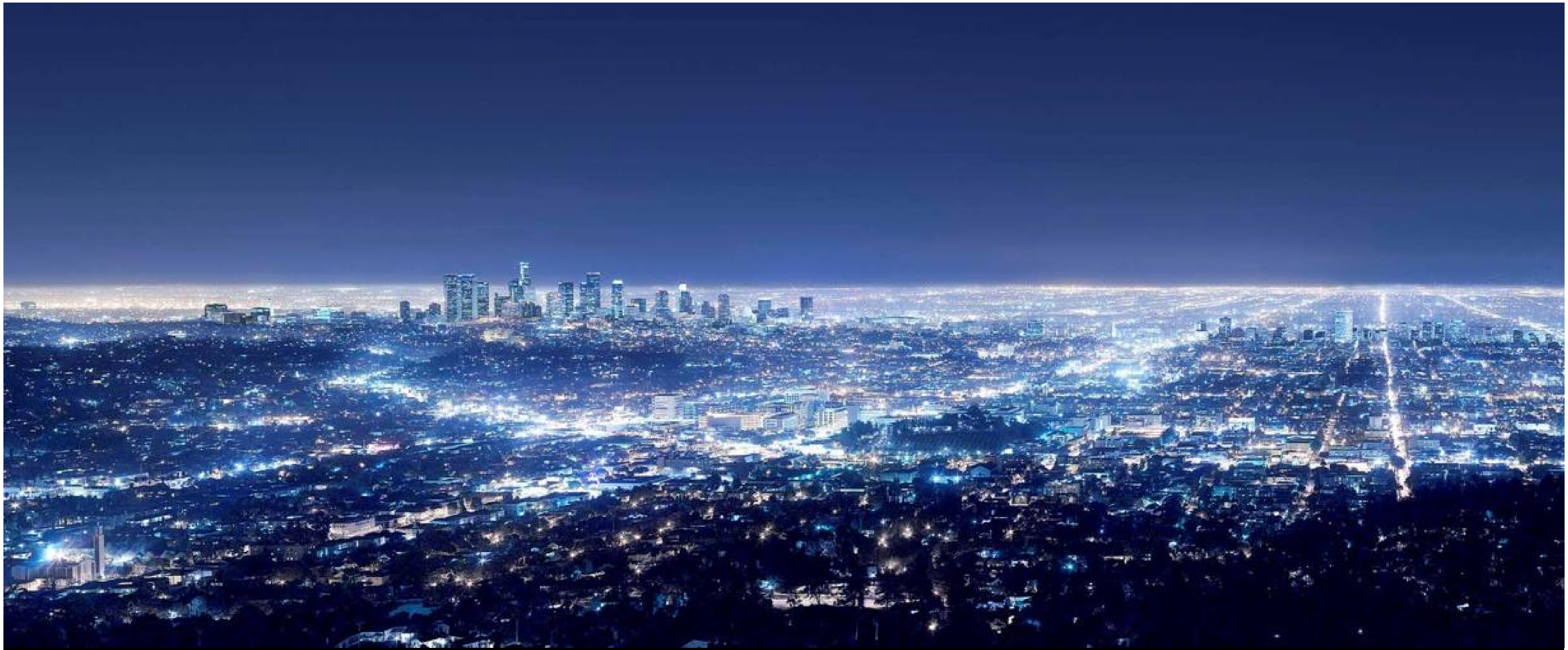

ABB Inc., Measurement Products, June 2014

Refinery Flare Gas Analysis
Subpart Ja Made Easy

Subpart Ja for Refinery Flares
Flare vs. Fuel Combustion Device

- A flare is a specific unit or facility, not a specific type of fuel gas combustion device
  - Foundation, flare tip, structural support, burner, igniter, flare controls, including air injection or steam injection systems, flame arrestors and the flare gas header system
- The flare on an interconnected flare gas header system unit includes:
  - Each combustion device
  - All interconnected flare gas header systems

Subpart Ja for Flares
EPA Standards for Subpart Ja

1. The flare minimization work practice standard requires each flare that is subject to Subpart Ja to prepare a Flare Management Plan (FMP)
2. Capture when waste gas sent to flare exceeds a flow rate of 500,000 scf in a 24 hour period
   - *Requires a root cause analysis*
3. Capture when the emissions from the flare exceed 500 lb of SO_2 in a 24 hour period
   - *Requires a root cause analyses and corrective action*
4. Mange the SO_2 exposure from fuel gas by limiting the short term concentration of H_2S to 162 ppmv during normal operating conditions
   - Monitored by a 3 hour rolling average

✓ All root cause analyses and corrective actions must be complete less than 45 days after either event above

Subpart Ja for Flares
Flare Management Plan

- The FMP requires the following items:
  1. A listing of all refinery process units and fuel gas systems connected to each affected flare
  2. Assessment of whether discharges to affected flares can be minimized
  3. A description of each affected flare
  4. Evaluation of the baseline flow to the flare
  5. Procedures to minimize or eliminate discharges to the flare during planned startups and shutdowns
  6. Procedures to reduce flaring in cases of fuel gas imbalance (i.e., excess fuel gas for the refinery's energy needs)
  7. If equipped with flare gas recovery systems, procedures to
     a) Minimize the frequency and duration of outages of the flare gas recovery system
     b) Minimize the volume of gas flared during such outages

Subpart Ja for Flares
Flares Requiring Monitoring

- Any new construction after June 24, 2008
- Any reconstructed flare after June 24, 2008
- Any modification to existing flares after June 24, 2008:
  1. New piping from a refinery process unit physically connected to the flare
     - Includes ancillary equipment
     - Includes fuel gas system
  2. The flare is physically altered to increase the flow capacity of the flare

- These changes to a flare system (note: that a flare is now defined to include the piping and header system) will cause the flare to become subject to the Subpart Ja regulations
- EPA does grant a 1-year delay of the affected date for flares if they become modified

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Subpart Ja for Flares
Flares Exempt to Online Monitoring

- Flares that receive only inherently low sulfur fuel gas streams
  - Flares used for pressure relief of propane or butane product spheres
  - Fuel gas streams meeting commercial grade product specifications for sulfur content of 30 ppmv or less
- Flares burning natural gas only low in sulfur content
  - Fuel gas is monitored elsewhere – no H2S monitor needed
- Gases exempt from H2S monitoring due to low sulfur content are also exempt from sulfur monitoring requirements for flares
- Emergency flares
- Flares equipped with flare gas recovery systems designed, sized and operated to capture all flows, except those from startup and shut down

Subpart Ja for Flares
Important Dates

Summary of Key NSPS Subpart Ja Deadlines					
Flare Applicability Dates	*Any flare built or reconstructed after June 24,2008 is NEW* *Any flare modified after June 24, 2008 is MODIFIED*				
Rule Promulgation Date	*September 12, 2012*				
Rule Effective Date	*November 13, 2012*				
Subpart Ja Specific Deadlines (Modified flares are subject to a phased implementation schedule; new flares are not)					
		Modified or Constructed AFTER June 24, 2008 and BEFORE rule promulgation (September 12, 2012)		**Modified or Constructed AFTER rule promulgation (September 12, 2012)**	
Deadlines	**Citation**	**Modified flare**	**New flare**	**Modified flare**	**New flare**
Flare Management Plan	60.103a (b)(1)	November 11, 2015	November 13, 2012	Startup or November 11, 2015 (whichever is later)	Upon Startup
Root Cause Analysis program	60.108a (c)(6)(x)	November 11, 2015	November 13, 2012	Startup or November 11, 2015 (whichever is later)	Upon Startup
Flow and TRS/H_2S Monitoring	60.107a(e) 60.107a(f)	November 11, 2015 – if not in place	November 13, 2012	Startup or November 11, 2015 (whichever is later)	Upon Startup
162 ppmv H_2S limit in flare gas (relief valve leakage and emergencies are exempt)	60.103a(f) 60.103a(h) 60.107a(2)(vi)(A)	-IF Not subject to Subpart J prior to Ja: November 11, 2015 -IF Subject to Subpart J prior to Ja: November 13, 2012 -IF Subject to Subpart J prior to Ja, but AMP was granted under Subpart J: November 11, 2015 -IF Subpart J applicability accepted under a Consent Decree: November 11, 2015	November 13, 2012	IF Not subject to subpart J prior to Ja: Startup or November 11, 2015 (whichever is later) IF Subject to subpart J prior to Ja: Startup or November 13, 2012 (whichever is later) IF Subject to Subpart J prior to Ja but currently under CD: November 11, 2015	Upon Startup

Subpart Ja for Flares
Environmental Flare Measurement Requirements

Total Sulfur Measurements

- Determine the Sulfur Dioxide (SO_2) emissions from the flare
  - Measurement ranges of 1.1 to 1.3 times the maximum anticipated sulfur concentration
  - No less than 5,000 ppmv

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Total Sulfur Measurement

It is the intent of the EPA to require a method that best correlates with the potential SO2 emissions from a flaring event

EPA – New Source Performance Standards (NSPS)
Total Sulfur – Subpart Ja

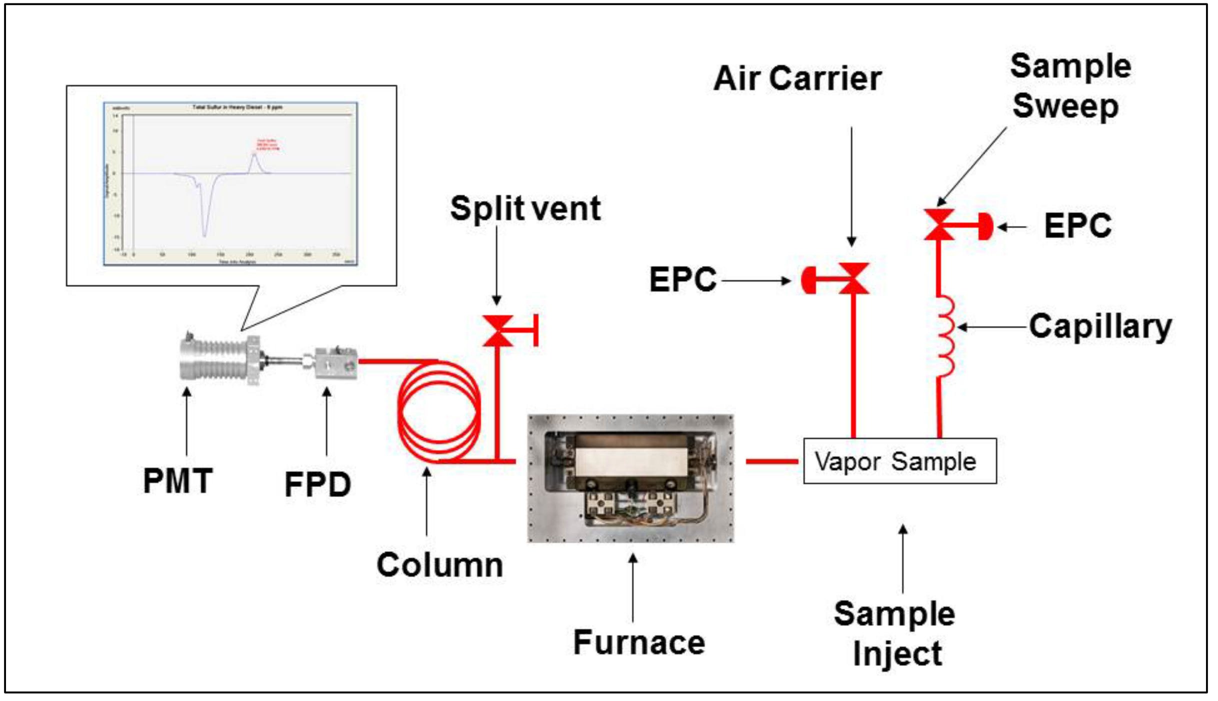
- Total sulfur measurement in flare gas
  - PGC5007B – Total Sulfur Analyzer

- Analytical Method
  - Sample Injection → Oxidation → Separation → Measurement
  - The PGC5007B measures the ***Total Sulfur*** content as SO2 after hydrocarbon conversion

$$\text{R-S} + \text{R-H} + \text{Air}(O_2) \xrightarrow[900\,^{\circ}\text{C}]{} SO_2 + CO_2 + H_2O$$

Total Sulfur Analyzer
Application Design

- Easy to understand, straightforward design
  - The analytical method is sample injection, component separation, and sulfur detection

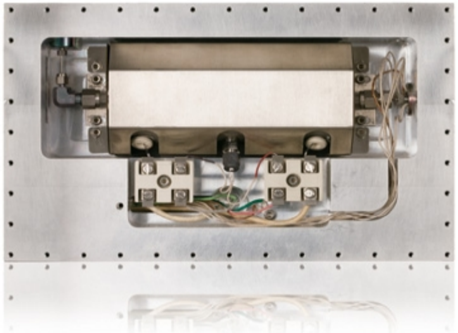


Sample Injection
Low cost of ownership, High performance valve

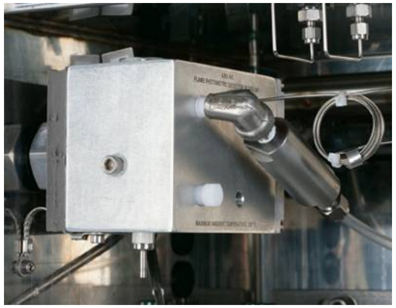
- Vapor Injection
  - Sulfinert treated stainless steel
    - Made for chemical inertness
  - Surface finishes polished to 2 rms
    - Excellent sealing properties
    - Low mechanical wear
  - Maintenance friendly design
    - Lowest MTTR of all analytical valves
    - Lowest air actuation pressure requirements (40 psig)

Oxidation Furnace
Low cost of ownership, High performance furnace

- Oxidation Furnace
  - Made from high performance, low moisture quartz
  - Mechanically grounded for support while at operating temperatures
- Lower Temperature Control
  - 900 °C for complete hydrocarbon conversion and long life-expectancy of the quartz tube
- Reliability
  - Easy to access and maintain furnace assembly



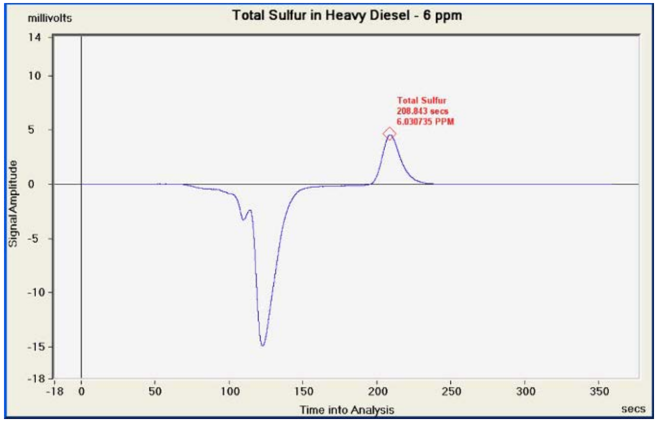
FPD Detector Hardware
High performance, Enhanced functionality



- Flame Photometric Detector (FPD)
  - Small, compact design
    - Enhances sensitivity for ppm and ppb sulfur measurements
- PhotoMultiplier Tube (PMT)
  - Thermo electrically cooled long life expectancy
- Linearization and sensitivity features
  - Enhanced linearity calculations designed into detector DSP
  - Sulfur addition module to enhance sulfur sensitivity and linearity

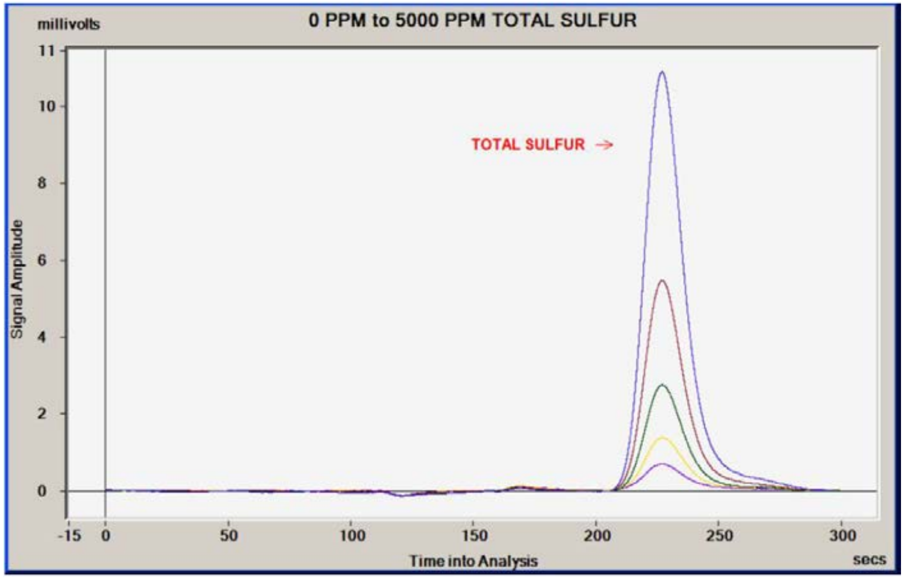
Analysis Results
Superior chromatography, Higher performance

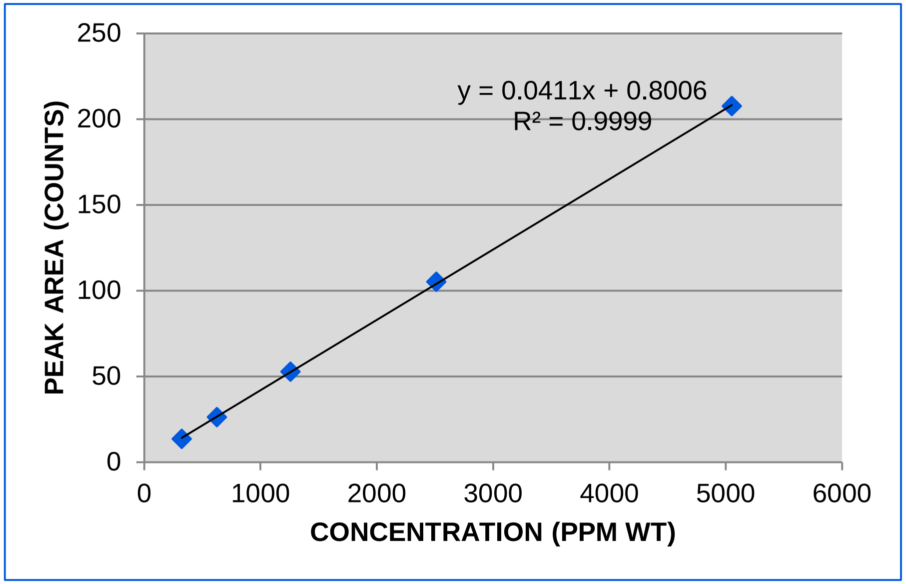
- Complete, baseline separation
  - Eliminates any possibility of stream matrix interferences
  - Guarantees an interference free measurement, unlike common spectroscopy methods
- Excellent peak shape
  - Highly robust column designed specifically for SO_2 separation and detection



Measurement Range and Linearity Plot
0 ppm – 5000 ppm

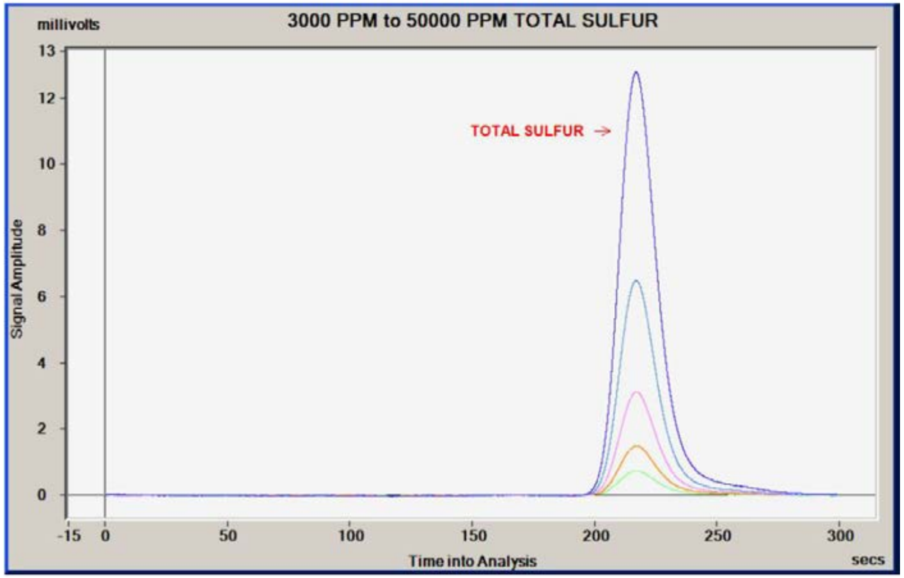
- Excellent detector response and measurement linearity
  - R2 = 0.9999
  - Repeatability = +/- 0.5% of the full scale measurement

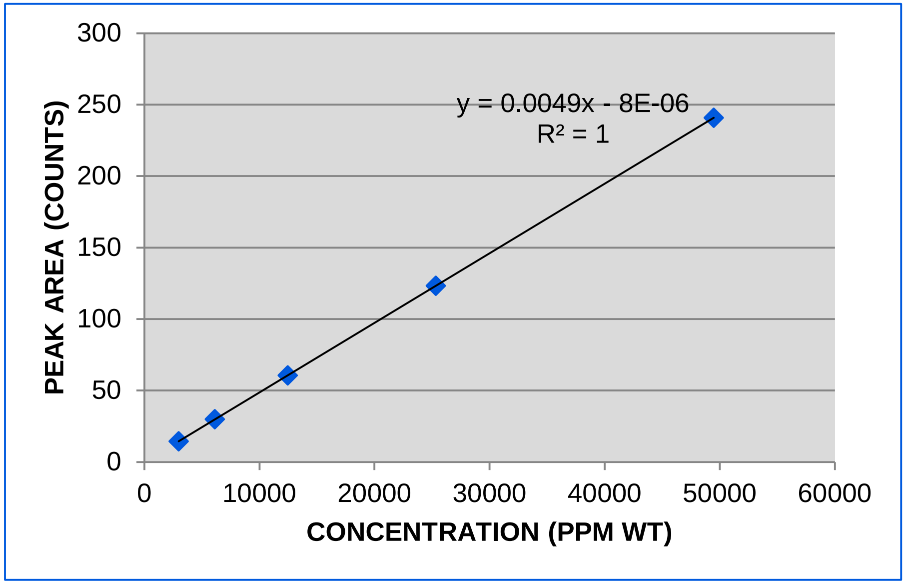




Measurement Range and Linearity Plot
5000 ppm – 50%

- Excellent detector response and measurement linearity
  - $R2 = 1$
  - Repeatability = +/- 0.5% of the full scale measurement





Subpart Ja for Flares
Environmental Flare Measurement Requirements

Total Sulfur Measurements

- Determine the Sulfur Dioxide (SO_2) emissions from the flare
  - Measurement ranges of 1.1 to 1.3 times the maximum anticipated sulfur concentration
  - No less than 5,000 ppmv

Hydrogen Sulfide (H_2S) Measurements

- Determine the Hydrogen Sulfide (H_2S) in the fuel gas to the flare
  - Short-term limit of 162 ppmv as a feed to the flares
  - Span value for this measurement is 300 ppmv H_2S

H2S in Fuel Gas Analyzer System

It is the intent of the EPA to limit short term H2S to 162 ppmv, rolling 3 hour average, in the flare fuel gas during normal operating conditions

EPA – New Source Performance Standards (NSPS)
H2S in Fuel Gas – Subpart J and Ja

- **Option 1:**
- PGC5000B **or** PGC5000C (with BTU)
- Analytical Method
  - Direct measurement of H2S in fuel gas using a FPD
  - PGC5000C also includes BTU measurement

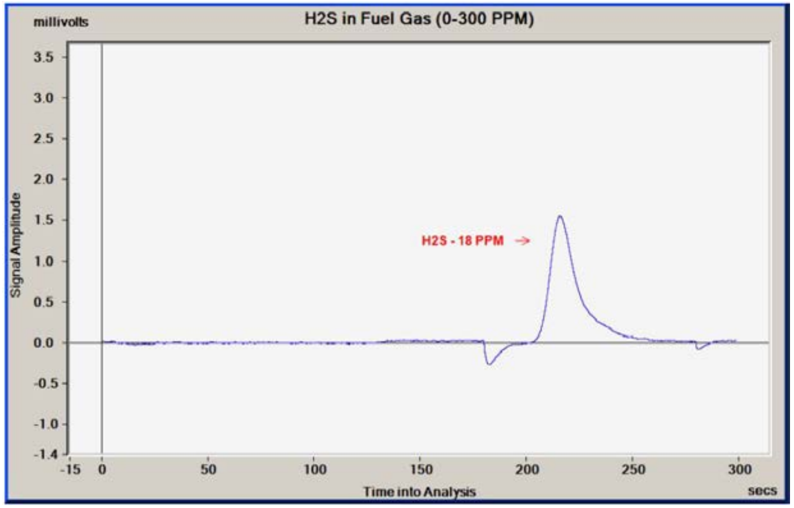
- **Option 2:**
- PGC5007 Total Sulfur Analyzer
- Analytical Method
  - Multistream with the Total Sulfur Analyzer System
  - *The H2S concentration will always be less than the total reduced sulfur concentration therefore this analytical method can be used*

H2S Measurement
Option 1 – PGC5000B or PGC5000C (with BTU)

- Benefits:
  - Fuel gas stream isolation from flare gas
  - No potential of cross contamination when flare gas exceeds 300 ppm
  - Utilizes separate and simultaneous daily validation and CGA audit analyses
    - Less downtime
    - Lower cost of ownership
  - Parallel method of analysis to the Total Sulfur application
  - Can be designed to include a BTU analysis using the PGC5000C analyzer

Analysis Results
Superior chromatography, High performance

- H_2S Application
  - Separation and the detector selection eliminates all potential hydrocarbon interferences
  - Repeatability = +/- 0.5% of the full scale measurement



H2S (with BTU) Application Alternative
Option 1 – PGC5000C

- H2S application included with a multiport TCD measuring the BTU value
  - Dual detector analyzer utilizing parallel chromatography to measure the H2S and BTU content of the fuel gas within the same analyzer system
- PGC5000C Benefits
  - There is no need for a separate BTU analyzer system since this measurement can be included with the H2S value

H2S Measurement
Option 2 – PGC5007B

- Benefits:
  - Measurement can be made using the Total Sulfur Analyzer System designed for the flare gas stream
  - Both sulfur measurements can be made on a single analyzer
    - Lower cost of ownership
  - *Due to the broad range of measurement, the Total Sulfur Analyzer can be used to assess compliance with the short-term 162 ppmv H2S concentration in the fuel gas*

H2S Application Design
Option 2 – PGC5007B

- Multistream analyzer
- Broad range of sulfur measurement
- Short analysis cycle time = 4-5 minutes

PGC5007 Total Sulfur Analyzer System

Total Sulfur Measurement

Short Term H_2S Measurement

Subpart Ja for Flares
Environmental Flare Measurement Requirements

Total Sulfur Measurements

- Determine the Sulfur Dioxide (SO_2) emissions from the flare
  - Measurement ranges of 1.1 to 1.3 times the maximum anticipated sulfur concentration
  - No less than 5,000 ppmv

Hydrogen Sulfide (H_2S) Measurements

- Determine the Hydrogen Sulfide (H_2S) in the fuel gas to the flare
  - Short-term limit of 162 ppmv as a feed to the flares
  - Span value for this measurement is 300 ppmv H_2S

Net Heating Value

- Maintain a minimum BTU content and measure net heating value to the flare
  - 300 Btu/scf or greater if the flare is steam-assisted or air-assisted
  - 200 Btu/scf or greater if the flare is non-assisted

Net Heating Value

It is the intent of the EPA to maintain a minimum BTU content and measure the net heating value to the flare

EPA – New Source Performance Standards (NSPS)
Net Heating Value

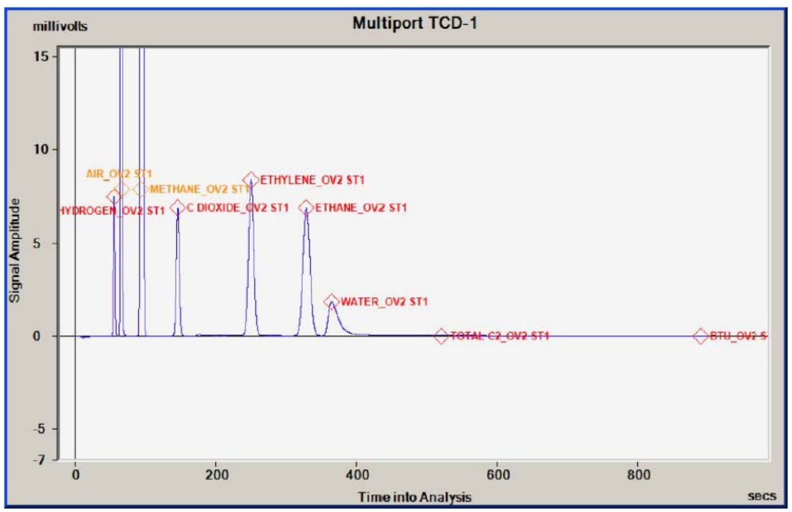
- PGC5000B **or** PGC5000C (with H_2S)
- Analytical Method
  - Hydrocarbon separation and measurement using a multiport TCD
  - Direct hydrocarbon measurements are used to calculate the net heating value of the fuel gas stream
  - PGC5000C also includes H_2S measurement

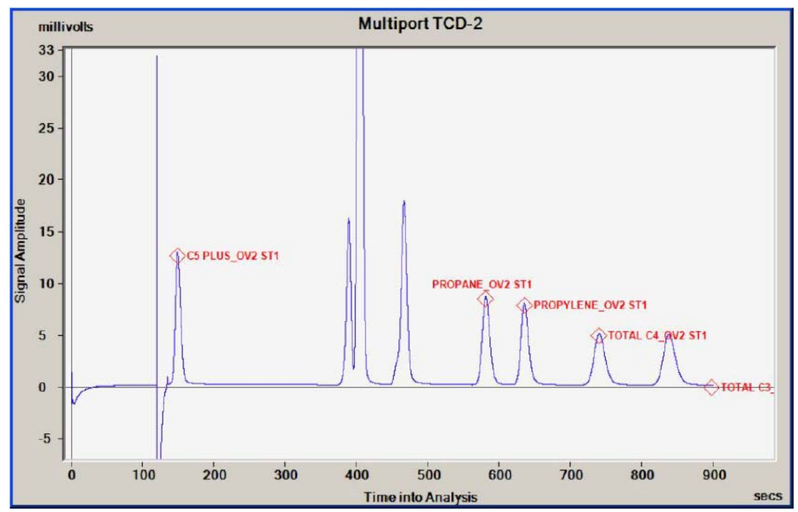
Net Heating Value Measurement
PGC5000B or PGC5000C

- Benefits:
  - Common analytical method, technology and hardware to the PGC5007B Total Sulfur Analyzer
  - Complete analytical solution for the entire flare monitoring package
  - Parallel method of analysis to the Total Sulfur application
  - Can be designed to include a H_2S analysis using the PGC5000C analyzer

Analysis Results – Option 1
Superior chromatography, High performance

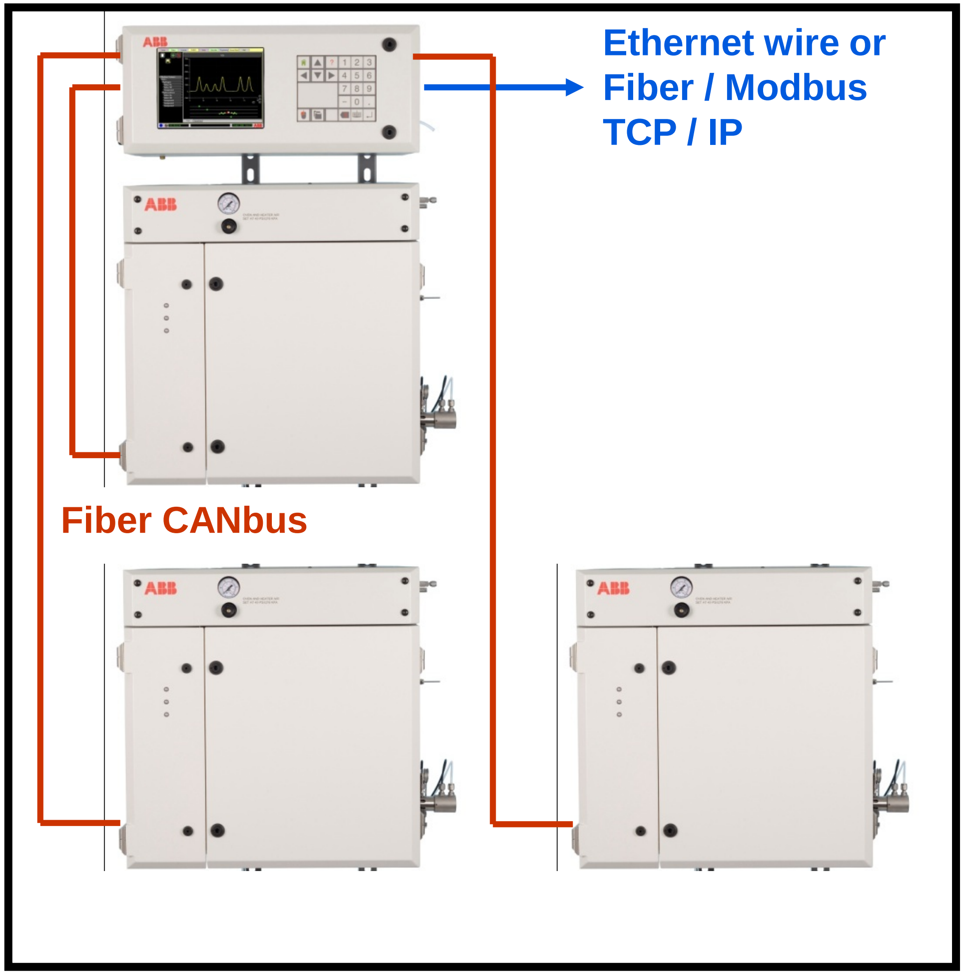
- PGC5000B and PGC5000C – BTU Application
  - Chromatography designed to eliminate any potential water interferences on the BTU value
  - Multiple ASTM methods and GPA calculation packages available
  - Repeatability = +/- 0.5% of the full scale measurement





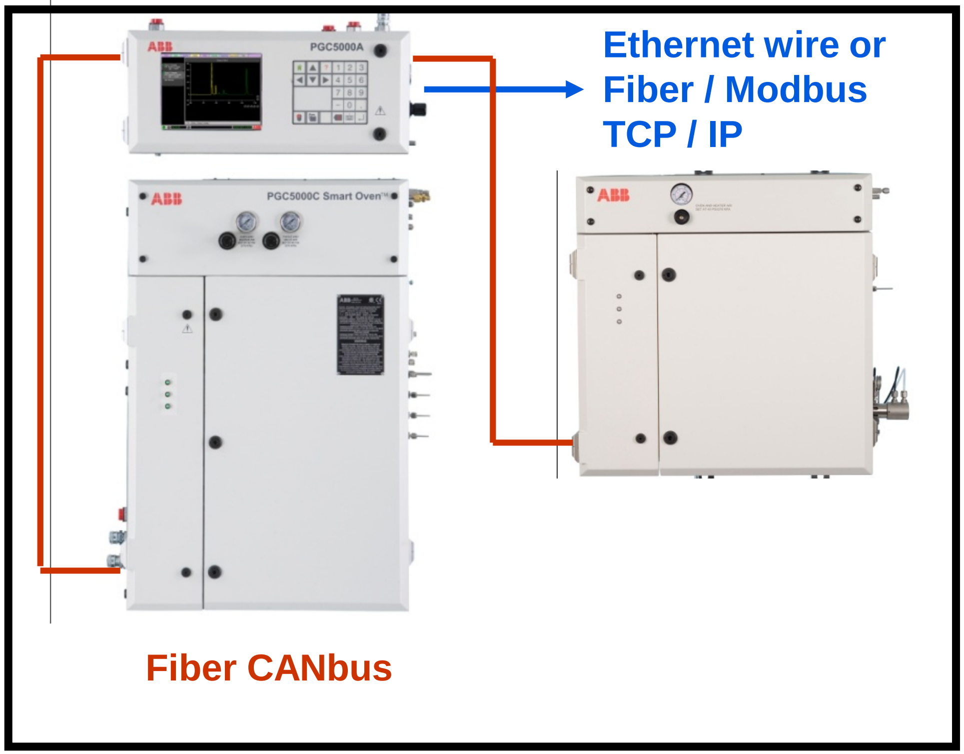
Flare Analyzer Monitor Systems Summary

Option 1: Three Ovens (PGC5007B, 2 x PGC5000B)
Subpart Ja: Total Sulfur and H2S compliant
Net Heating Value compliant



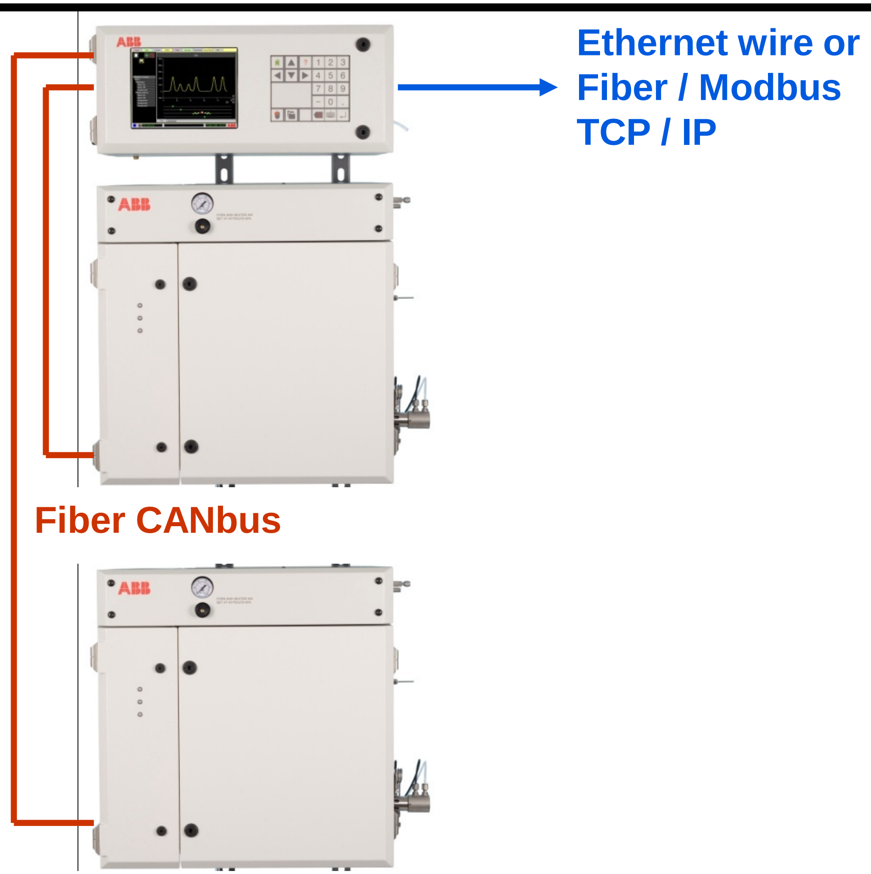
Three Isothermal Ovens Oven 1: TS (ppm to %) Oven 2: H2S (ppm) Oven 3: BTU
Oven 1 – Detector 1: FPD - TS
Packed columns
Measured Components: Two Internally Switched Ranges Total Sulfur = (0 ppm – 5000 ppm) Total Sulfur = (5000 ppm – 50%)
Oven 2 – Detector 1: FPD
Packed columns
Directly Measured Component: H2S (0 – 300ppm)
Oven 3 – Detector 2: *m*TCD
Packed columns
Measured components: Complete Stream composition, calculated BTU

Option 2: Two Ovens (PGC5000C, PGC5007B)
Subpart Ja: Total Sulfur and H2S compliant
Net Heating Value compliant



Two Isothermal Ovens Oven 1: TS (ppm to %) Oven 2: H2S (ppm) And BTU
Oven 1 – Detector 1: FPD - TS
Packed columns
Measured Components: Two Internally Switched Ranges Total Sulfur = (0 ppm – 5000 ppm) Total Sulfur = (5000 ppm – 50%)
Oven 2 – Detector 1: FPD
Packed columns
Directly Measured Component: H2S (0 – 300ppm)
Detector 2: *m*TCD
Packed columns
Measured components: Complete Stream composition, calculated BTU

Option 3: Two Ovens (PGC5007B, PGC5000B)
Subpart Ja: Total Sulfur and H2S compliant
Net Heating Value compliant

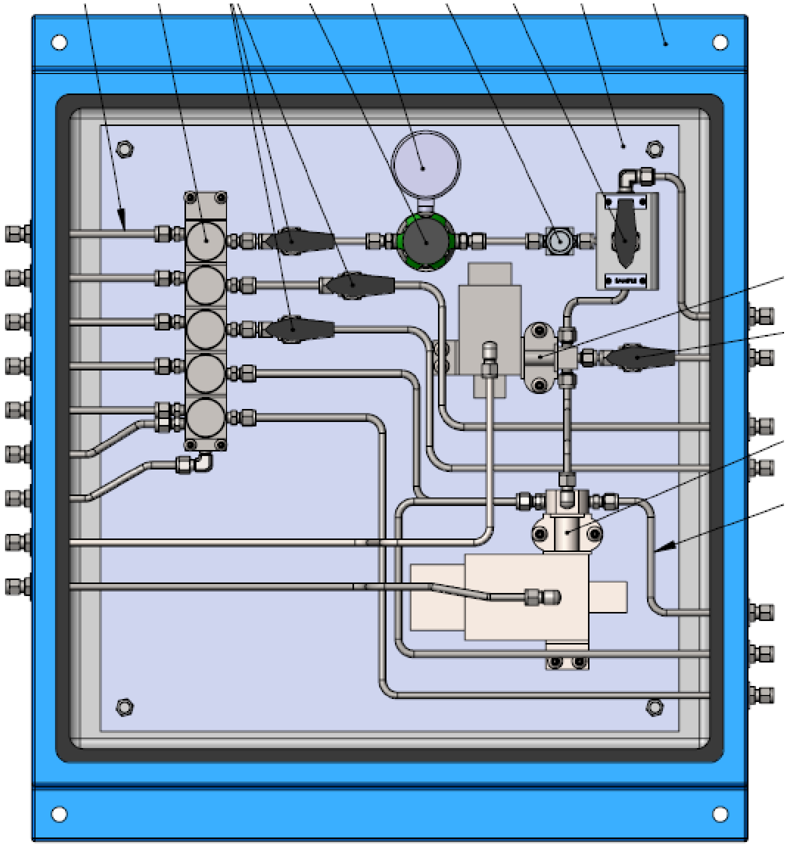


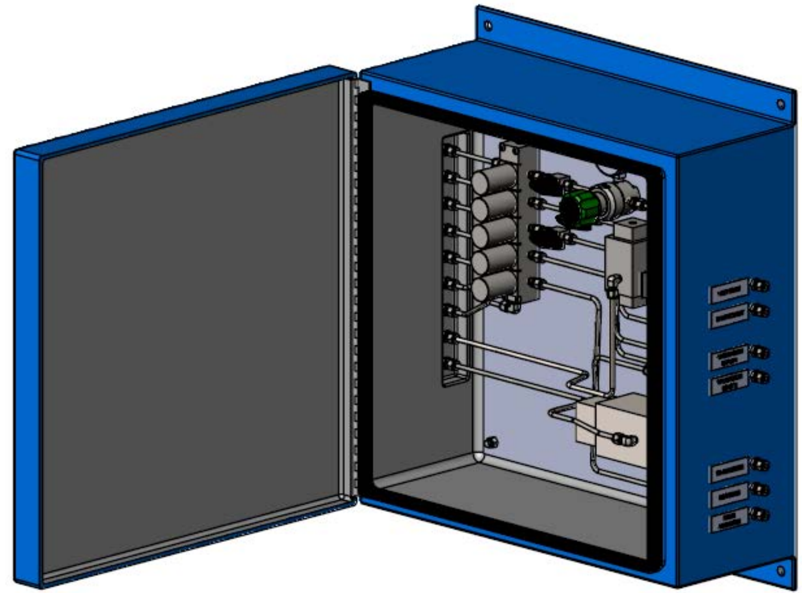
Two Isothermal Ovens **Oven 1: TS (ppm to %) and H2S (ppm)** **meaured as Total Sulfur** **Oven 2: BTU**
Oven 1 – Detector 1: FPD - TS
Packed columns
Measured Components: Two Internally Switched Ranges Total Sulfur = (0 ppm – 5000 ppm) Total Sulfur = (5000 ppm – 50%)
Reported H2S (0 – 300 PPM) Measured as Total Sulfur
Oven 2 – Detector 2: *m*TCD
Packed columns
Measured components: Complete Stream composition, calculated BTU

Flare Application Summary

Application Option	Total Sulfur Application Method	H2S Application Method	BTU	Ovens
1	Two Internally Switched Ranges Total Sulfur = (0 ppm – 5000 ppm) Total Sulfur = (5000 ppm – 50%)	Directly Measured Component: H2S (0 – 300ppm)	Yes	Three B Ovens
2	Two Internally Switched Ranges Total Sulfur = (0 ppm – 5000 ppm) Total Sulfur = (5000 ppm – 50%)	Directly Measured Component: H2S (0 – 300ppm)	Yes	Dual One C and One B Oven
3	Two Internally Switched Ranges Total Sulfur = (0 ppm – 5000 ppm) Total Sulfur = (5000 ppm – 50%)	Measured as Total Sulfur Reported H2S (0 – 300 PPM)	Yes	Dual Two B Ovens

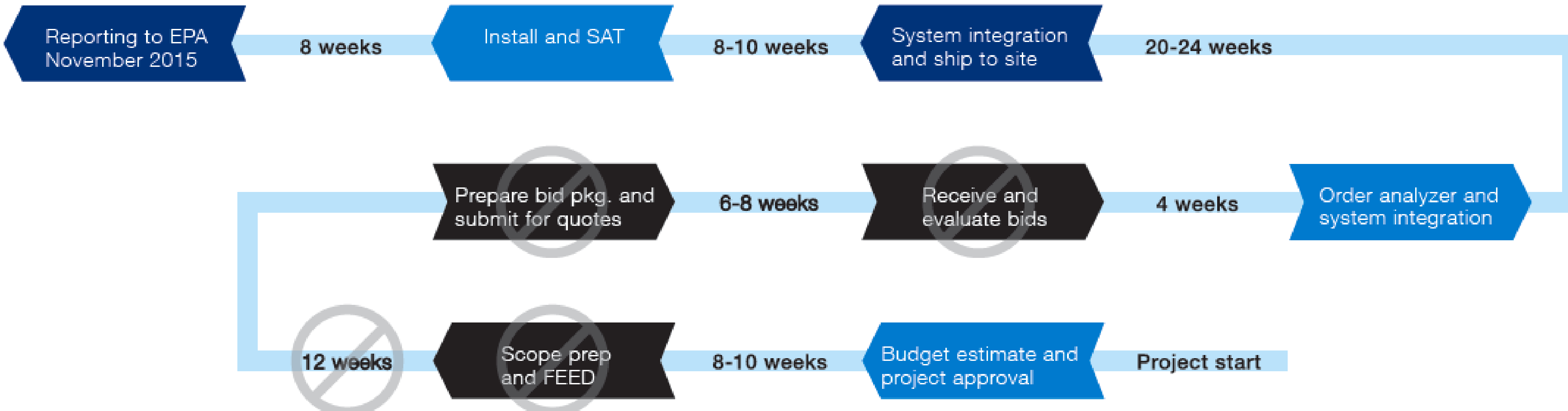
Subpart Ja for Flares
Modular Sample Systems





- Common design between TS, H2S and BTU applications
- Insulated cabinet
- Modular design for small footprint
- Multiple, isolated validation inputs for daily validations, CGA audits and RATA tests
- Chemically treated for sulfur applications

Subpart Ja for Flares
System Integration



- Total project path could reach 20 months
  - Reduce cycle time ~50% with total solution from ABB

Experience and Installation Base Total Sulfur Methods and Flare Solutions

Total Sulfur Application Experience

- The PGC5007B Smart Oven™
- Designed into the PGC5000B platform

- Based on the Online ASTM Method D7041-04 (10)
  - *Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Motor Fuels, and Oils by Online Gas Chromatography with Flame Photometric Detection.*
- Over 30 years of application experience and development of the Total Sulfur Solution

System Integration Facilities
Probes, Sample Handling Systems, and Enclosures

- ABB Houston
  - 12 flare systems designed and installed
- 3 regional integration partners
  - Northeast – 7 flare systems designed and installed
  - Central – 3 flare systems designed and installed
  - Midwest – 2 flare system designed and installed
- Additional experience with other independent, regional integrators
- All SI facilities have ABB certified, factory trained resources for sales, service, and after-sales support
- ***These resources provide ABB the experience, bandwidth, and personalized service necessary to support our customers with this EPA requirement***

Power and productivity
for a better world™

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