Ballot notes

556 will change from a single document to an eight-part document. 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)

This "Comment-Only" ballot is on the proposed API Std 556-4, 1st Edition, which provides requirements and recommendations for the selection and application of flue gas analyzers to fired heaters in general refinery and petrochemical service:

a. designed according to API 560 5th edition including addenda 1 and 2,

b. containing burners that are designed and tested as per API 535 4th edition,

c. have instrumentation in accordance with API-556-1,

d. have controls in accordance with API 556-2, and

e. have protective functions as specified in API 556-3.

Instrumentation, Control, and Protective Systems for Gas Fired Heaters – Part 4: Flue Gas Analyzers

API Standard 556-4
1st Edition

Ballot Draft

Contents

0 Introduction

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 x) or stated in the inquiry or purchase order.

1 Scope

API 556-4 specifies requirements and provides recommendations for the selection and application of flue gas analyzers to fired heaters in general refinery and petrochemical service.

1.1 Inclusions

This Standard applies to flue gas analyzers installed in fired heaters that are built in accordance with API 560 and that have a project authorization date that occurred on or after the publication date of this standard.

1.2 Exclusions

This standard does not apply to Continuous Emission Monitoring Systems (CEMS). Information for CEMS analysis can be found in API 555 and site-specific requirements should be discussed with the local regulatory agency.

NOTE With the exclusion of CEMS, all flue gas measurements within the context of this document are reported as a wet basis measurement rather than a dry basis measurement.

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 Standard 560, *Fired Heaters for General Refinery Service*

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions – Work Force

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

NOTE 1 The following general definitions are provided to better define and distinguish the multi-disciplined workforce and the typical areas of responsibility involved in the specification, design, and supply work processes required in the overall procurement process for fired heat transfer equipment such as a reforming furnace. These definitions are intended to build upon the typical definitions of purchaser and vendor normally used in API Standards.

NOTE 2 Recognizing that the work process and areas of responsibility may differ between projects and owner organizations, the terms and definitions contained in the purchaser's procurement documentation take precedence over definitions of parties of the multi-disciplined workforces and their respective areas of responsibility.

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.

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

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.

NOTE 1 The owner or purchaser typically 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. The term purchaser within this document will be considered synonymous with the term "contractor" or "owner".

NOTE 2 Construction includes installation/erection of purchased equipment.

3.1.3

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

NOTE 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.

3.1.4

vendor

The party that provides engineered products, sub-components, or services for the project work.

NOTE 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. Vendors typically supply sub-components such as; burners, fans, dampers, instrumentation, pipe hangers, castings, refractory, pipe / tubes, 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.

3.2 Terms and Definitions – Technical

3.2.1

analyzer system response time
The time required for a step change in flue gas composition at the point of measurement to be reported at 63% or 90% (i.e., T63 or T90) of the final value at the signal output terminal of the flue gas analyzer (i.e., wired to the BPCS or logic solver).

NOTE 1 For a close-coupled extractive analyzer, the analyzer system response time will typically include the lag time associated with integral flame arrestors and the internal volume of the sample probe (e.g., 3 m / 36 in. length). The end user will typically consider these potential differences when comparing published response times

NOTE 2 Unless the response time is published as either T63 or T90 response to a process step change, the published value may be the sensor's response to calibration gas and may not accurately reflect the analyzer system response time. Alternatively, T63 or T90 response to a process step change may be available from the vendor upon request (e.g., with or without integral flame arrestors or sample probe).

3.2.2

Basic Process Control System (BPCS)

A computer-based implementation of the control functions necessary to operate and manage a specific process unit or area.

NOTE 1 The BPCS includes field instrumentation, the communications between field devices and the control processors, HMIs, and any other computers and communications required to support or report upon process performance.

NOTE 2 The BPCS does not include general-purpose business computers and networks, desktop workstations, or other computing resources not used exclusively to operate, configure, or maintain a process unit or area.

NOTE 3 Protective functions are considered to be independent from the BPCS functions but can share communication network components, engineering tools, and HMI.

3.2.3

bridgewall

the location where the flue gas exits the radiant section and enters the convection section.

3.2.4

calibrated gas

a compressed mixture of gases that is used to calibrate and maintain the accuracy of gas detectors and analyzers.

3.2.5

calibration

A maintenance procedure during which a calibrated gas is applied to the analyzer and the corresponding signal output is adjusted, if required, to keep the deviation between the measured and reported values within the supplier's specified tolerance.

3.2.6

close-coupled extractive analyzer

A point-based analyzer directly mounted to the heater flange which uses an aspirator to extract a continuous sample to a heated sensing element within the enclosure that measures the concentration of one or more components before returning the sample to the flue gas.

NOTE The analyzer sensor enclosure is typically heated and insulated to ensure the sample gas stays above the dewpoint.

3.2.7

combustibles

Carbon monoxide (CO) and hydrogen (H_2) as products of incomplete combustion.

3.2.8

combustibles sensor

A heated, multi-element detector that measures combustibles in the flue gas stream.

NOTE 1 The active element is coated with a catalyst to promote oxidation while the reference element is treated to inhibit oxidation. The reaction is exothermic and the heat generated raises the temperature of the active element which also changes the resistance of the element. The temperature increase or resistive change is measured electrically to produce a signal that varies linearly with the combustibles concentration in the measured gas stream.

NOTE 2 This is a historical term commonly associated with catalytic bead sensors operated at a low enough temperature that methane will not be detected. When transitioning from incomplete combustion to partial loss of flame, a separate detector is required to measure methane, ethane, propane, etc.

3.2.9

complete combustion

Occurs when sufficient excess air allows the fuel to react completely with the oxygen (O_2) to produce only carbon dioxide and water.

3.2.10

dry basis measurement

A method of analysis that reports analytical results based on the condition of the sample being free of any condensable compounds, including moisture.

3.2.11

flue gas analyzer

A device that reports the concentration of one or more components in the flue gas stream of a fired heater.

3.2.12

gross oxygen analysis

A measurement which reports the amount of oxygen in the flue gas regardless of any other constituents

NOTE Gross oxygen is also known as total oxygen.

3.2.13

incomplete combustion

Occurs when insufficient excess air (e.g., due to either poor mixing or substoichiometric combustion) does not allow the fuel to react completely with the oxygen to produce only carbon dioxide and water.

NOTE For typical refinery fuel gas, an incomplete reaction will yield carbon monoxide and other combustibles gases which can be detected by a flue gas analyzer.

3.2.14

net oxygen analysis

A measurement which reports the residual or excess oxygen at the heated sensor after all combustible compounds are consumed.

NOTE 1 Net oxygen is also known as excess or residual oxygen.

NOTE 2 When no combustibles or unburned hydrocarbons are present, a net oxygen analyzer will report the actual concentration of oxygen in the flue gas.

NOTE 3 When combustibles or unburned hydrocarbons are present, a net oxygen analyzer will report a lesser than actual value for the concentration of oxygen in the flue gas

3.2.15

overall system response time

The time required for the flue gas analyzer to reach 63.2% of its final value in response to a step change in heat release at the burners, which includes the radiant section time constant and the analyzer system response time.

NOTE 1 While the analyzer system response time may benchmark T90 published values, the control systems engineer will typically use the first order time constant (e.g., T63) for control loop tuning purposes.

NOTE 2 For a ZrO_2 sensor, the rate of adsorption (i.e., step change decrease in heat release at the burners) and desorption (i.e., step change increase in heat release at the burners) are not the same. To keep the heater within operational limits, the sensor response to a step change increase in heat release at the burners is prioritized for control loop tuning purposes.

3.2.16

path-averaged analyzer

An instrument mounted directly to the fired heater that measures the concentration of specific gases in a path across a section of the fired heater.

3.2.17

point-based analyzer

An instrument mounted directly to the fired heater that measures the concentration of components in the flue gas at a specific point within the fired heater.
NOTE This may be a close-coupled extractive or laser-based probe analyzer.

3.2.18

Quantum Cascade Laser (QCL) Absorption Spectroscopy

A method of analysis using a laser source operating in the mid-infrared region for detection of specific component in the flue gas.

3.2.19

radiant section time constant

The time required for the oxygen content in the flue gas at the top of the radiant section to reach 63.2% of its final value in response to a step change in heat release at the burners.

NOTE The oxygen trim controller can be modeled as a first order lag process

3.2.20

reference gas

A gas used for the reference side of ZrO_2 sensors, typically instrument grade air with ~20.9% O_2 content.

3.2.21

tramp air

Any air that enters the fired heater except through an operating burner.

3.2.22

Tunable Diode Laser (TDL) Absorption Spectroscopy

A method of analysis using a laser source operating in the near-infrared region for detection of specific component in the flue gas.

3.2.23

validation

A maintenance procedure during which a calibration gas standard is applied to the analyzer and the corresponding signal output is not adjusted. If the deviation is outside of the supplier’s specified tolerance, calibration is typically performed.

3.2.24

wet basis measurement

A method of analysis that reports analytical results based on all components in the sample, including moisture.

3.2.25

zirconium oxide (ZrO_2) sensor

A heated electrochemical cell that generates a millivolt output in response to the difference between the flue gas oxygen concentration and the reference oxygen concentration, typically ambient air or instrument air.

NOTE Using the Nernst equation, the magnitude of the millivolt output is inversely proportional to the logarithm of the ratio of the oxygen concentrations on the two sides of the sensor.

3.3 Abbreviations

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

3.3.1	BPCS	basic process control system
3.3.2	FEL	front end load
3.3.3	HMI	human machine interface
3.3.4	QCL	quantum cascade laser
3.3.5	RTD	resistance temperature detector
3.3.6	TDL	tunable diode laser
3.3.7	ZrO_2	zirconium oxide

4 Overview

4.1 For new fired heaters built in accordance with API 560, API 556-4 prescribes the measurement of both O_2 and CO/combustibles in the flue gas.

4.2 Depending on the selected technology, flue gas analyzers can measure oxygen, combustibles, carbon monoxide, hydrocarbons and/or methane.

4.3 Flue gas analyzers are part of the control system strategy to monitor combustion efficiency and to keep the fired heater within operational limits. Examples include:
1) O2 trim controller
2) CO / combustibles trim controller
3) Low O2 and high combustibles override to the fuel gas controller
4) Operator response to BPCS alarm

4.4 Where applicable, protective functions may utilize flue gas analyzers to take corrective action when the heater exceeds operational limits. Examples include:
1) Low O2 trip
2) High CO / combustibles trip

4.5 Important considerations when selecting a flue gas analyzer for a specific heater application include:
1) the capability to establish a representative sample
2) the rate of change in fuel gas composition versus the overall system response time for the selected technology (e.g., close-coupled extractive ZrO2 or laser-based measurement).

NOTE 1 Refer to API 556-2 for the application of flue gas analyzers to process control.

NOTE 2 Refer to API 556-3 for the application of flue gas analyzers to protective functions.

NOTE 3 Refer to API 560 for guidelines regarding connections for point-based or path-averaged measurement (e.g., the number, size, location and spacing of analyzer flange connections, distance above platform, etc.).

5 Work Process

5.1 Perform Fuel Gas Analysis

5.1.1 The purchaser shall specify the variability in the fuel gas supply pressure, temperature, and composition (e.g., P, T, and MW) and the associated change in air demand (i.e., represented as a percent change in flue gas oxygen) to resolve the application requirements to keep the heater within operational limits. The change in air demand may be specified using historical trend data or a calculated basis.

5.1.2 When evaluating the variability in the fuel gas supply, the amount of change and rate of change are equally important to resolve.

5.1.2.1 The amount of change (i.e., and the resulting change in air demand) informs the selection of fuel flow measurement (e.g., volume or mass), the selection of the %O_2 setpoint, and the potential addition of a fuel gas heating value analyzer (e.g., energy flow control). For additional clarification, see API 556-1 Annex X.X.

5.1.2.2 The rate of change informs the selection of the flue gas analyzer (e.g., close-coupled extractive ZrO_2 or laser-based measurement).

5.1.3 When the rate of change in fuel gas heating value yields an increase in air demand faster than 25% to 33% of the overall system response time, a flue gas analyzer with a faster response time (e.g., laser-based measurement) should be considered.

5.1.3.1 To maintain control stability criteria at design conditions, the time constant of the O_2 trim controller should be at least 3X to 4X faster than the rate of change in heat release at the burners.

5.1.3.2 When applying active CO control, laser-based analyzer technology with an analyzer system response time of less than 5 seconds is recommended. The overall system response time of this measurement should be at least 3X to 4X faster than the rate of change of CO concentration in the flue gas.

5.2 Select the Applied Technology

For fired heaters built in accordance with API 560, API 556-4 prescribes the measurement of both O_2 and CO/combustibles in the flue gas with either a point-based (i.e., close-coupled extractive or probe style laser) or path-averaged (i.e., laser-based technology) analyzer.

NOTE 1 In-situ ZrO_2 probes do not meet the response time requirements (see 6.2).

NOTE 2 Historically, as a net O_2 measurement, ZrO_2 sensors have been considered inherently safe since they malfunction low upon the presence of combustibles at the heated sensor (see Annex B.3). However, getting a representative sample with a single point measurement can be a challenge across a large cross-sectional area (see Annex B.5).

NOTE 3 With a path-averaged measurement, the capability to get a more representative sample across an open path is significantly improved. However, temperature compensating the measurement to achieve the desired accuracy can be a challenge across either the top of the radiant section or base of the convection section.

NOTE 4 When selecting either point-based or laser-based technology, there are unique challenges (e.g. pros and cons) to be resolved. If point-based measurement is preferred, multiple locations (i.e., mounting flanges and sensors) may be required for large heaters to meet the application requirements (see Annex B.4). If laser-based measurement is preferred, the mounting pad and flange will have vendor specific requirements to maintain acceptable nozzle alignment and reduce the effects of heater flexure. Additionally, when temperature compensating laser-based measurement with an external input, it is important to locate the temperature measurement in proximity (e.g., within 1 m / 3 ft) to the flue gas measurement to reduce the offset between actual flue gas temperature and reported flue gas temperature (i.e., due to radiated temperature loss near process tubes). For additional clarification, see 556-1 Annex X.X.

5.3 Select Analyzer Placement - Radiant Outlet versus Stack Inlet

5.3.1 Flue gas analyzer connection location and quantity shall be per API 560, Section 15.1.3.

5.3.2 Flue gas analyzer shall be direct mounted (i.e., not remote mounted).

5.3.3 Purchaser shall specify whether the analyzer(s) shall be located at the top of the radiant section, the base of the convection section, or the inlet of stack beneath the stack damper.

5.3.4 The following are considerations when choosing the location for the flue gas analyzers:

1) Radiant outlet / base of convection
    a) Pros
        i) Measures the O2/CO/Combustibles in the flue gas before entering the convection section. Combustibles entering the convection section, with sufficient quantity and temperature (e.g., above 610 ºC / 1130 oF for CO), can potentially result in afterburning within the convection section.
        ii) Removes the convection section as a source of tramp air that impacts the O2 indication. Tramp air can occur in any opening (tube penetrations, out of service burners, observation ports, header boxes, etc.).

- b) Cons
    - i) More challenging to obtain a representative O2/CO/Combustible indication due to the differences in heater geometry, burners in service and recirculation patterns within the radiant section.
    - ii) Requires extra attention to mounting to reduce the impact of heater flexure with a longer path length.
    - iii) More challenging to obtain a representative flue gas temperature indication due to interference from process tube radiated heat.

2) Inlet of the stack
    - a) Pros
        - i) Flue gas flow is more turbulent and better mixed when exiting the convection section over the operating range of the heater.
        - ii) Requires less attention to mounting to reduce the impact of stack flexure with shorter path length.
        - iii) Less challenging to obtain a representative flue gas temperature indication.
    - b) Cons
        - i) If afterburn occurs in the convection section, the CO / combustibles will report lower than what is present in the radiant section outlet.
        - ii) If not properly sealed, tramp air introduced in the convection section will a higher O2 indication than in the radiant section outlet.

5.4 FEL the Heater Design Process

In general, the content for flue gas analyzer equipment in API 560 and API 556 are in general alignment. However, all design requirements (e.g., the number and location of flanged mounting connections and the associated service platforms) may not be fully addressed for each flue gas analyzer application. With this consideration, the end user should select their preferred flue gas analyzer technology and address any specific mounting and service requirements as soon as possible in the heater design process (i.e., before the bidding process) to reduce or eliminate the potential for field changes after delivery.

6 Design Requirements

6.1 Measurement Requirements

6.1.1 Oxygen and combustibles shall be measured with either close-coupled extractive or laser-based technology that meets the response time requirements.

6.1.2 Purchaser shall specify if methane is to be measured.

6.1.3 For laser-based combustibles measurement, the purchaser shall specify which product(s) of incomplete combustion shall be measured (i.e., CO or H_2).

NOTE 1 During normal cycle of operation, RTD/catalytic bead detectors may be used to detect combustibles.

NOTE 2 During normal cycle of operation, laser-based analyzers may be used to detect CO when the hydrogen concentration in the fuel gas is <80%. If hydrogen concentration in the fuel gas is ≥ 80%, these analyzers may be used with approval from the analyzer vendor. While current laser-based technology cannot detect hydrogen in the flue gas at temperatures that exist in a fired heater, emerging technology may permit measuring hydrogen in the future. Hydrogen concentration < 80% assumes enough hydrocarbons are present in the fuel gas to generate and allow detection of CO as a product of incomplete combustion.

6.2 Analyzer System Response Time Requirements

6.2.1 For laser-based analyzers, the analyzer system response to a flue gas composition step change shall be:

- Less than 5 seconds for O_2
- Less than 5 seconds for CO or H_2
- Less than 5 seconds for CH_4

6.2.2 For close-coupled extractive analyzers with integral flame arrestors, the analyzer system response to a flue gas composition step change at commissioning (i.e., not calibration gas introduced at the sensor behind diffusers or flame arrestors) shall be:

- Less than 15 seconds to T90 for O2

- Less than 25 seconds to T90 for combustibles
- Less than 25 seconds to T90 for CH4

NOTE 1 While the analyzer system response time may benchmark T90 published values, the control systems engineer will typically use the first order time constant (e.g., T63) for control loop tuning purposes.

NOTE 2 In-situ ZrO_2 sensors with flame arrestors, which are specified in this standard, do not meet the response time requirements.

NOTE 3 Close-coupled extractive analyzer system response times are based upon vendor specified sample flow with a newly commissioned clean system (e.g., clean sample tubing, sample filters, and flame arrestors).

NOTE 4 If the close-coupled extractive analyzer system response time degrades to twice that of a newly commissioned clean system, corrective action should be taken. Response time degradation may be detected using a low flow alarm or time verification testing as noted in Annex B.1.

6.3 Overall System Response Time Considerations

6.3.1 Pending the results of fuel gas analysis (section 5.1), the resulting change in air demand due to a step change in heat release at the burners (i.e., fuel gas composition or firing rate) will inform the selection of the flue gas analyzer (e.g., close-coupled extractive ZrO_2 or laser-based measurement).

6.3.1.1 Referencing Table 1, note the following observations for a sample heater operating at design absorbed duty:

- a rate of change in RFG composition of 180 seconds would allow selection of either a close-coupled-extractive or laser-based flue gas analyzer.
- a rate of change in RFG of 60 seconds would infer selection of a laser-based flue gas analyzer.

6.3.1.1.1 Before the installation of flare gas recovery systems, the rate of change in RFG composition being introduced at the burner (i.e., first order time constant T63) for most refineries was typically ≥ 180 seconds. This inferred that an O2 trim controller with close-coupled extractive technology (i.e., with a representative sample) was suitable for most heater applications operating at design absorbed duty. However, hydrogen PSA units (i.e., during startup and shutdown) or flare gas recovery units (i.e., during flaring events) can yield a rate of change in RFG composition ≤ 180 seconds. On this basis, each site should confirm their unique rate of change in RFG composition before selecting the applied technology.

6.3.1.1.2 In the rare case that the rate of change in RFG composition is < 60 seconds, the O_2 trim controller will be challenged to maintain control loop stability criteria with laser-based technology. In this scenario, the end user should evaluate the capability to increase the combined residence time in the fuel gas system (e.g., mixing drum, knockout drum, coalescing filter, etc.) upstream of the heater with the design objective to decrease the rate of change in fuel gas heating value being introduced at the burner. Reference API 560.

HEATER OPERATING AT DESIGN ABSORBED DUTY					
LASER-BASED ANALYZER (NO SAMPLE SYSTEM)					
Sensor Type	Analyzer System Response (sec)	Radiant Section Time Constant (sec)	Overall System Response Time (sec)	Control Loop Stability Multiplier (e.g. 3X to 4X)	Rate of Change RFG Composition (sec)
TDL	5	15	20	3	≥ 60
CLOSE-COUPLED EXTRACTIVE ANALYZER WITH CLEAN SYSTEM (e.g., clean sample tubing, sample filters, and flame arrestors)					
Sensor Type	Analyzer System T90 Response (sec)	Radiant Section Time Constant (sec)	Overall System Response Time (sec)	Control Loop Stability Multiplier (e.g. 3X to 4X)	Rate of Change RFG Composition (sec)
ZrO2	15	15	30	3	≥ 90
COMB	25	15	40	3	≥ 120
CLOSE-COUPLED EXTRACTIVE ANALYZER WITH FOULED SYSTEM (E.G., ADD 15 SEC) (e.g., fouled sample tubing, sample filters, or flame arrestors)					
Sensor Type	Analyzer System T90 Response (sec)	Radiant Section Time Constant (sec)	Overall System Response Time (sec)	Control Loop Stability Multiplier (e.g. 3X to 4X)	Rate of Change RFG Composition (sec)
ZrO2	30	15	45	3	≥ 135
COMB	40	15	55	3	≥ 165

Table 1 – Analyzer Information with Heater at Design Duty

6.3.1.2 Referencing Table 2, note the following observations for a sample heater operating at turndown absorbed duty:

- a rate of change in RFG composition of 300 seconds (5 minutes) would allow selection of either a close-coupled-extractive or laser-based flue gas analyzer.
- a rate of change in RFG of 210 seconds (3.5 minutes) would infer selection of a laser-based flue gas analyzer.

HEATER OPERATING AT TURNDOWN ABSORBED DUTY					
LASER-BASED ANALYZER (NO SAMPLE SYSTEM)					
Sensor Type	Analyzer System Response (sec)	Radiant Section Time Constant (sec)	Overall System Response Time (sec)	Control Loop Stability Multiplier (e.g. 3X to 4X)	Rate of Change RFG Composition (sec)
TDL	5	60	65	3	≥ 195
CLOSE-COUPLED EXTRACTIVE ANALYZER WITH CLEAN SYSTEM					
Sensor Type	Analyzer System T90 Response (sec)	Radiant Section Time Constant (sec)	Overall System Response Time (sec)	Control Loop Stability Multiplier (e.g. 3X to 4X)	Rate of Change RFG Composition (sec)
ZrO2	15	60	75	3	≥ 225
COMB	25	60	85	3	≥ 255
CLOSE-COUPLED EXTRACTIVE ANALYZER WITH FOULED SYSTEM (E.G., ADD 15 SEC) (e.g., fouled sample tubing, sample filters, or flame arrestors)					
Sensor Type	Analyzer System T90 Response (sec)	Radiant Section Time Constant (sec)	Overall System Response Time (sec)	Control Loop Stability Multiplier (e.g. 3X to 4X)	Rate of Change RFG Composition (sec)
ZrO2	30	60	90	3	≥ 270
COMB	40	60	100	3	≥ 300

Table 2 – Analyzer Information with Heater at Turndown Duty

7 Installation Requirements

7.1 Path-averaged measurement (Laser-Based) – O2 or CO

Laser based measurements operate in the near-IR (TDL) or mid-IR (QCL) region of the electromagnetic spectrum.

NOTE See Annex D for technology specifics.

7.1.1 Mounting Requirements

7.1.1.1 Per API 560, each pair of connections for an in-situ pathlength averaged analyzer shall be opposed, aligned, and concentric. Consult with the analyzer vendor for specific requirements (e.g., mounting pads, gussets, etc.).

NOTE Laser misalignment can lead to signal degradation and ultimately analyzer malfunction.

7.1.1.2 To reduce the potential for heater flexure to misalign the laser across the open path, the analyzer shall have an alignment adjustment mechanism that may be used with the fired heater in operation. This adjustment can be performed manually or automatically.

7.1.2 Nozzle Purge Requirements

7.1.2.1 The nozzle shall be purged with nitrogen or instrument grade air. Analyzer vendor shall specify the purge utility gas and volumetric flow rate to be used for window/nozzle and optics purging.

7.1.2.2 Nitrogen is preferred as a purge gas. If instrument air is used in lieu of nitrogen, data from the manufacturer shall be obtained quantifying the impact on the oxygen measurement.

7.1.3 Temperature Compensation

The measurement shall be temperature compensated. A temperature measurement that is representative of flue gas temperature at the analyzer's optical measurement path shall be connected to the analyzer. Refer to API 556-1 and API 560, Section X.X for specifics.

NOTE 1 When the reported flue gas temperature measurement is lower or higher than actual, both the laser-based O_2 measurement and the laser-based CO measurement are impacted. The offset in O_2 and CO indications is proportional to the offset in temperature indication. Approximate offsets are shown below:

	Actual	Reported	Delta
Flue Gas Temperature, °F	1600	1500	-100
%O_2	3	2.55	-0.45
CO, ppm, volume, wet basis	1000	850	-150

	Actual	Reported	Delta
Flue Gas Temperature, °F	1600	1700	+100
%O_2	3	3.45	+0.45
CO, ppm, volume, wet basis	1000	1150	+150

7.2 Point Based Measurement

7.2.1 Zirconium Oxide – Oxygen

7.2.1.1 Reference Air

7.2.1.1.1 The reference gas shall be ambient air or instrument air.

7.2.1.1.2 When instrument air is used as a reference gas for critical control or safety applications, nitrogen shall not be used to back up the instrument air supply.

NOTE Nitrogen backup would cause the analyzer indication to be in error high.

7.2.1.2 Power to Heated Sensors

The ZrO_2 sensor shall be electrically heated independent of the flue gas to facilitate accurate reporting during start-up and normal operation.

NOTE 1 An unheated ZrO_2 sensor technology will not allow the sensor to be at proper operating temperature (e.g., above 500-550°C / 930-1020ºF) until well after start-up rendering the analyzer's signal unreliable during this critical time. In contrast, an independent heat source allows sensor operation without depending on the flue gas as a heating mechanism.

NOTE 2 A cold ZrO_2 sensor at ambient conditions may have an extended warm-up period (e.g., 4 to 6 hours) for the sensor to stabilize and provide results to published accuracy. Refer to the vendor's operation manual for warm-up and stabilization times.

7.2.1.3 Integral Flame Arrestors

The close-coupled extractive analyzer shall have integral flame arrestors to prevent a propagation of flame to the firebox.

NOTE 1 The ZrO_2 sensor is heated above the auto-ignition temperature of the flue gas.

NOTE 2 With a low oxygen and high combustibles override to the fuel gas controller, the flame arrestor within the flue gas analyzer should not be in continuous exposure to a fuel rich environment. This significantly reduces the potential for flame arrestor failure due to burn through.

7.2.2 RTD/Catalytic Bead – Combustibles and Methane

7.2.2.1 RTD and catalytic bead technologies require the presence of oxygen in the flue gas for combustibles detection. In the absence of oxygen in the flue gas, the analyzer shall either fail safe or be provided with an alternative source of air to support the combustibles measurement.

NOTE 1 Some sensors may report lower than actual combustible values at low oxygen concentrations. As the measured oxygen concentration approaches 0%, some analyzers will automatically (via software) drive the combustibles measurement to full scale. Other analyzers supply the combustibles sensor with independently sourced “auxiliary, supplemental, or dilution” air to permit combustibles measurement through the low oxygen condition.

NOTE 2 A cold combustibles or methane sensor at ambient conditions may have an extended warm-up period (4 to 6 hours) for the sensor to stabilize and provide results to published accuracy. Refer to the vendor’s operation manual for warm-up and stabilization times.

7.2.2.2 When methane measurement is specified, a separate detector shall be supplied.

NOTE The methane measurement may be used to detect unburned fuel gas in the heater as part of the pre-ignition purge interlock.

7.2.3 Laser-based probe – O_2, CO, and/or CH_4

Nozzle purge requirements and temperature compensation apply to the probe-based laser. Refer to 7.1.2 and 7.1.3 for specifics.

NOTE The methane measurement may be used to detect unburned fuel gas in the heater as part of the pre-ignition purge interlock. With a lower limit of detection, methane may be used to detect a partial loss of flame introducing a hazard.

8 Regulations

The purchaser and the vendor shall mutually determine the measurements required to comply with all local and national regulations applicable to the equipment.

9 Proposals

9.1 Purchaser’s Responsibilities

9.1.1 The purchaser’s inquiry shall include data sheets (including the API 556 analyzer data sheet in Annex A – still in development), checklists, and other applicable information outlined in this standard. This information shall include any special requirements or exceptions to this standard.

9.1.2 The purchaser should complete, as a minimum, those items on the datasheet that are designated by an asterisk (*). Refer to Annex A.

9.1.3 The fired heater’s API 560 data sheet normally lists combustion design conditions for normal mode of operation, at start-of-run, end-of-run and process design cases. In addition, consideration should be given to providing combustion design conditions for one or more of the following cases:

1) Startup mode of operation, including:

    a) burner lighting state of operation
    b) ramp-up state of operation.
2) Normal mode of operation / turndown state of operation.
3) Maintenance mode of operation / coke removal.
4) Potential upset conditions.

9.1.4 The purchaser's inquiry shall state clearly the supplier's scope of supply.

9.1.5 Performance and guarantee requirements shall be communicated through the equipment datasheets and documentation requirements as defined in the inquiry documents. Specific guarantee requirements for all guaranteed criteria shall be clearly noted in the purchase order.

9.2 Supplier's Responsibilities

The supplier's proposal shall include:

1) Completed data sheets for each analyzer and the associated equipment (see examples in Annex A).
2) Description of the full scope of supply and work.
3) An outline drawing showing the dimensions of the analyzer and any associated equipment as may be applicable.
4) Wiring diagrams. The wiring diagram shall include the signal types (4-20 mA current source, Ethernet data stream, fiber optic, etc.), and shall clearly indicate the terminations required.
5) Detailed description of any exceptions to the specified requirement.
6) A time schedule for submission of all required drawings, data, and documents.
7) A program for scheduling the work after receipt of an order.

    NOTE The program schedule should include a specified period of time for the purchaser to review and return drawings, procurement of materials, manufacture, and the required date of supply.

8) A list of utilities and quantities required.
9) Equipment warrantees and process performance guarantees.

9.2.1 Documents and Drawings for Purchaser's Review

The supplier shall submit the following documents and drawings for review and approval prior to fabrication:

1) Documentation list.
2) Confirmation of performance requirements listed on application data sheet.
3) Analyzer weights and dimensions.
4) Installation manual and details (e.g., mounting pads and bracing, where applicable).

    NOTE For laser-based analyzers, the basis of design is to ensure optical alignment and stability across all operating temperature ranges of the heater.

5) Analyzer power and signal wiring details.
6) Auxiliary equipment details (e.g., calibration and purge panels, where applicable).
7) A list of utilities required with expected consumption and nominal pressure rating. This may include but is not limited to: calibration/validation gas, instrument air, nitrogen, steam, water, electric power (voltage, current, phase requirements).
8) Operating and maintenance manual.
9) Ongoing inspection, testing and maintenance instructions to meet availability requirements listed on application data sheet.
10) Inspection and test plan (ITP) covering all phases of supply.

9.2.2 Drawings and Diagrams

Following receipt of the purchaser's comments and confirmation to proceed on the general arrangement drawing and other documentation submitted for approval, the supplier shall provide the following:

1) General arrangement drawing.
2) Detailed wiring and interconnection drawings.

9.2.3 Final Records

Within a specified time after completion of shop fabrication or shipment, the supplier shall furnish the purchaser with the following documents:

1) Data sheets and drawings for each analyzer and all equipment in the scope of work, representing the as-manufactured equipment. In the event field-changes are made, as-built drawings and data sheets shall not be provided unless specifically requested by the purchaser.
2) Installation, operation, and maintenance instructions for the analyzer and auxiliary equipment.
3) Bill of materials.
4) All other test documents, including test reports and nondestructive examination reports.
5) Factory acceptance test results, if applicable.
6) Equipment shop-test results.
7) Field commissioning reports.

10 Inspection, Examination, and Testing

10.1 General

10.1.1 Performance tests shall be performed when specified by the purchaser.

10.1.2 The test protocol shall be mutually agreed to by supplier and purchaser.

10.1.3 The purchaser reserves the right to inspect, after prior notice, all analyzer 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.

10.1.4 The vendor shall examine all individual analyzer components and their shop-assembled units to ensure that materials and workmanship are in accordance with applicable standards, specifications, codes, and drawings.
If specified by the purchaser, pre-inspection meetings between the purchaser and the equipment manufacturer shall be held before the start of fabrication.

10.2 Positive Materials Identification (PMI)

10.2.1 The purchaser shall specify the components that are subject to PMI (e.g., sample probes).

10.2.2 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.

ANNEX A
(informative)

Equipment Datasheets – included for reference only, still under development

A.1 General

This annex includes datasheets for the following equipment items:

a) Flue gas analyzers

ANNEX B

(informative)

B.1 Evaluating the Analyzer System Response Time

Response time procedure with point-based ZrO_2 analyzer installed on heater:

- Note the flue gas analyzer readings before starting test.
- Open the calibration gas valve to apply instrument air or a known calibration gas.
- Close the calibration gas valve and sample the flue gas. Note the time to reach 90% of the difference between starting concentration and previously noted flue gas concentration.
    - Example: If flue gas is 3% O_2 and the starting concentration is 20.9% O_2, a reading of 4.79% should be achieved within 15 seconds to meet the specification (the delta is 17.9%, 90% of which is 16.11%...20.9-16.11 = 4.79%).

B.2 Flame Arrestors

Flame arrestors perform the mechanical function of reducing the propagation of a deflagration. Their design is prone to two potential sources of failures: plugging and corrosion. A plugged or partially restricted flame arrestor would be a failure in the safe direction with regards to the flame arrestor functionality; however, this would negatively impact the analyzer function creating an unsafe condition as the analysis results would be incorrect or delayed. A flame arrestor with corroded or missing internals may no longer function as designed resulting in a dangerous failure mode. Precautions for corrosive environments may require the use of alloys, including Inconel or Hastelloy C, for flame arrestor construction. The most problematic environment is during shutdown which could accumulate liquid which causes corrosion of the flame arrestors and all other parts.

The integrity of the flame arrestors should be verified at a prescribed inspection interval to monitor and detect plugging and/or corrosion. This verification could be performed through a visual inspection or functional test, including verification of inline flow sensor or DP flow measurements. The inspection and testing interval varies based on the consistency and corrosivity of the process and compatibility of the materials of the device.

B.3 ZrO_2 Sensors Ratio of Consumption

ZrO_2 sensors are “net oxygen” analyzers which are heated (i.e., typically 550-800°C / 1020-1470ºF) and utilize a platinum electrode with catalytic properties and will burn any combustible compounds with oxidation potential such as CO, hydrogen, and high concentrations of sulfur dioxide, etc. The analyzer will indicate the resulting oxygen after the combustion is complete which is typically a slightly lower value than the gross oxygen concentration.

During combustibles breakthrough, H_2 and CO are typically the largest combustible components. The ratio of consumption for H_2 and CO to O_2 at a heated ZrO_2 sensor is approximately 2:1. As an example, a sample with 2000 ppm (0.2 %) H_2 and CO has the potential to consume 0.1 % O_2 at the sensor. Likewise, a sample with 10,000 ppm (1.0 %) H_2 and CO has the potential to consume 0.5 % O_2 at the sensor. Therefore, at low oxygen levels, it is possible for high concentrations of H_2 and CO to mask (malfunction low) the true oxygen concentration at the sensor.

Upon complete loss of flame, methane may be the largest component. The ratio of consumption of methane to oxygen at a heated ZrO_2 sensor is approximately 1:2. As an example, a sample with 1 % methane has the potential to consume 2 % oxygen at the sensor. Likewise, a sample with 5 % methane has the potential to consume 10 % oxygen at the sensor. Therefore, in a fuel rich environment, it is possible for a high concentration of methane to mask (malfunction low) the true oxygen concentration at the sensor.

NOTE A ZrO_2 oxygen sensor uses the difference in partial pressure between a sample and reference gas, typically air. Oxygen concentration and the sensor’s signal (typically in mV) output are inversely proportional and dependent on the oxygen sensor’s temperature. For example, when the sample gas is ambient air (20.9% O_2), the output from the sensor will be 0 mV. The relationship between oxygen concentration and sensor mV output is logarithmic as the oxygen concentration decreases, as governed by the Nernst Equation.

As the oxygen concentration in the sample gas decreases, the mV output signal from the sensor increases.
Close coupling to the flue gas analyzer connection, as opposed to mounting it remotely, will reduce long-term maintenance requirements and potential failure points in the system.

B.4 Point-based Sample Location Quantity in Large Fireboxes

For large combustion zones one analyzer for every 10 m (30 ft) of firebox length is recommended due to non-uniformities in the firebox flue gas circulation and to facilitate balancing the burners. Oxygen measurements should be taken as near as possible to the point where combustion is completed, normally at the exit of the radiant section and before the transition to the convection section to avoid tramp air. To minimize the impact of air ingress, stack measurements for oxygen concentrations should be avoided where possible. If a stack sample is utilized, a portable oxygen analyzer should be used to prove heater integrity (no air leaks) by directly correlating the stack measurement with the oxygen concentration leaving the radiant section. Stack measurement for control is only an option if the heater is properly sealed.

Note that percent oxygen measurement is a process control variable which may be used for improving heater efficiency and maintaining safe heater operation. Percent excess combustion air should not be confused with percent oxygen measurement.

B.5 Close-Coupled Extractive Analyzer - Sample Probe Length

The location of the sampling point within the flue gas stream is important in obtaining a representative sample. For analyzers located at the bridgewall, sample probes may penetrate into the furnace 600 mm (24 in.) or more from the inside wall. Customized probe lengths are available to ensure the sample taken is representative of the majority of the flue gas flowing out of the radiant section. With longer probes, the vendor may offer additional probe support. As a general rule, the probe tip should be in the middle 1/3 of the duct, stack, or sampling area.

Bibliography

API Recommended Practice 555, *Process Analyzers*

API Standard 556-1 *Instrumentation, Control, and Protective Systems for Gas Fired Heaters - Part 1: Instrumentation*

API Standard 556-2 *Instrumentation, Control, and Protective Systems for Gas Fired Heaters - Part 2: Control*

API Standard 556-3 *Instrumentation, Control, and Protective Systems for Gas Fired Heaters - Part 3: Protective Functions*