–200°F)

c. For T304 « T347H materials: 80–140°C (150–250°F)

APH Hot-end temperatures

The temperature of the hot flue gas leaving a fired heater is the product of the heater service, design and duty or firing rate. Thus, the hot flue-gas temperature to the preheater is not a variable that can be controlled and it shall be accommodated by the preheater design.

However, for any given set of conditions, a heater's hot flue-gas temperature can be manipulated by altering the heater's radiant- and/or convection-section design. The hot flue-gas temperature can be reduced by increasing the radiant- and/or convection-surface areas.

As a point of reference, current design practices for general-service fired heaters usually produce convection section cold-end approach temperatures in the range of 60°C to 160°C (100°F to 300°F). For a conventional countercurrent convection section, the cold-end approach temperature is defined as the temperature differential between the flue gases leaving the convection section and the process fluid entering the convection section. Reducing the approach temperature increases the heater's efficiency and vice versa. Fired heaters with higher cold-end approach temperatures are simply less efficient than current practices and are candidates for efficiency enhancement.

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<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td colspan="2">Added in 3rd Edition</td><td colspan="3">Table E-1- Comparison of various air preheat systems</td></tr>
<tr><td colspan="2">Added in 3rd Edition</td><td colspan="3">Fan Sizing and Performance Guidelines</td></tr>
<tr><td colspan="4">FD Fan Design mass flow rates
The forced-draught fan's design mass flow rate is defined as the sum of the following items a) to c):
a) the heater’s, or heaters’, combustion-air mass flow rate at design (i.e. 100 % duty) conditions;
b) the APH exchanger’s design leakage air mass flow rate;
c) the maximum hot-air recycle mass flow rate
The design volumetric-flow-rate equivalent of the design mass flow rate should be based on the following three items:
– design ambient pressure;
– design ambient humidity;
– design ambient temperature [typically 16 °C (60 °F)].</td><td>FD Fan Design Mass Flow Rates
The forced-draft fan’s design mass flow rate is defined as the sum of the following:
a) combustion air mass flow rate at heater design conditions and at design excess air;
b) the APH’s design leakage air mass flow rate that normally applies to regenerative type APHs;
c) the maximum hot-air recycle mass flow rate, if applicable;
d) fuel composition that requires the highest air rate
The design volumetric-flow-rate equivalent of the design mass flow rate should be based on the following:
— design ambient pressure (atmospheric pressure at site elevation above sea level),
— design ambient humidity (typically 60 %),
— design ambient temperature [typically 16 °C (60 °F)].
The project design basis should specify the design parameters.</td></tr>
</table>

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Platformer Heaters Capacity Improvement and NOx Reduction Project

Furnace Improvements (FIS) was employed to re-rate Heater process using Low NOx Burners and increase the Capacity on Platformer Heaters (H-4 / H-5). The heaters were originally built in 1959. The heaters were changed to forced draft in 1977. Common air pre-heater, induced draft and forced draft fan were added to pre-heat the combustion air. Process fluid is heated in radiant sections. Convection section is used for steam generation.

Heaters design capacity is 32 MBPD. The client wanted to revamp the heaters for a higher capacity of 40 MBPD. The conventional revamp option has disadvantages: very high cost, requires large size manifolds and piping total pressure drop was very high.

The process heat duty increased by 22.0 MMBtu/hr. The revamp heaters firing rate shall be 8.5 MMBtu/hr lower than existing design. The new design reduces the air preheat temperature to 270°F from operating temperature of 600-700°F. FIS carried out the entire scope of activities from conceptualization to commissioning of these heaters. The project is currently in the execution phase. It is schedule to be commissioned on first quarter of 2011.

Heater Section	Design Heat Duty	Revamp Heat Duty	Extra Duty Required
Process Duty			
H-4	73.8	82.7	8.9
H-5	72.0	80.5	8.5
H-6	37.5	42.1	4.6
Total	183.3	205.3	22.0
Steam Generation	80.5	51.4	-
Firing Rate	292.2	283.7	(-)8.5

FD Fan- Design Conditions

The volumetric flow rate equivalent of the design mass flow rate should be based on the heater's design ambient pressure, design ambient humidity, and a temperature of 16°C (60°F).

E.7.2.6 Test Block Conditions

The volumetric flow rate equivalent of the test block mass flow rate should be based on the heater's design ambient pressure, design ambient humidity, and maximum ambient temperature.

Test-block flow rate

The above design mass flow rate, which reflects the heater's combustion-air requirements at design conditions (with maximum hot-air recycle, as applicable), should be multiplied by a test-block flow factor to obtain the test block mass flow rate. For typical APH-system applications, a test-block flow factor (Æbf) of 1.15 (115 %) is recommended. This 1,15 test-block flow factor accounts for the following:

a) inaccuracies in the calculation of the heater's air requirements;
b) inaccuracies and/or potential increases in the exchanger's leakage rate;
c) inaccuracies in the FD fan's rating/sizing correlations;
d) changes in the fuel composition(s) and/or excess-air percentages;
e) a small tolerance for unforeseen air losses. Test-block flow rate The test-block volumetric-flow-rate equivalent of the test-block mass flow rate should be based on the following
design variables:

Test-block Flow Rate

The design mass flow rate described above should be multiplied by a test-block flow factor to obtain the test-block mass flow rate. For typical APH-system applications, a test-block flow factor (Æbf) of 1.15 (115 %) is recommended. This 1.15 test-block flow factor accounts for the following:

a) inaccuracies and/or potential increases in the APH leakage rate,
b) inaccuracies in the FD fan's rating/sizing correlations,
c) changes in the fuel composition(s) and/or excess-air percentages,

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
		– design ambient pressure; – design ambient humidity; and – Maximum ambient temperature		d) a small tolerance for unforeseen air losses.

Reactor Charge Heater (B-301) Capacity Increase Project

A Port Arthur Refinery has a reactor charge heater in the GFU Unit. The charge heater is a vertical cylindrical heater built in 1981 with an air preheating system. It was designed for a total heat duty of 60 MM Btu/hr.

Furnace Improvements (FIS) was employed in March 2005 to rerate the heater. The rerating was to be done with new process conditions to minimize the pressure drop.

FIS rerated the heater for new process conditions using our patented **"Split Flow Technology"**. FIS also utilized the convectional series flow technology to minimize the pressure drop and hardware changes, therefore, overall minimizing project cost.

FIS recommended rearrangement of the number of passes or the replacement of the radiant and convection sections. FIS carried out the entire scope of activities from conceptualization to commissioning of this heater revamp. The heater was successfully revamped in December 2006 and restarted operation in January 2007. The client is very pleased with the heater performance.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Design static pressure The FD fan's design static pressure should account for all the APH-system static pressure losses (i.e. draught losses) for the forced-draught zone (see F.8.6.2. for details), plus a small contingency of 10 % to 15 %. The following forced-draught-zone components should be included in the static-pressure-loss tabulation: a) FD-fan suction ducting (screen, silencer, suction stack, ducting and fan transition); b) cold-air ducting from the FD fan to exchanger (outlet transition, ducting and exchanger transition); c) air-side losses of the exchanger; d) hot-air ducting from exchanger to burners (outlet transition, ducting and burner plenum); e) burner design static pressure loss.				**Design Static Pressure** The FD fan's design static pressure should account for all the APH static pressure losses for the forced combustion air circuit, see F.8.6.2. The following forced-draft circuit components are typically included in the static pressure-loss tabulation: a) FD-fan suction ducting (screen, air filter if applicable, silencer, suction stack, inlet flow meter if required, steam-APH if applicable, ducting, and fan transition); b) cold-air ducting from the FD fan to

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				APH (outlet transition, ducting, and APH transition); c) air-side losses of the APH (main APH, air flow meter, and balancing damper, if applicable); d) hot-air ducting from APH to burners (outlet transition, ducting, and burner plenum); e) burner static pressure loss at the maximum burner heat release; f) flow control devices, control dampers, shut off dampers if applicable, expansion joints, etc.
Induced-draught-fan performance **Design mass flow rate** The induced-draught fan's design mass flow rate is defined as the sum of the following items a) to c): a) the heater's, or heaters', flue gas mass flow rate at design (i.e. 100 % duty) conditions; b) the APH exchanger's design leakage air mass flow rate; c) the heater's design leakage air (through the casing and ducting joints) flow rate.				**Induced-draft Fan Sizing** **Design Mass Flow Rate** The induced-draft fan's design mass flow rate is defined as the sum of the following: a) the flue gas mass flow rate at heater design conditions; b) the APH design leakage air mass flow rate, this will generally apply to regenerative APHs; c) the heater's leakage air flow rate (through casing joints, ducting joints, piping penetrations, etc.); d) dilution air if an SCR is used.
ID Fan test-block flow rate The above design mass flow rate, which reflects the heater's flue-gas removal requirements at design conditions, should be multiplied by a test-block flow factor. For typical APH systems, a test-block flow factor of 1.15 (115 %) is recommended. This flow factor accounts for the following items a) to e):				**ID Fan test-block Flow Rate** The above design mass flow rate should be multiplied by a test-block flow factor.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
a) inaccuracies in the calculation of the heater's flue-gas generation rate; b) inaccuracies and/or potential increases in the exchanger's leakage rate; c) inaccuracies in the ID fan's rating/sizing correlations; d) changes in the fuel composition(s) and/or excess-air percentages; e) a small tolerance for unforeseen air leakage. The test-block volumetric-flow-rate equivalent of the test-block mass flow rate should be based on the following four design variables: – fuel composition, i.e. the flue-gas relative molecular mass; – ambient pressure; – relative humidity; – test-block temperature of flue-gases leaving the APH exchanger. The test-block temperature is the temperature of the flue gases leaving the preheater (APH exchanger) at design conditions plus a small temperature allowance or factor. For typical APH applications, a temperature allowance of 25 °C (45 °F) is recommended.				For typical APH systems, a test block flow factor of 1.20 (120 %) is recommended. This flow factor accounts for the following: a) inaccuracies and/or potential increases in the APH leakage rate, b) changes or fluctuations in the fuel composition(s) and/or excess-air percentages, c) an allowance tolerance for unforeseen air leakage, d) loss of heater efficiency due to fouling The test-block volumetric-flow-rate equivalent of the test-block mass flow rate should be based on all of the following design variables: — flue gas molecular weight, — design ambient pressure (atmospheric pressure at site elevation above sea level), — test-block temperature of flue gases entering the induced draft fan. The test-block temperature is the temperature of the flue gases leaving the APH at design conditions plus a small temperature allowance. For typical APH applications, a temperature allowance of 28°C (50°F) is used.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
ID fan Design static pressure The ID fan's design static pressure should account for all the APH system static pressure losses (i.e. draught losses) for the induced-draught and flue-gas-return zones (see F.8.6.3 and F.8.6.4 for details), plus a small contingency of 10% to 15%. Included in the static-pressure-loss tabulation should be the following five induced draught and flue-gas-zones components: a) convection-section coil(s) flue-gas side-pressure drop (draught losses); b) hot flue-gas ducting (ducting and transition upstream of the APH exchanger); c) flue-gas side losses of the exchanger; d) ID-fan suction ducting (exchanger transition, ducting and fan inlet); e) cold flue-gas ducting (fan transition, ducting and stack inlet)				**ID fan Design Static Pressure** The ID fan's design static pressure should account for all the APH system static pressure or draft losses for the induced-draft and flue gas-return circuit (see F.8.6.3 and F.8.6.4 for details). The design should also include losses due to fouling of the system's components. The following components are typically included: a) convection-section coil(s); b) hot flue gas ducting (ducting and transitions upstream and downstream of the APH); c) flue gas side losses of APH and emission control equipment (SCR, ESP,

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				CO reduction, and other equipment as applicable); d) ID-fan suction ducting (associated equipment, transitions, ducting, and fan inlet); e) cold flue gas ducting (fan transition, ducting, and stack inlet); f) losses for other miscellaneous equipment such as dampers, expansion joints, etc.; g) stack effects (draft changes) due to elevation changes; h) draft at radiant section arch
ID Fan test-block static pressure The above design static pressure, which reflects the induced-draught and flue-gas-return zones' static pressure requirements at design conditions, should be multiplied by a test-block static pressure factor. For typical APH systems, a test-block static pressure factor of 1.30 (130%), is recommended. This factor provides a test-block static pressure that complements the test-block flow rate calculated in F.7.4.2. For systems that apply a test-block flow factor different from that mentioned in F.7.4.2 (115 %), the test-block static pressure factor, Ftbsp, should be calculated by squaring the test block flow factor [i.e. Ftbsp = (Ftbf)2].				**ID Fan Test-block Static Pressure** The above design static pressure should be multiplied by a test-block static pressure factor. For typical APH systems, a test-block static pressure factor of 1.44 (144%), is recommended corresponding to the recommended flow factor of 1.20 (120 %). For systems that apply a test-block flow factor different from that recommended in F.7.4.2 (120 %), the test-block static pressure factor, Ftbsp, should be calculated by squaring the test block flow factor, i.e. Ftbsp = (Ftbf)2.
Duct Velocity guidelines In the absence of project-specific values, the following design parameters should be used: a) straight ducts: design velocity of 15 m/s (50 ft/s);				**Duct Velocity Guidelines** In the absence of project-specific values, the following design parameters should

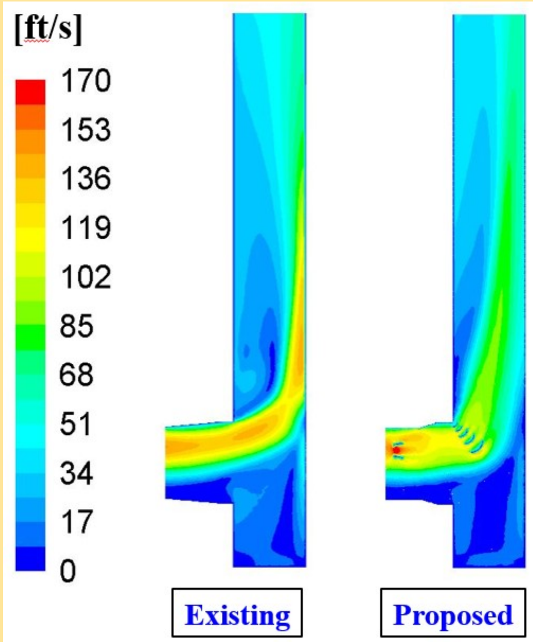
1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
b) turns or tees: design velocity of 15 m/s (50 ft/s); c) burner air-supply ducts: design velocity of 8 m/s to 10 m/s (25 ft/s to 35 ft/s). The above design guidelines should be altered to reflect the system's physical constraints and energy costs (lower velocities can be economically justified by savings in hydraulic power). An alternative burner-air-supply duct design methodology is to set the velocity head in these ducts equal to 10% of the burner air-side pressure drop.				be used. a) Straight duct velocity should be limited to 15 m/s (50 ft/s) at 100 % of design end-of-run conditions. b) Turns or tee velocity should be limited to 15 m/s (50 ft/s) at 100 % of design end-of-run conditions. c) Burner air-supply duct velocity should be based on the velocity head in these ducts equal to a maximum of 10% of the burner-air side pressure drop. The resulting velocities should be no more than the following: 1) 8 m/s (25 ft/s) for forced or balanced draft systems with natural draft capability; 2) 9 m/s (30 ft/s) for forced or balanced draft systems without natural draft capability. These guidelines can be altered to reflect the system's physical constraints and target efficiency. Lower velocities may be justified by lower power requirements.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Reducing Pressure Losses for ID Fan- Suction and Discharge ducts

Existing ID fan location was such that it had a sharp turning duct on the suction side and short discharge duct going into the stack.
The CFD analysis was done for the existing configuration of ID fan suction and discharge ducts. It was found that due to the sharp bend, there was uneven flow distribution at the fan inlet and large pressure drop in the duct. On the discharge side, all the flue gas was flowing along the stack wall, leading to large pressure drop and non-uniform flow in the stack.

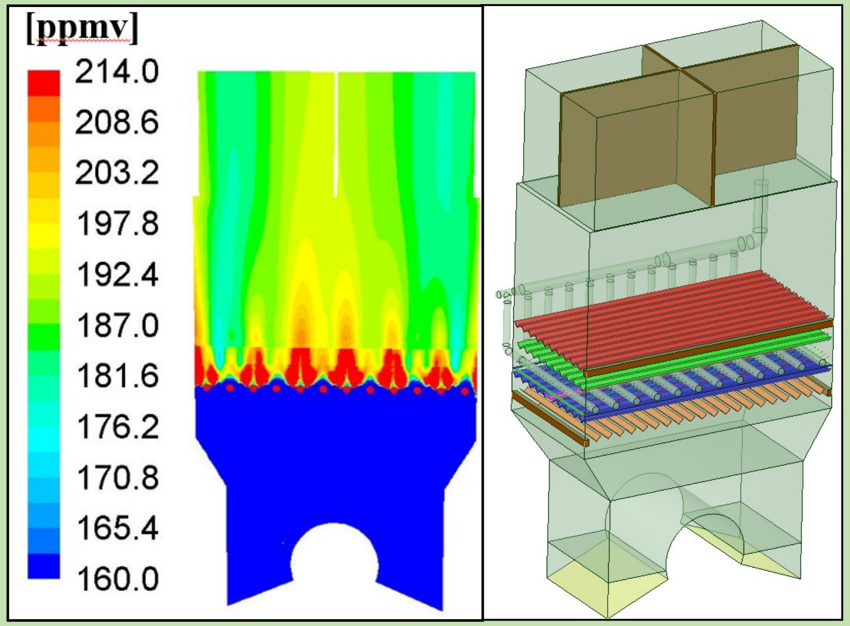
Minor modifications to the duct were made to have smooth bend, and a gradual transition to fan inlet. Small turning vanes were used in the duct to achieve uniform flow profile at fan inlet. Around 0.5 inches WC pressure drop was reduced on the suction side. Duct from ID fan outlet to stack was modified to have larger opening. Few entry baffles and turning vanes were installed to direct the flow into the stack, and achieve uniform flow profile at the stack cross section. A pressure drop of 0.25 inches w.c. was reduced with the proposed modifications



1st – 4th Edition	5th Edition
Forced-draught zone The forced-draught zone usually consists of the following: inlet stack, suction ducting, forced-draught fan, cold-air ducting, preheater, hot-air ducting, burner plenum and burners. Using the ends of this zone (e.g. the burner discharge and suction-stack inlet) as the anchor points, the operating pressure profile within the FD zone can be described as follows. a) The pressure at the burner discharge, inside the fired heater, is the draught at the floor (i.e. the arch draught plus the radiant-section draught). It is necessary to add the pressure drop across the burner to this floor draught pressure (whether it be negative or positive) to obtain the burner-plenum or burner-duct pressure. b) If appropriate, the pressure losses of the feeder ducts (i.e. branch connections) should be added to the burner plenum pressure to arrive at the hot-combustion-air-duct terminus pressure. c) As appropriate, the pressure losses of the hot-combustion-air ducting should be added to the hot-air-duct terminus pressure to arrive at the preheater's hot-air outlet pressure. d) As appropriate, an allowance should be made for any dampers and/or flow-measurement devices in the hot combustion-air ducting. e) The preheater's air-side pressure drop should be added to the preheater's outlet pressure to arrive at the preheater's inlet pressure. f) The pressure losses of the fan-discharge ducting should be added to the preheater's inlet pressure to arrive at a FD-fan discharge pressure. g) The pressure losses through the suction stack, silencer and suction ducting should be subtracted from the atmospheric pressure to obtain the FD-fan's suction pressure. h) By definition, the FD-fan's static pressure rise is the FD-fan's discharge pressure minus its suction pressure.	**Forced-draft Zone** The forced-draft zone usually consists of the following: inlet stack, suction ducting, forced-draft fan, cold-air ducting, preheater, hot-air ducting, burner plenum, and burners. Using the ends of this zone (e.g. the burner discharge and suction-stack inlet) as the anchor points, the operating pressure profile within the FD zone can be described as follows. a) The pressure at the burner discharge, inside the fired heater, is the draft at the floor (i.e. the arch draft plus the radiant-section draft). It is necessary to add the pressure drop across the burner to this

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Clearly, the above overview is conceptual and the pressure profile of each zone requires a specific analysis that accounts for the unique features of the system.				floor-draft pressure (whether it be negative or positive) to obtain the burner-plenum or burner-duct pressure. b) As appropriate, an allowance should be made for any dampers and/or flow-measurement devices in the hot combustion-air ducting. c) As appropriate, the pressure losses of the hot-combustion-air ducting should be added to the hot-air-duct terminus pressure to arrive at the preheater's hot-air outlet pressure. d) The preheater's air-side pressure drop should be added to the preheater's outlet pressure to arrive at the preheater's inlet pressure. e) The pressure losses of the fan-discharge ducting should be added to the preheater's inlet pressure to arrive at a FD-fan discharge pressure. f) The pressure losses through the suction stack, silencer and suction ducting should be subtracted from the atmospheric pressure to obtain the FD-fan's suction pressure. g) By definition, the FD-fan's static pressure rise is the FD-fan's discharge pressure minus its suction pressure. Clearly, the above overview is conceptual and the pressure profile of each zone

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				requires a specific analysis that accounts for the unique features of the system.
Dual Draft System To facilitate swift conversion to natural draft, it is common practice to operate the burner plenum at slightly negative or zero pressure when in the forced or induced draft mode. This should be accounted for in the basic design of the system.	**Dual Draft System** To facilitate swift conversion to natural draft, it is common practice to provide “natural draft air doors” on, or adjacent to, the burner plenum. These doors will fail open as appropriate to provide a local source of ambient combustion air for the heater.			
External or Internal Duct Linings		**Deleted**		



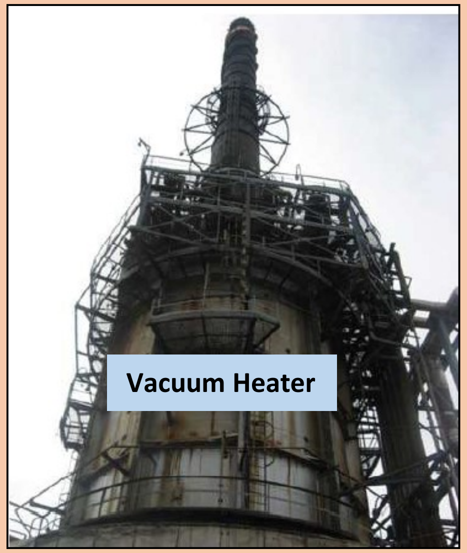
The ductwork requirements for APH systems can be separated into two classifications: flue-gas ductwork and combustion-air ductwork. The mechanical and structural design principles are the same for both. General recommended design requirements are the following. a) Design and fabrication should comply with this International Standard. b) Ducts should be gas-tight. c) Field joints should be flange-and-gasket or seal-welded construction.	The ductwork requirements for APH systems can be separated into two classifications: flue gas ductwork and combustion air ductwork. The mechanical and structural design

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
d) Ductwork should permit replacement of components (e.g. dampers, blowers, heat exchangers and expansion joints). e) Ductwork should provide uniform fluid flow distribution into the APH exchanger. Failure to achieve a uniform velocity distribution can reduce the performance of preheaters and fans. Internal duct bracing, if used, should not be installed within three diameters of equipment since disruption or restriction of the flow can occur. Use of turning vanes or straightening vanes should be considered to ensure uniform distribution.				principles are the same for both. General recommended design requirements are the following: a) ducts should be gas-tight; b) field joints should be flange-and-gasket or seal-welded construction; c) ductwork should permit replacement of components (e.g. dampers, blowers, heat exchangers, and expansion joints); d) ductwork should provide uniform fluid flow distribution into the APH exchanger; e) ductwork should provide uniform fluid flow distribution in the SCR reactor (if present) Failure to achieve a uniform velocity distribution can reduce the performance of preheaters, fans, and SCRs. Internal duct bracing, if used, should not be installed within three diameters of equipment since disruption or restriction of the flow can occur. Use of turning vanes or straightening vanes should be considered to ensure uniform distribution. In multiple burner installations, combustion air ductwork design should promote even distribution of air to the burners. Air distribution ductwork should be designed for constant velocity, so that the variance in the static and

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				velocity pressure components to each burner is minimized. The variance in air flow to any one burner should be no greater than ±5 % from the average. When NOx emissions must be minimized, the variance should be ±2.5 % when operating at 10 % excess air and normal heat release. The burners should account for 90 % of the total air side pressure drop from the inlet of the combustion air distribution duct through the burners. The purchaser shall specify if modelling of combustion air ductwork is required in order to demonstrate even distribution of air to the burners. This modeling may include computational fluid dynamics, or cold flow model
Added in 5th Edition	F.9.2.2 Where branch connections are required to maintain even flow distribution, rectangular ducts are preferred.			
Layout and routing considerations The following are recommended ductwork layout and routing guidelines. e) Manways should be a minimum of (460×460) mm [(18×18) in] and so located in the ductwork (if size permits) to provide for internal access to the entire duct system.				**Layout and routing considerations** The following are recommended ductwork layout and routing guidelines. e) Manways should be a minimum of 600 mm × 600 mm (24 in. × 24 in.) and located (if size permits) to provide for internal access to the entire duct system.

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition

Capacity Increase on CDU-2; Crude & Vacuum Heaters (11/12-F-01)



The Furnace Improvements (FIS) was employed by an Indian Refinery at Visakhapatnam, to provide recommendations to increase the capacity of the Crude Heater (11-F-01) and Vacuum Heater (12-F-01) by 15%.
The crude heater was commissioned in 1985 for a heat duty of 60 MMBtu/hr. The existing heater was operating at a thermal efficiency of around 83% which client wished to improve. The average flue gas temperature leaving the stack was around 342°C. This was 110°C higher than the design stack temperature of 230°C.

The vacuum heater was commissioned in 1985 for a heat duty of 184 MMBtu/hr. The existing heater was operating at a thermal efficiency of around 83% and the client wished to improve the same. The average flue gas temperature leaving stack was around 308°C. This was 78°C higher than the design stack temperature of 230°C.

The client was already planning to install a new in-kind convection section, new stack, and a new tight shut-off damper during the forthcoming shutdown. FIS analyzed the design of the Crude Heater (11-F-01) and developed a scheme to increase the capacity and improve the efficiency of both Heaters.

FIS proposed to add a new convection section below the new-in kind convection for both heaters. The proposed convection will increase the absorbed duty across the convection and will help in reducing the stack temperature to around 276°C in crude heater and 165°C for vacuum heater. The results in both heaters were:

1. Capacity Increase by 15%
2. Heat duty Increase by 15%
3. Efficiency Improve to >90%
4. Stack Temperature reduction

1st – 4th Edition	5th Edition
Miscellaneous construction details The following features are recommended. a) Dampers constructed integral to ducts should be of a bolted design to allow replacement of parts. b) Damper bearings shall not be covered by insulation. c) Damper shafts shall be of austenitic stainless steel or a more corrosion-resistant material suitable for the operating conditions. d) Actuator design should be based on weathered, or in-service, bearing-friction loads (not new and clean values).	**Miscellaneous** Construction Details The following features are recommended: a) dampers constructed integral to ducts should be of a bolted design to allow replacement of parts, b) damper bearings shall not be covered by insulation,

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
				c) damper shafts shall be of austenitic stainless steel or a more corrosion-resistant material suitable for the operating conditions
Dampers may be classified into four types based upon the amount of internal leakage across the closed damper at operating pressures. a. Tight shutoff—low leakage. b. Isolation or guillotine (slide gate)—no leakage. c. Flow control or distribution—medium to high leakage. d. Natural draft air inlet doors—low leakage to full open. Tight shutoff dampers may be of single blade or multi-blade construction. Leakage rates of 0.5 percent or less of flow at operating conditions are typical. Isolation or guillotine (slide gate) dampers are designed to have no internal leakage when closed and may include double- gate with air purge or double-block-and-bleed designs consisting of one or more dampers in series with an air purge between. Internal leakage rates of 0 percent are expected with this type of damper. Dampers may have insulated blades to allow personnel to safely enter ductwork (downstream of the damper) during operation of connected equipment. Natural draft air inlet doors shall be designed as fail-open devices in the event of loss of mechanical draft furnished by combustion air fan.		In any duct-system design, the selection and location of the system's dampers should consider safety, maintenance, process and control needs and requirements. In short, each damper application has its own unique set of requirements. Table F.3 provides recommended damper types for the common APH-system applications. When selecting a damper, the following should be considered: a) design pressure and design differential pressure; b) design temperature; c) design leakage rate; d) application type, as discussed below; e) mode of operation (manual, automatic, etc.); f) materials of construction of blades, shafts, bearings, frame, etc.; g) rate of operation; h) local instrumentation (limit switches, positioners, etc.). Dampers can be classified into four types, based upon the amount of internal leakage across the closed damper at operating pressures: – tight shutoff: low leakage; – isolation or guillotine (slide gate): no leakage; – flow control or distribution: medium to high leakage; – natural-draught air-inlet doors: low leakage to full open. Tight shutoff dampers may be of single blade or multi-blade construction. Leakage rates of 0.5 % or less of flow at operating conditions are typical. Guillotine blinds or slide gates are used to isolate equipment, either after a change to natural draught or when isolating one of several heaters served by a common preheat system. The design should consider exposure of personnel, the effects of leakage on heater operation, the tightness of damper shutoff and the location of the damper (close to or remote from the affected heater). Isolation or guillotine (slide gate) dampers are designed to have no internal leakage when closed and may include double-gate with air purge or double-block-and-bleed designs consisting of one or more dampers in series with an air purge between. Internal leakage rates of 0 % are expected with this type of damper. Guillotines may have insulated		

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
		blades to allow personnel to safely enter ductwork (downstream of the damper) during operation of connected equipment. Refer to F.9.4.3 for further guidelines. Flow-control dampers are typically multiple-louvre, opposed-acting, multiple-blade dampers because such dampers have superior flow-control capabilities. Parallel-blade or single-blade dampers should not be applied where the flow-directing feature inherent in their design can impair fan performance or provide an unbalanced flow distribution in the preheater. Actuation linkage for dampers used for control or tight shutoff should have a minimum number of parallel or series arms. The potential for asymmetrical blade movement and leakage increases with linkage complexity. Natural-draught air doors shall be designed as fail-open devices in the event of loss of mechanical draught provided by combustion-air fan. Natural-draught air doors should be sized and located in the ductwork such that combustion-air flow to the burners during natural-draught operations is symmetrical and unrestricted. The expected leakage or the leakage to be tolerated shall be stated in specifying damper requirements. Except for isolation-damper designs, the amount of leakage varies with type and operating conditions.		
Miscellaneous Construction Details Modified	**Miscellaneous Construction Details** The following miscellaneous features are recommended: a. Dampers constructed integral to ducts should be of a bolted design to allow replacement of parts. b. Damper bearings shall not be covered by insulation. c. Damper shafts shall be of Type 304 stainless steel as a minimum. d. Bearing friction loads used for actuator design should be representative of a weathered, in service condition (not as new shop values).			
Added in 4th Edition		Table F.3- Recommended damper type		
Added in 4th Edition		Internal refractory and external insulation systems		
The minimum castable refractory thickness should be 2 in. (50 mm). The service temperature of the castable refractory should be least 300°F (170°C) above the maximum calculated temperature of the material. In fuel oil fired applications, the burner plenum should minimize the absorption of oil into the refractory. High density and/or oil resistant refractory should be considered. Provide refractory on the floor of the plenum and for at least 4 in. (100 mm) up the side walls.		The minimum castable refractory thickness should be 50 mm (2.0 in). In oil-fired applications, castable refractories should be used for all burner plenum and adjoining hot-air ducting. Castable refractories do not absorb fuel oil (unlike ceramic fibre products, which do absorb liquids), thus greatly reducing the fire hazard beneath the heater.		

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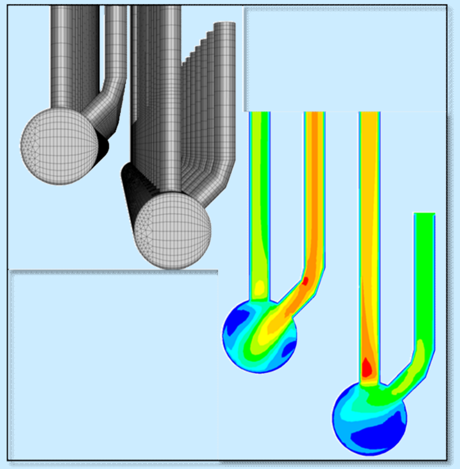
CFD Modeling

At Furnace Improvements, we utilize CFD modeling to analyze problems and provide solutions. This tool enables us to study the existing design and operating conditions of heaters and determine recommendations for solving any difficulties. CFD gives a competitive edge over other analyses due to its visual presentation of the observed conditions and proposed modifications. The following are a few areas where FIS has used this tool effectively:
• Flow maldistribution
• Mixing (ammonia injection grid & flue gas recirculation mix box design)
• Combustion (burner & heater design)
• Tube failures
• Heat transfer
However, the CFD applications are not limited to these items. FIS is making every effort to explore its varied applications and use this powerful tool if and when it is required.



CFD Modeling of Flow Distribution in an Economizer Coil
</td></tr>
<tr><td colspan="2">The application of unlined ceramic fiber blanket refractory for hot flue gas or combustion air ducts should be in accordance with Section 7 of this standard. Ceramic fiber blanket refractory systems with protective metal liners should be in accordance with API Recommended Practice 534. When ceramic fiber construction is used, the casing shall have an internal protective coating to prevent corrosion of metal ductwork. Do not use unlined ceramic fiber refractory in erosive areas, such as duct bends, baffles, changes of axis, and/or changes in flow areas.</td>
<td colspan="2">Ceramic-fibre-blanket refractory
Ceramic-fibre-blanket refractory systems with protective metal liners should be in accordance with API RP 534.
Application of unlined ceramic-fibre-blanket refractory for hot flue-gas or combustion-air ducts should be limited to applications with fluid velocities less than 12 m/s (40 ft/s) and the design should be in accordance with Clause 11.
Flue-gas ducting using relatively porous ceramic-fibre blanket and/or block refractory should have either a
protective internal coating (applied to the ducting's internal casing surfaces prior to application of refractory materials) or a stainless-steel-foil vapour barrier (sandwiched within the refractory layers, if possible) for applications with fuels containing more than 1,0 % (mass fraction) of sulfur in a liquid fuel or 1,5 % (volume fraction) of hydrogen sulfide in a fuel gas.</td>
<td>Ceramic-fibre-blanket Refractory
Ceramic-fibre-blanket refractory systems with protective metal liners should be in accordance with API 534.
Application of unlined ceramic-fibre-blanket refractory should be in accordance with Section 11. Flue gas ducting using relatively porous ceramic-fibre and/or block refractory should have either a protective internal coating (applied to the ducting’s internal casing surfaces prior to application of refractory materials) or a stainless steel-foil vapor barrier (sandwiched within the refractory layers, if possible) for applications with fuels containing more than 1.0 % (mass fraction) of sulfur in a liquid fuel or 1.5% (volume fraction) of</td></tr>
</table>

<table>
<tr><th>1st Edition</th><th>2nd Edition</th><th>3rd Edition</th><th>4th Edition</th><th>5th Edition</th></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td>hydrogen sulfide in a fuel gas.
Exposed ceramic fiber insulation should not be used in flue gas ducting upstream of SCR reactors. Loose fibres may migrate downstream and plug SCR catalyst.</td></tr>
<tr><td colspan="4">Block and board refractories are defined as rigid and semi-rigid, respectively. Refractory should be specified as ASTM C 612, Class 3. If such refractory is not to be shielded by other materials, single layers may be used below 260°C (500°F). It may be used as a backup layer with other refractories with fuels containing more than 1,0 % (mass fraction) of sulfur in a liquid fuel or 100 ml/m^3 (100 ppm volume fraction) of hydrogen sulfide in a fuel gas. The velocity of the flowing gas stream shall not exceed 6 m/s (20 ft/s) unless the surface is protected with wire mesh, expanded metal or solid metal. Two layers of insulation are preferred.</td><td>Block and Board Refractory Block and board refractories are defined as rigid and semi-rigid. Single layers may be used below 260°C (500°F). It may be used as a backup layer with other refractories. The velocity of the flowing gas stream shall not exceed 6 m/s (20 ft/s). Two layers of insulation are preferred.</td></tr>
<tr><td colspan="4">Thermal pollution
Application of an APH system results in a lower flue-gas exit temperature thereby reducing thermal pollution.</td><td>Deleted</td></tr>
<tr><td colspan="4">Effluent
The air preheater can collect small quantities of solids combined with sulfur. During wash down cycles, if required, the liquid effluent can contain particulates in a weak acid that should be handled in an appropriate disposal system. Normally, the additional quantities produced as a consequence of the APH system are negligible.</td><td>Deleted</td></tr>
<tr><td>APH INQUIRY
Modified</td><td colspan="4">APH INQUIRY
Final selection of the air preheat system often requires cost and technical information on more than one system. This information is usually obtained from suppliers responding to the bid inquiry. An inquiry for an air preheat system should include:
a. Data sheets for the fired heater(s), existing or proposed.
b. Air preheater data sheets.
c. Air preheat system specifications and P&ID.
d. Plot plan, plot area, or definition of the APH system plot area restrictions.
The data for item “a” above is often available from the OEM’s data book. The fired heater operating data must represent the intended heater operation, which in the case of retrofit may vary from the original design data. If so, both the original and the intended operating data must be supplied.</td></tr>
</table>

1st Edition	2nd Edition	3rd Edition	4th Edition	5th Edition
Added in 4th Edition		Flue-gas dew point		
Appendix G				
Added in 2nd Edition	Appendix G - Measurement of the thermal efficiency of fired process heaters			
Appendix H				
Added in 3rd Edition	Annex I (informative) Measurement of Noise from Fired-process Heaters			
Appendix I				
Added in 3rd Edition	Annex J (normative) Refractory Compliance Data Sheet			

Section 3
References

3.1 API 560 Editions

S. No.	Documents
1	API Standard 560- 1st edition, January 1986
2	API Standard 560- 2nd edition, September 1995
3	API Standard 560- 3rd edition, May 2001
4	API Standard 560- 4th edition, August 2007
5	API Standard 560- 5th edition, February 2016