Ballot notes on the proposed changes to API 556, 2nd edition

- 556 will change from a single document to an eight-part document;
- 556 will change from an API Recommended Practice to an API Standard- except for part 5 which will remain a Recommended Practice; and

The subtitles for the eight parts of the proposed eight parts are listed below. The first six parts are dedicated to fired heaters designed to burn fuel gas. Part 7 is an overlay of Parts 1 through 6 for fired heaters designed to burn fuel oil. Part 8 is an overlay of Parts 1 through 6 for steam methane reforming furnaces.

Part 1 – Instrumentation
Part 2 – Control
Part 3 – Protective Functions
Part 4 – Flue Gas Analyzers
Part 5 – Main Burner Ignition Criteria
Part 6 – Tube Skin Thermocouples
Part 7 – Overlay for Oil Fired Heaters (planned publication in March 2028)
Part 8 – Overlay for Steam Methane Reforming Furnaces (planned publication in March 2028)

API Std 556-6, 1st Edition contains requirements and background information for tube skin thermocouples used for gas fired heaters in general refinery service:

a. designed according to API 560 latest edition,
b. containing burners that are designed and tested as per API 535 latest edition,
c. have controls and protective functions in accordance with API 556

Instrumentation, Control, and Protective Functions for Gas Fired Heaters - Tube Skin Thermocouples

API STANDARD 556-6
First Edition, MONTH YEAR

1 Contents

Introduction

API 556 is transitioning from a single document to a multipart series of documents, each issued as a first edition.

The subtitles for the eight parts are listed below.

— Part 1: Instrumentation
— Part 2: Control
— Part 3: Protective Functions
— Part 4: Flue Gas Analyzers
— Part 5: Main Burner Ignition Criteria
— Part 6: Tube Skin Thermocouples
— Part 7: Overlay for Oil-Fired Heaters (reserved for future publication)
— Part 8: Overlay for Steam Methane Reforming Furnaces (reserved for future publication)

This document is the sixth part of API Standard 556, Instrumentation, Control, and Protective Functions for Gas-Fired Heaters. API 556-6 contains requirements tube skin thermocouples utilized within new fired heaters for general refinery service that:

a) are designed in accordance with API 560;
b) contain burners which are designed and tested in accordance with API 535;
c) have instrumentation, controls, and protective functions in accordance with the respective parts of API 556.

Tube Skin Thermocouples (TSTC) are specialized thermocouples designed for direct contact temperature measurement of tube wall surfaces in fired equipment via a weld pad form. Unlike standard process thermocouples, TSTC are not protected by a thermowell or pipewell, necessitating additional application-specific considerations. For detailed guidance on thermocouple weld pad design, heater connection types, and sheath materials installation bend recommendations, refer to API 551. This standard is intended to be used by owner/operators, instrumentation design engineers, heater fabricators, and TSTC manufacturers.

This standard has been formulated to provide a benchmark for specifying the technical requirements to enable the formation of the TSTC instrument data sheet. Use of this standard will ensure that detailed information is provided to the manufacturer to provide the TSTC and associated documentation with all process considerations taken into account including details of the measuring point location point on the associated heater tube and exit point of the TSTC out of the heater. The information will enable formulation of correct routing information including bending and expansion methodology requirements.

This standard applies to TSTC for new heaters in general refinery service. This standard may be used as a reference for the refurbishment, modernization, or modification of existing heaters but application to existing heaters is not the focal intent of the standard.

TSTC are used to monitor the temperature of the outer surface of heater tubes in fired heaters. This information is critical for assessing the condition of the tubes, detecting potential overheating, and optimizing operational parameters. TSTC can be used for monitoring tube skin temperatures in both the radiant and convection sections of fired heaters to identify areas of excessive heat flux and help prevent potential tube failures.
Users of this Standard should be aware that further or differing requirements may be needed for individual applications. This Standard is not intended to inhibit a supplier from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the supplier should identify any variations from this standard and provide details.

In API Standards, the SI system of units is used. In this standard, where practical, US Customary (USC) units are included in brackets for information.

A bullet (●) at the beginning of a clause or sub-clause indicates that either a decision is required, or further information is to be provided by the purchaser. This information should be indicated on the purchaser's checklist (see Annex B) or stated in the inquiry or purchase order.

1 Scope

API 556-6 contains requirements, recommended practices, and background information on tube skin thermocouples (TSTC) installed in new gas fired heaters that are designed, operated, and safeguarded in accordance with API standards.

API 556-6 focusses on:

1. Roles and responsibilities of the parties included in procurement, design and installation of TSTC as well as documentation standards.

2 TSTC placement, design, and access requirements standards.

3. Standards for fabrication, shipment, field installation and inspection of TSTC.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 551, *Process Measurement*

API Standard 560, *Fired Heaters for General Refinery Service*

ASME B31.3, *Process Piping*

ASME E-1350, *Standard Guide for Testing Sheathed Thermocouples, Thermocouples Assemblies, and Connecting Wires Prior to, and After Installation or Service*

3.0 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
fabricator
the party that provides the facilities and services to physically construct all or part of the project work as directed by the supplier

3.1.2
owner
purchaser
the party with responsibility for all or part of the process and thermal design / definition, the mechanical specification, procurement, and construction of the purchased equipment

3.1.3
supplier
the party that manufactures or supplies equipment and services to perform the duties specified by the purchaser

3.1.4
technology provider
the party that provides licensed or proprietary technology information and is typically in the form of a process design or licensor package including a process performance guarantee

3.1.5
TIG welding
gas tungsten arc welding

3.1.6
vendor
the party that provides engineered products, sub-components, or services for the project work

3.1.7
weld pad form
device used to firmly affix a temperature sensor to a tubewall and is attached via welding to the tubewall

3.3 Abbreviations

For the purposes of this document, the following abbreviations apply.

APH	air preheat system
Cr-Mo	chromium molybdenum steel
FCS	facility control system
PWHT	post weld heat treat
PQR	procedure qualification record
SS	stainless steel
TSTC	tube skin thermocouple
WPS	welding procedure specification

4 Responsibilities

4.1 Purchaser's Responsibilities

NOTE 1 The owner or purchaser most often works through an engineering contractor (contractor) as an agent undertaking owner's requirement for the engineering, procurement, and construction phases of work including representation of the owner on decisions related to operation and maintenance as may be required

NOTE 2 Construction includes installation / erection of purchased equipment.

4.1.1 The purchasershall provide the supplier with data sheets (see Annex A) and other applicable information outlined in this standard. This information shall include any special requirements or exceptions to this standard.

NOTE The items on the datasheet designated by an asterisk (*) are, at a minimum, the purchaser's responsibility for providing information in the inquiry. Refer to Annex A. Additionally refer to API 551 for typical materials and construction recommendations

4.1.2 The purchaser shall determine the correct process specification to enable the supplier to design and supply the appropriate TSTC assemblies.

4.1.3 Process engineers historically provide process conditions (where applicable), but not limited to:

a) normal mode of operation;

b) start-of-run;

c) end-of-run;

d) process design cases;

e) turn down;

f) steam / air decoke;

g) regeneration.

4.2 Supplier's Responsibilities

NOTE 1 The supplier typically has the prime responsibility for the thermal design, detailed engineering, material procurement, project management, and manufacturing processes involved in the physical supply of the fired equipment including all aspects of quality assurance, quality control for work of their own and others whom they qualify for providing work, products, or services on their behalf, i.e. vendors, fabricators, refractory manufacturers, and refractory contractors.

NOTE 2 The vendor, whether they directly produce the materials or are agents in supply of such components, have responsibility for the quality of the product to either recognized industry or other standards as directed by the purchaser, whomever they may be. Vendors typically supply sub-components such as burners, fans, dampers, instrumentation, pipe hangers, castings, refractory, pipe / tubes, and fittings etc. A vendor may also provide specialty engineering services such as finite element analysis (FEA). Within the context of this standard, the supplier has prime responsibility for the products and services provided by the vendor.

4.3 Documentation

The documentation required by this section shall be provided by the supplier to the purchaser after award of the contract for supplying and installing new TSTC.

4.3.1 Drawings for purchaser review

4.3.1.1 The vendor shall submit drawings for each TSTC to the purchaser for review.

4.3.1.2 Each TSTC drawing shall include the following title block or notes information:

a) heater service;

b) the purchaser's equipment number;

c) the project name and location;

d) type of fired heater;

e) tube metallurgy;

f) radiant section tube support / guide design metal temp;

NOTE See API 560 fired heater data sheet, mechanical design conditions.

g) the purchase order number;

h) the vendor's reference number;

i) TSTC data tag; and

j) coil number.

4.3.1.3 Each TSTC drawing shall include:

a) orientation of tip form relative to the burner and elevation on tube;

b) distance to exit penetration from elevation on tube;

c) penetration type;

d) refractory thickness;

e) tube size (O.D.);

f) tube growth (amount and direction);

g) routing / expansion considerations, if applicable include number and size of expansion loops which should open in the direction of tube growth;

h) number of clips based on routing design; and

i) any application specific considerations noted for approval.

4.3.2 Documents for purchaser's review

4.3.2.1 The supplier shall submit TSTC documents to the purchaser for review.

4.3.2.2 TSTC documents to be submitted include:

a) completed TSTC data sheet;

b) component level details for the TSTC;

c) the design resistance from conductor to conductor;

d) the design resistance from conductor to sheath; and

e) scope of shop assembly design, including

   i. thermocouple-to-pad welds;

   ii. sheath bends.

4.3.3 Final drawings, diagrams, and documents

4.3.3.1 After receiving the purchaser's comments on the drawings and diagrams, the vendor shall furnish finalized design drawings and diagrams.

4.3.3.2 The vendor shall furnish design-detail drawings, incorporating installation details.

4.3.3.3 Drawings of auxiliary equipment shall also be furnished.

4.4 Final Records

4.4.1 Within two weeks after all TSTC are installed, the supplier shall furnish the purchaser with:

a) as-built drawings and data sheets representing the as-installed equipment;

b) measurements;

c) test reports;

d) non-destructive examination reports; and

e) the bill of materials.

5 Tube Skin Thermocouple Placement, Design, and Access Requirements

5.1 Placement

Refer to API 560 for placement details and recommendations.

5.2 Design

5.2.1 Thermocouple assembly routing and expansion considerations shall be designed to accommodate all tube movement listed on the data sheet.

5.2.2 Sheath routing shall be approved by the end user.

5.2.3 The thermocouple shall:

a) be a single pair wire design;

b) be tangentially orientated with respect to the tube to minimize the portion of the sheath with a line-of-sight to flames;

c) be located to measure the hottest portion of the tube's circumference; and

d) have welded components be 310 SS unless otherwise required due to process conditions.

e) If required, a circumferentially routed 310 SS heat shield filled with insulation and curved to match the tube's outside diameter.

5.2.4 For single fired tubes (i.e., the tubes are located close to a wall), the sheath shall run down the back side of tubes located close to the wall.

5.2.5 The sheath shall maintain close contact with the tube.

5.2.6 The sheath shall be clipped to the tube within four inches after the first bend from welded tip form.

5.2.7 The sheath shall be clipped to the tube every 0.30 m (12 in.) thereafter until the expansion loop is reached.

5.2.8 When the sheath needs to be bent, the requirements are:

a) the vendor's guidance for a minimum bend radius (e.g. 5X the sheath O.D.) shall be followed;

NOTE Sharp bends / over bending of the sheath can lead to conductor damage and premature failure.

b) whenever possible sheaths shall be bent at the manufacturer; and

c) field bends shall be minimized and not be done unless field bend modifications are approved by the owner with consultation from the tubeskin vendor as needed.

5.2.9 The sheath shall be routed in a way that:

a) minimizes radiant heat transfer to the sheath; and

b) position the penetration point to minimize the length of sheath not attached to the tube;

5.2.10 TSTC Tip Forms

Various tip forms have been developed to firmly affix a temperature sensor to a tube wall so that its measuring junction will maintain proximity to the tube wall surface throughout the period of its installation. The below forms are provided as generic and acceptable examples of commonly used TSTC tip forms. Alternative designs may be equally acceptable so long as they maintain the thermocouple junction in close and consistent proximity to the tube wall over the life of the installation.

The thermocouple tip form needs to be properly attached to the tube as shown in Figures 1 and 2 at the hottest location on the tube and then routed as directly as practical to the shadow side of that tube to protect the thermocouple sheath from flame impingement. Care should be exercised to minimize the mass at the point of

measurement as additional mass slows the response and increases conduction errors. The contact area on the tube should be free of scale and oxide.

5.2.10.1 Form A: Shielded Weld Pad

Weld pads should be constructed so that they are radiused to ensure a minimal gap with the tube outside diameter. The thermocouple sheath shall be welded to the pad so that the bottom of the sheath is flush with the bottom of the pad. Shield, pad, and sheath materials need not match the tube but should be compatible with the tube material.

Type 310 SS is frequently used as a base pad material compatible with many commonly used tube materials. Thermocouple junctions may be grounded or ungrounded per end user preference.

Thermocouple shields are intended to reduce the influence of radiant heat energy in a given installation. Shields are typically curved and contain insulation to reduce radiant energy influence on the thermocouple measurement.

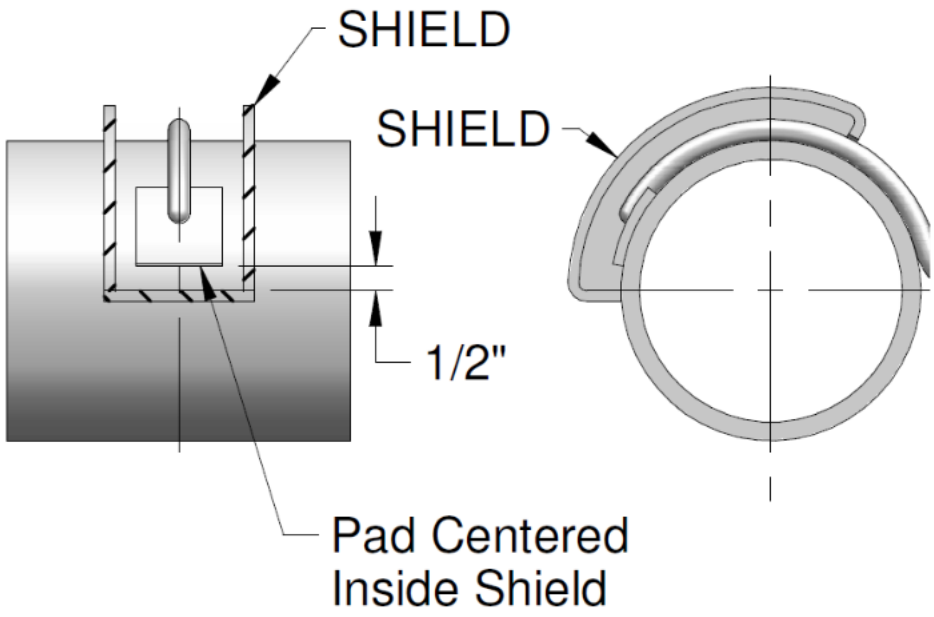

Figure 1 – Shielded Weld Pad Form

5.2.10.2 Form B: Unshielded Forms (Wedged with Flat Contact Point)

Unshielded forms are designed to be welded directly to the tube wall without a heat shield. With these designs, a heat shield will perturb the tube wall temperature and reduce the ability of the installed thermocouple to accurately reflect the true tube metal temperature.

Unshielded forms shall have grounded measuring junctions positioned within the body so that the wires have direct contact with the tube wall when attached to the tube by welding. The materials of construction for these forms need not match the tube wall nor sheath material. Materials such as AISI 310 SS, UNS N06002, and UNS N06600 are commonly selected but other materials may also be incorporated as best suits an end user's preference.

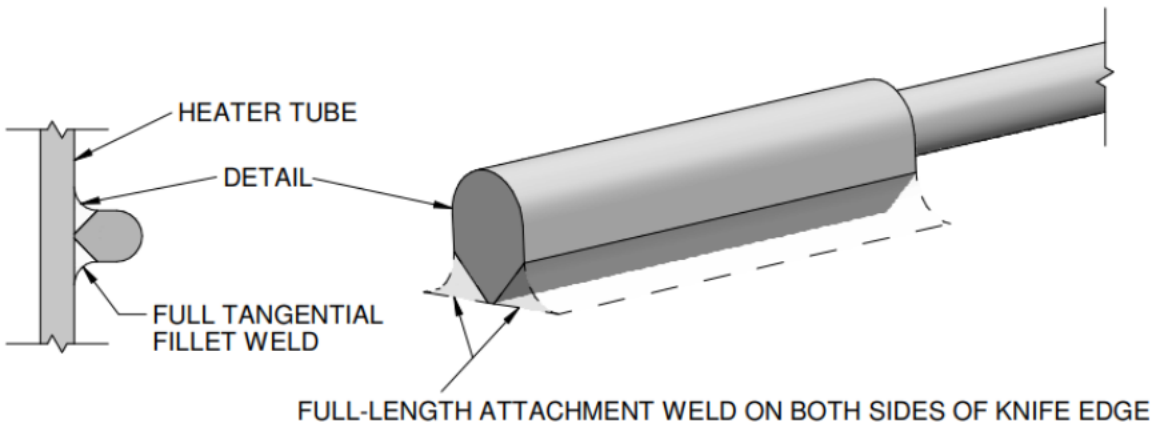

Figure 2 – Unshielded Wedge Form

5.11 Welded tip form shall be located a minimum of 0.46 m (18 in.) from tube guides, supports, or other TSTC.

5.12 For single fired tubes, the expansion loop design shall be appropriate for the space between the tube and the wall.

5.13 When required, the expansion loop shall be protected from flame radiation by locating the expansion loop

a) directly behind the tube for single fired tubes; or

b) between tubes for double fired tubes.

5.14 Exit designs shall have furnace wall attachment:

a) a minimum of 0.20 m (7.5 in.) of sheath distance from the outside of the fired heater shell to keep the transition below 177 ºC (350°F);

b) have an instrument I.D. tag wired with 316 SS wire attached to each thermocouple head;

c) have a nipple-union-nipple assembled with nickel-based lubricants applied to the threads; and

d) all required compression fittings supplied by the vendor.

5.3 Access to Connections

5.3.1 The TSTC connection heads shall be accessible by grade, platforms, reinforced roofs, manlifts, or scaffolding.

5.3.2 Transmitters shall be accessible from grade or permanent platforms.

5.3.3 Any thermocouple head shall be no more than 2 m (6.5 ft) above the floor of the platform or grade.

6 Shop Fabrication

6.1 General

6.1.1 The TSTC shall be shop-assembled to the maximum extent possible consistent with the available shipping, receiving, and handling facilities specified by the purchaser.

NOTE The fabricator would be responsible for the quality control of their own work and quality assurance of any directly purchased or sub-contracted work by them.

6.1.2 The TSTC shall be properly braced and supported to prevent damage during shipment.

6.2 Preparation for Shipment

6.2.1 All openings shall be protected to prevent damage and the possible entry of water and other foreign material.

6.2.2 All threaded connections shall be protected by metal plugs or caps of compatible material.

6.2.3 All boxes, crates, and packages shall be identified with the purchaser's order number and the equipment item number.

6.2.4 All liquids used for cleaning or testing shall be drained from units before shipment.

6.2.5 The TSTC shall be free of foreign material prior to shipment.

6.2.6 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.

7 Field Installation

7.1 The field installation vendor shall be responsible and ensure that all TSTC are installed in accordance with:

a) the specifications and drawings furnished by the vendor; and

b) the applicable sections of this standard.

NOTE Delays and installation inconsistency can be reduced when the TSTC vendor provides either supervisory or installation services. Consistency in these areas has been proven to improve reliability and product accuracy.

7.2 Prior to installation of an ungrounded TSTC, the installing vendor shall either conduct or verify that a resistance check per ASTM E-1350; including

a) measure and record the resistance value from conductor to sheath;

b) compare readings to pass/fail criteria listed on the vendor's datasheet; and

c) discard any TSTC that fails this check.

NOTE If grounded thermocouples are utilized, post-manufacture resistance testing is not applicable.

7.3 All surfaces to be welded shall be free from scale, oil, grease, dirt, and other harmful agents.

7.4 Welding operations shall be protected from wind, rain and other weather conditions that can affect weld quality.

7.4.1 For TSTC with welded requirements, like welded tip forms, heat shield and clips that are being welded to a process pipe/tube the following welding requirements shall apply:

a) tubes shall be prepared for welding by removing all deposits and scale;

b) follow owner's site procedures for surface preparation and/or vendors installation procedures.

7.5 The cleaned areas shall:

a) be dye penetrate tested by the qualified welding examiner; and

b) have the qualified welding examiner check the tube thickness to determine if the tube is acceptable for further service.

7.6 The sheath exit point through the fired heater's wall shall be packed with ceramic fiber to keep the outside connections cool and minimize tramp air leak points.

8 Inspection, Examination and Testing

8.1 General

8.1.1 After prior notice, the purchaser and/or a designated representative reserve the right to inspect all TSTC components and their assembled units at any time during the material procurement, fabrication, and shop assembly to ensure materials and workmanship are in accordance with applicable standards, specifications, codes, and drawings.

8.1.2 The vendor shall examine all individual TSTC components and their shop-assembled units to ensure that materials and workmanship are in accordance with applicable standards, specifications, codes, and drawings.

- **8.1.3** If specified by the purchaser, pre-inspection meetings between the purchaser and the vendor shall be held before the start of fabrication.

8.2 Weld Examination

8.2.1 All TSTC related welds shall be inspected by a welding inspector.

8.2.2 The purchaser shall examine and verify the new locations before any welding is done.

8.2.3 After the welded tip form (e.g., shield weld pad, wedge with flat contact point, per API 551) is fit-up and tack welded to a tube, but before continuous welds are done, the inspector shall verify that the gap between the welded tip form and the tube does not exceed vendor's recommendation or end user requirement.

8.2.4 The inspector shall dye check the welded tip form welds for acceptance.

8.2.5 The inspector shall dye check tube-clip-to-tube welds for acceptance.

8.2.6 Before the shield is welded to the tube, the inspector shall verify that

a) the shield is not empty; and

b) the shield is positioned properly over the pad.

8.3 Testing

8.3.1 Functionality testing shall be performed per end user requirements.

8.3.2 One example of an acceptable functionality test is as follows:

8.3.2.1 After installation of the heat shield, the installer shall conduct and record the results of a temperature spike test to verify that:

a) the tube skin is functioning correctly;

b) the wiring to the control system is correct; and

c) The TSTC tag in the facility control system (FCS) agrees with the tag attached to the TSTC.

8.3.2.2 The purchaser shall specify the source used to create a distinct temperature spike (up or down) in TSTC reading for functional testing.

NOTE Examples are a propane torch, hot air gun (electrical), cold spray, or dry ice.

8.3.2.3 The results of the temperature spike test shall be approved before there is no access to the TSTC from the fired heater.

8.3.4 Ten percent of alloy components shall be subjected to positive material identification testing.

8.3.5 Tabulation of tested items shall be included within final data books, keyed to weld maps on as-built drawings and mill certification document stampings. Tested items shall be immediately marked.

- **8.3.6** Positive material identification program methods, degree of examination, testing instruments, and tester qualifications shall be agreed upon between the purchaser and the vendor prior to manufacturing.

ANNEX A
(normative)

NOTE At a minimum, the purchaser shall complete those items that are designated by an asterisk (*).

General	1	Project and Location	*
	2	Service	*
	3	Fired Heater Equipment Number	*
	4	Instrument Tag Number	*
	5	Coil Number	
	6	Type of Fired Heater (See API 560)	*
	7	Tube Section (Radiant or Convection)	*
	8		
Heater Specifics	9	Tube Metallurgy	*
	10	High Bridgewell Temperature Alarm Point - Check wording	*
	11	Heater Tube Outside Diameter (inches)	*
	12	Direction(s) of Tube Growth	*
	13	Tube Growth at Instrument Location (inches)	*
	14	Tube Bow Movement (inches and direction)	
	15	Coil Movement (inches and direction)	
	16	Distance between backside of single fired tube and nearest wall (in cold position, inches)	*
	17	Total thickness of refractory and wall plate at point of penetration	*
	18	Viewport Numbers with Line Of Sight to thermocouple	
	19	X, Y, Z of TSTC in cold position	
	20	X, Y, Z of nearby TSTC Shields	
	21	X, Y, Z of nearby tube supports/guides	
	22	X, Y, Z of fixed point on coil	
	23	X, Y, Z of nearest sheath-penetration point	
	24	Sheath Penetration Connection Size / Length / Style (e.g., 1-1/2" FNPT coupling, 1" long)	*
	25		
Connection	26	Assembly Type (e.g.,fixed, piston style)	*
	27	Material of Construction (SS)	*
	28	Remote Mount distance from penetration (inches, if applicable)	*

Accessories	29	Nipple Union Nipple Length (inches, if applicable)	*
	30	Routing External to the Fired Heater Details (e.g., remote mounted head or cabinet location)	*
	31		
Element	32	Thermocouple Type (N or K)	*
	33	Junction (Grounded or Ungrounded)	*
	34	Outer Diameter (1/4" 5/16" or 3/8")	*
	35	Lead Wire Design	
	36	Sheath Material	
	37	Sensing Tip Form Style	
	38	Sensing Tip Material	
	39	Sensing Tip Orientation	
	40	Weld Clip Material	
	41	Heat Shield Material	
	42	Lead Wire	
	43	Lead Wire Insulation	
	44	Total Element Length (by Vendor)	
	45	Weld Clip Quantity (by Vendor)	
	46		
Head	47	Type	
	48	Material	
	49	ATEX Certification	
	50	Ingress Protection	
	51	Customer Electrical Connection	
	52	Instrument Connection	
	53	Terminal Blocks	
	54	Additional Accessories	
	55		
Purchase	56	Purchase Order Number	
	57	Manufacturer	
	58	Manufacturer's Reference Number	
	59	Manufacturer's Drawing Number	
	60		

Notes:
1.
2.
3.
4.
5.
6.

Revision	By	Revision	Date	Instrument Data Sheet Page 1 of X

Bibliography

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API Standard 560, *Fired Heaters for General Refinery Service*

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