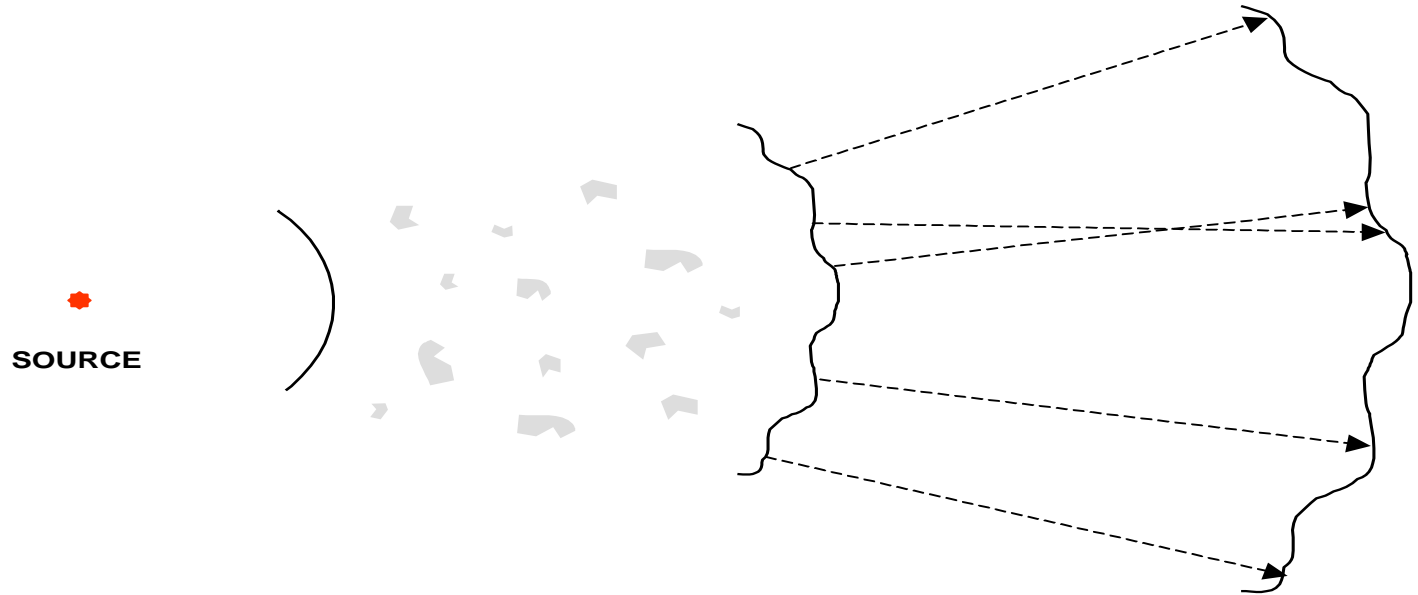


Optical Flow Sensors for Air & Steam Assist Flares



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What is Optical Scintillation?

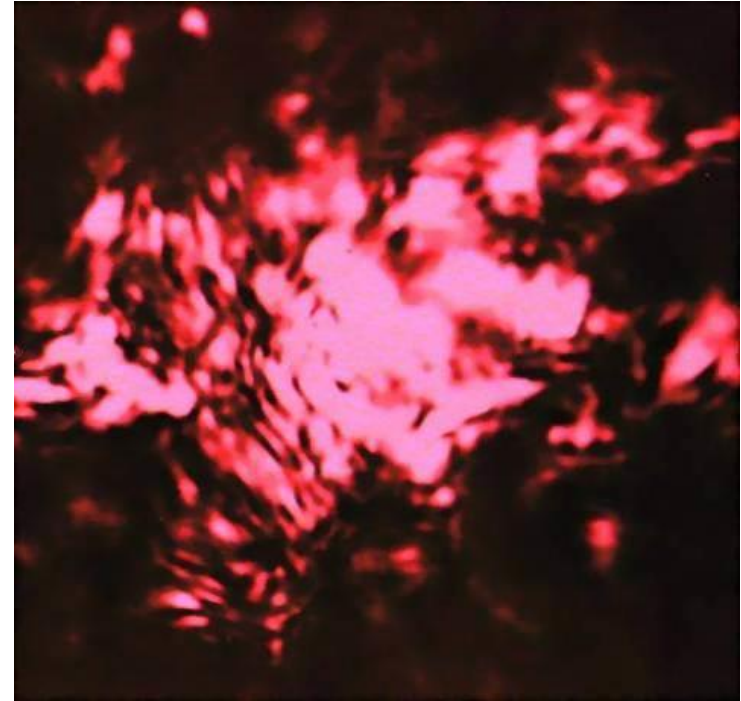


Optical Flow Sensors (OFS) Technology

OFS is based on:

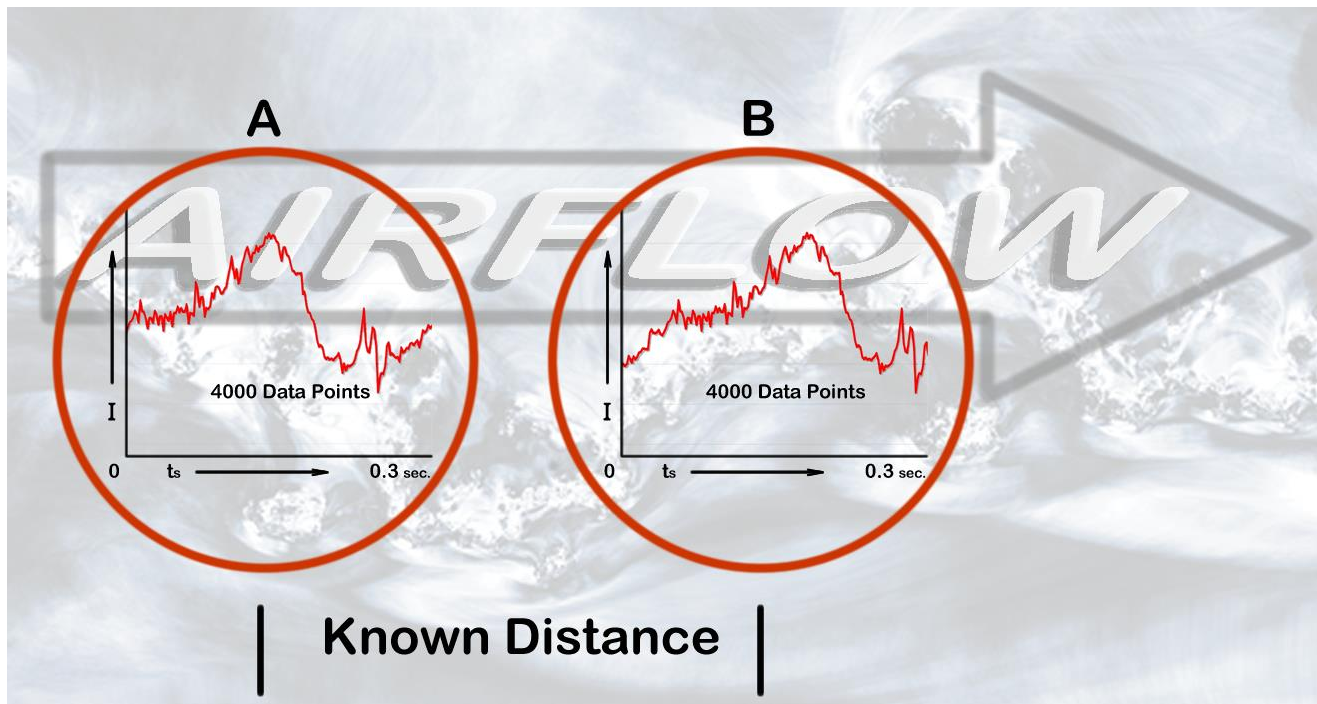
1. Optical Scintillation (Light Fluctuation)
2. Temporal cross-correlation (i.e. Time of Flight)

OFS uses a partially coherent LED and works by clock the speed of shadows that pass by two detectors.



Diffusion of light (Optical Scintillation)

OFS Digital Processing



Time of Flight

Why OFS can measure Low Flow

V = Velocity

D = Known distance between two detectors

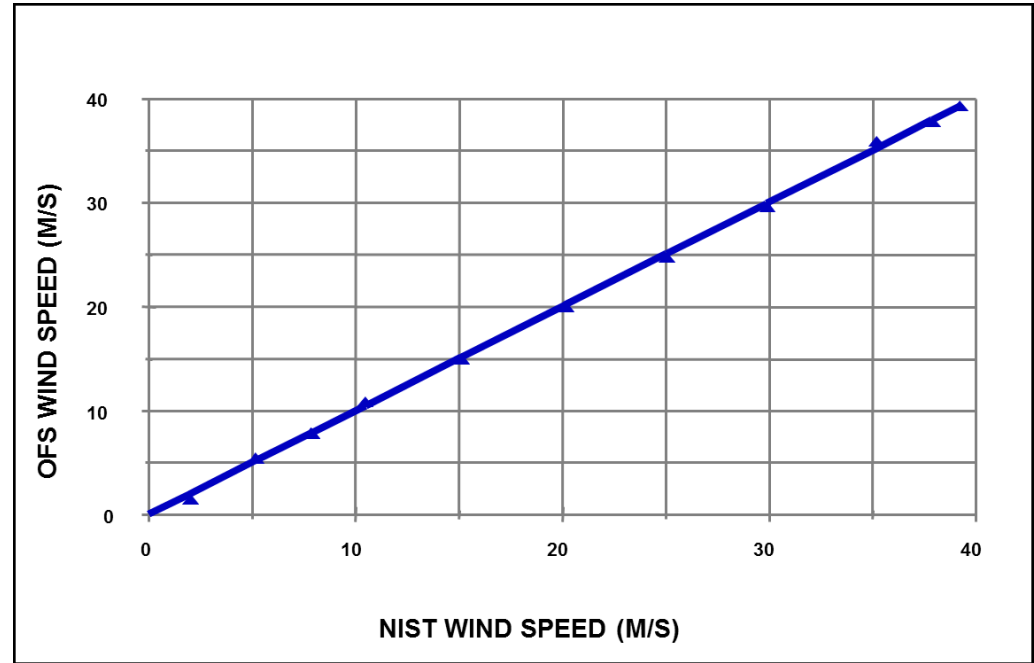
t = Transit Time

So OFS can measure velocity from very fast to extremely slow independent of any reference speed such as speed of light or the speed of sound

$$V = \frac{D}{t}$$

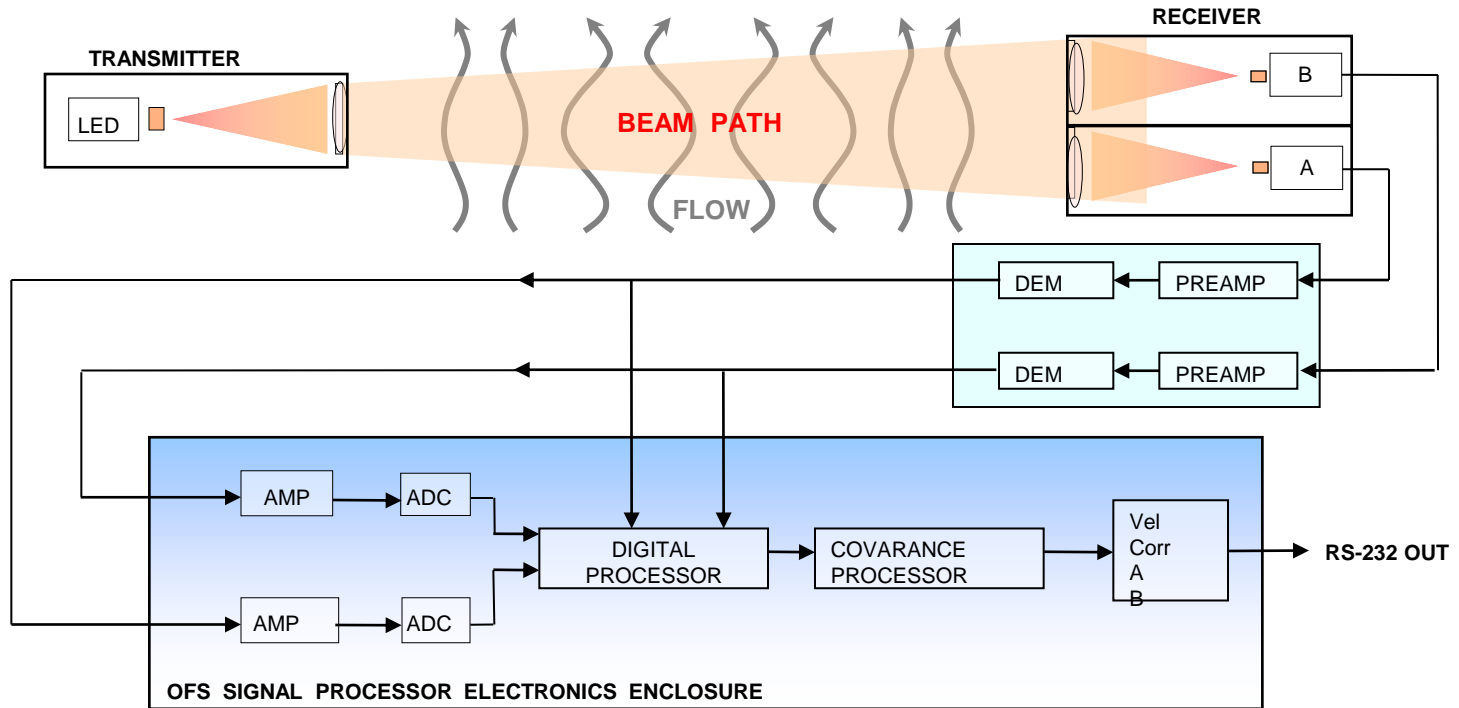
OFS Measures velocity with same accuracy throughout measurement

NIST Test: OFS vs. NIST Standard Array Avg

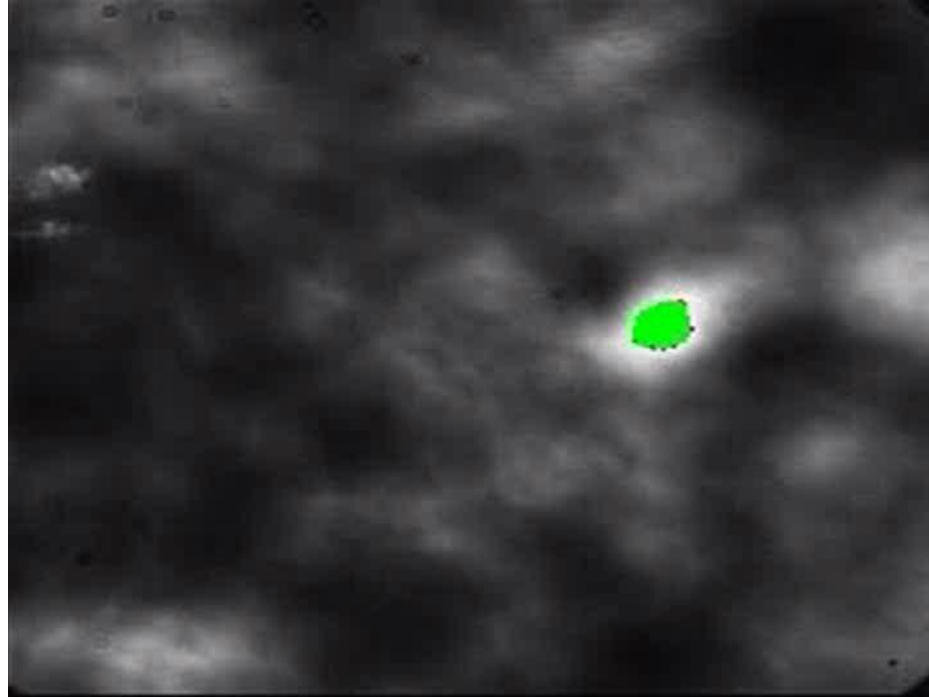


OFS is NIST Tested and Traceable!

OFS Block Diagram



Seeing the Flow



Video from Army Research Lab

EPA MACT RSR 40 CFR 63.670

In Dec. 2015, EPA finalized the Petroleum Refinery Sector Risk and new source performance standards.

Rule requires 96.5% combustion efficiency or 98% destruction efficiency on all flares.

If steam or air assist are used, the operator must account for all the flows of these gases to measure and report the dilution in the combustion zone.

OFS (Optical Flow Sensor)

OFS technology offers a pro-active, real-time data approach to monitoring/controlling air and steam assisted flare lines to avoid:

- Over-steaming
- Excess Aeration
- Flame Lift-off

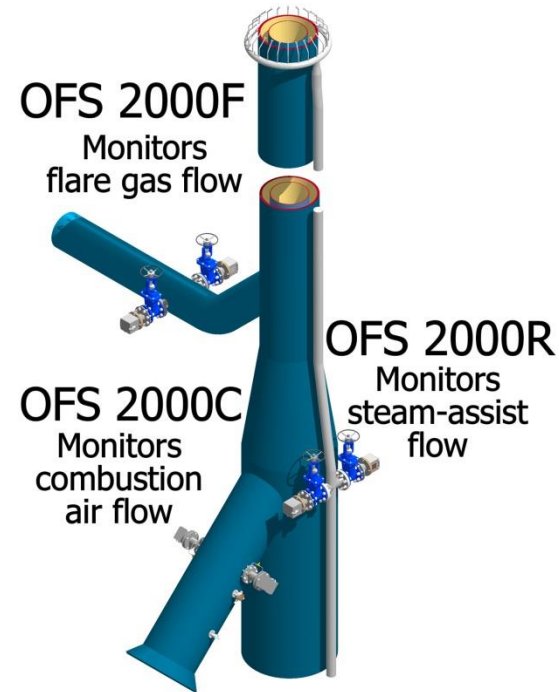
OFS 2000 sensors accurately monitor flow rates in flare headers as well as supplemental lines

- Flare Gas Line
- Combustion air assist line
- Steam assist lines

Optical Flow Sensor for Precision Flare Control

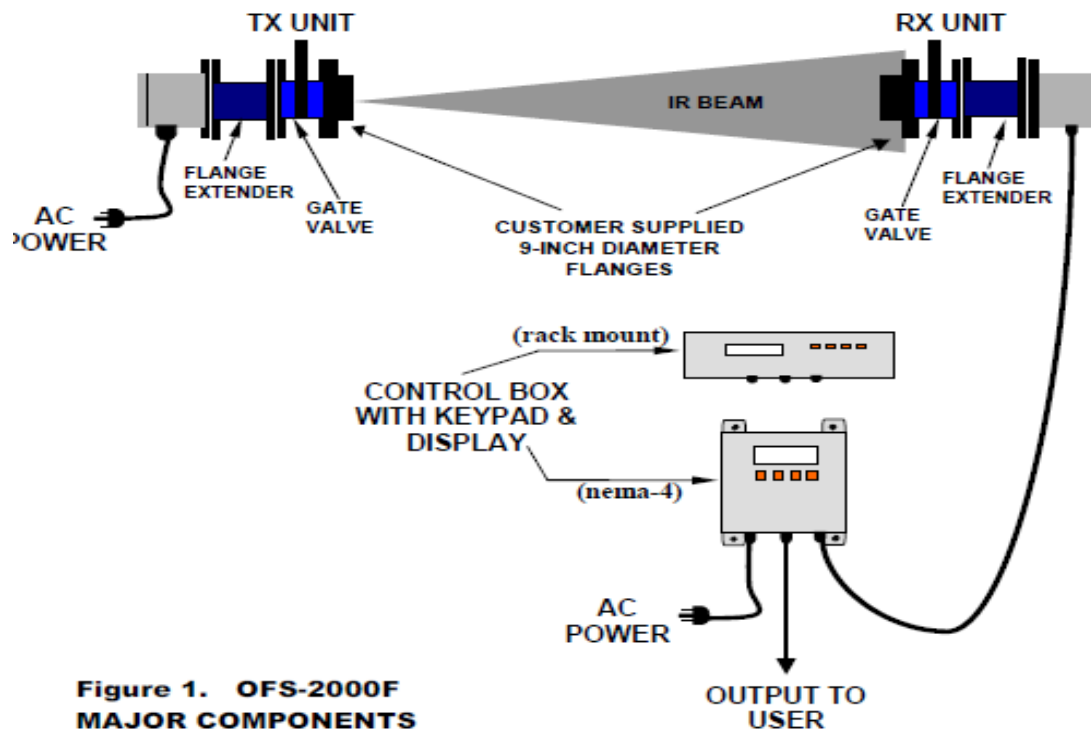
OFS technology enables an operator to continuously monitor and record flow rates in flare headers as well as supplemental lines.

OFS-2000F & OFS-2000C or OFS-2000R, when used in combination, give the operator a much improved capability to see that combustion is as complete and efficient as possible.



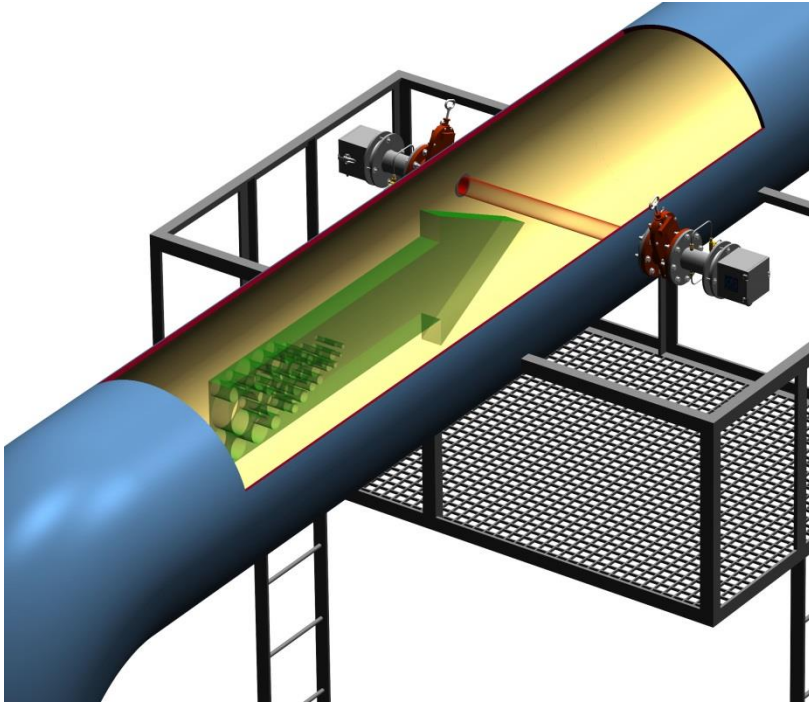
No more Guessing

OFS - Typical System Setup



**Figure 1. OFS-2000F
MAJOR COMPONENTS**

Why Use OFS Technology for Flares?



- Measures 0.03 to 150+ m/sec
- Non-intrusive (nothing in flow),
- No interference / dependence on media composition
- Measurement - zero effect from temp, pressure, molec.wt., humidity, etc..
- Measurement is an instantaneous cross-stack line average

Hydrogen? No Problem

Precision Control: OFS-2000F for Flare Line

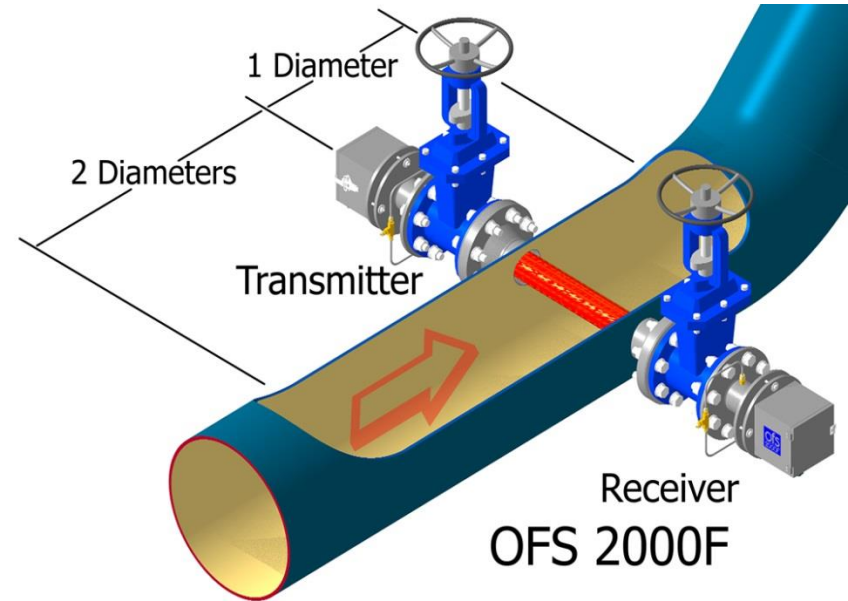
Single OFS reports flow velocities from 0.03 - 150 m/sec, +/- 2% accuracy.

3 sec. updating

Media independent measurement;
Hydrogen - no problem!

Fully path averaged

Heads do not have to be removed or zeroed; no need for "Fresh Air Service"



Flexible Placement Options

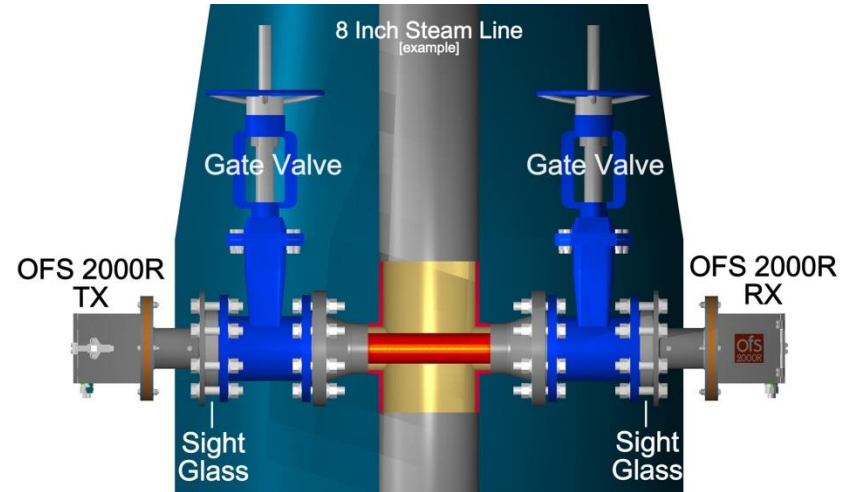
Precision Control: OFS-2000R for Steam Line

OFS-2000R can “see” through steam in the vapor phase, so the operator can match steam flow *exactly* to the flare output.

5000/1 turndown ratio

No pressure drop

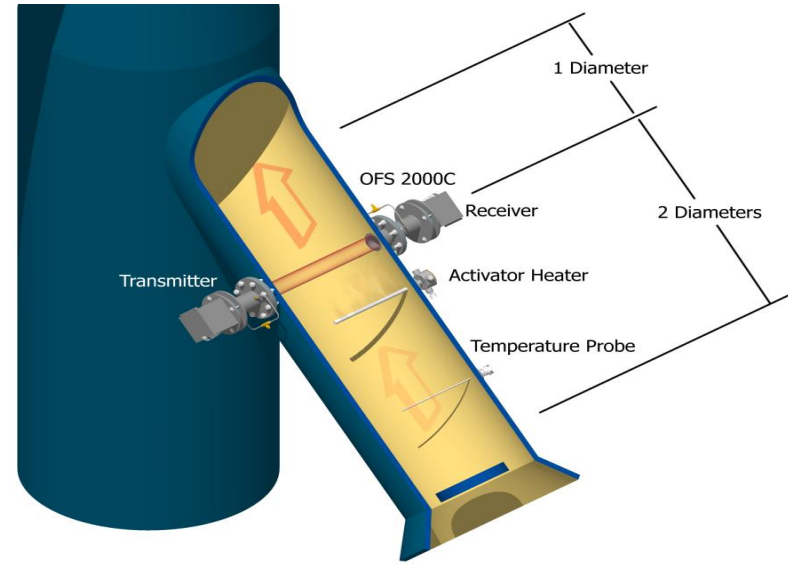
Precision measurement
Easily mounts on steam
lines



Precision Control: OFS-2000C for Intake Air

OFS-2000C Developed to precisely measure air inflow into combustion processes

- Reports velocity and moment-by-moment mass flow data.
 - Temperature / pressure probes included
- No more guesswork in tailoring fuel/air mix
- OFS 2000C = Optimum combustion - with no guesswork.
- (Title 40 Subchapter C Part 63.670 (i) (1), (4))



OFS EPA compliant

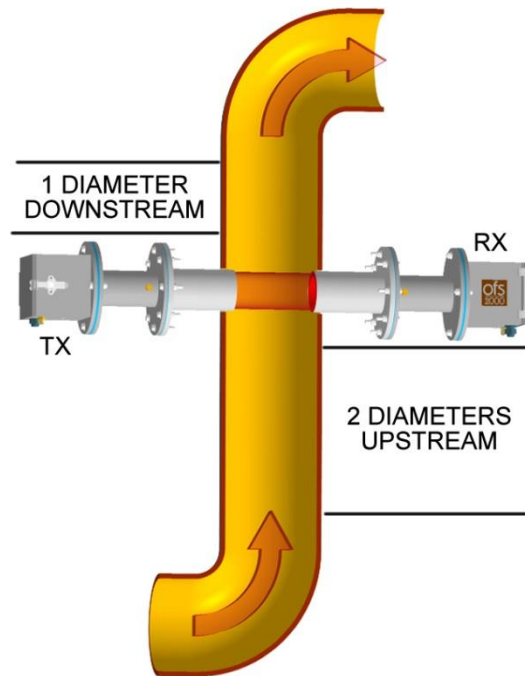
Compliance

- EPA 40 CFR 60, 63, 75
- Sub part J/Ja
- Refinery Sector Rule (RSR) flow
- SCAQMD Rule 1118
- API MPMS 14.10 Measurement of Flow to Flares
- NIST traceable

Automatic daily calibration & continuous performance monitoring

Why OFS Technology for Flares?

- OFS doesn't drift
- 5000/1 Turn Down
- Monitor forward & reverse flow
- Failed module can be swapped out in minutes – no recalibration
- One sensor for Low & High Flow
- Based on fluctuations in light not absolute light intensity
- Widely used in hundreds of flare applications for over a decade
- No moving parts

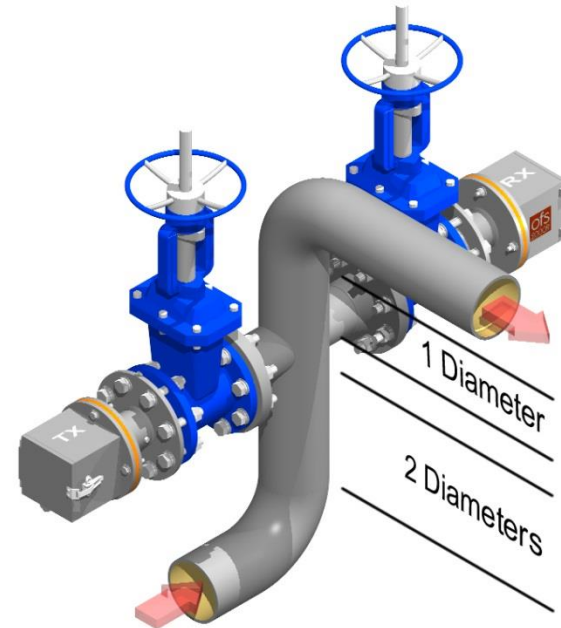


No re-piping required

OFS Placement Advantages

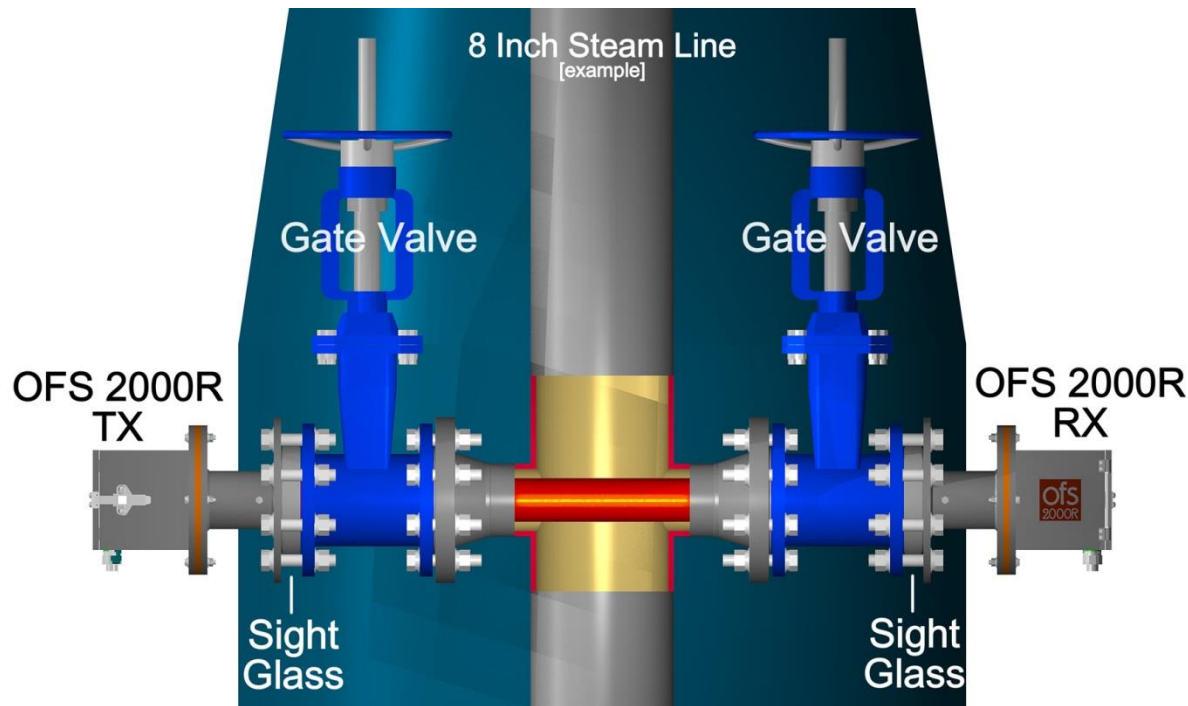
OFS technology offers much greater placement flexibility

- Can be located near or in bends / elbows in some applications
- Can be installed as a dual system in “X” pattern placement
- Platforms do not need to be hundreds of feet off the ground
- Does not Create a Pressure Drop



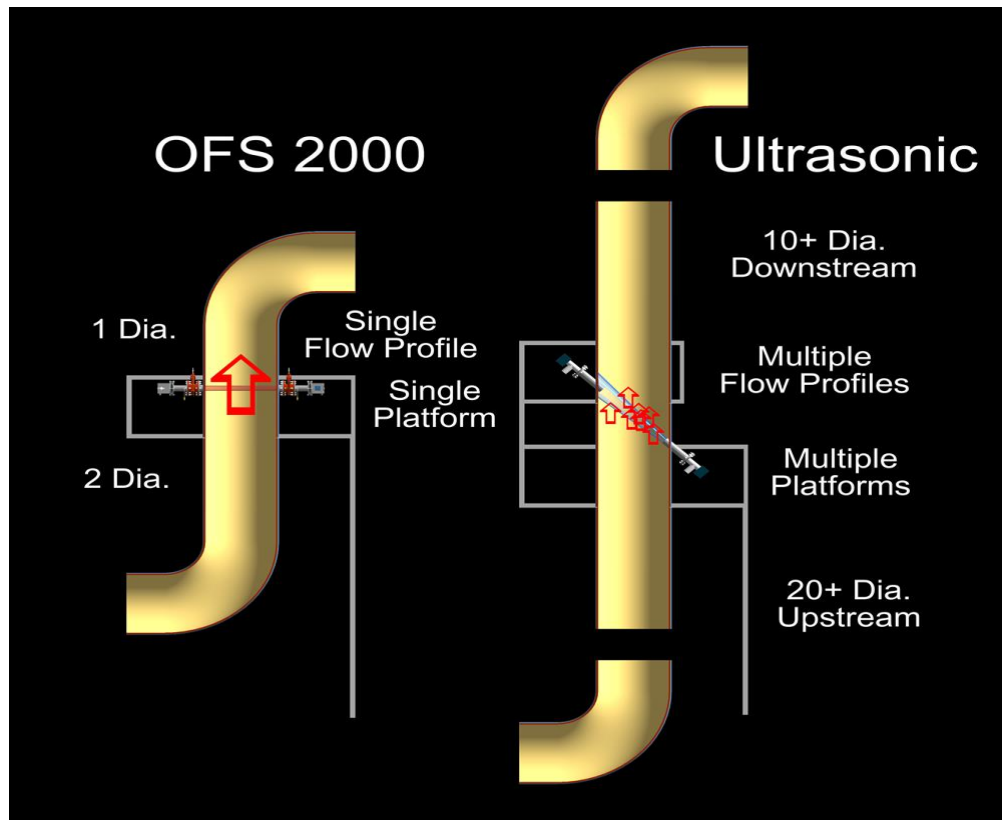
Easy Installation

Media Containment



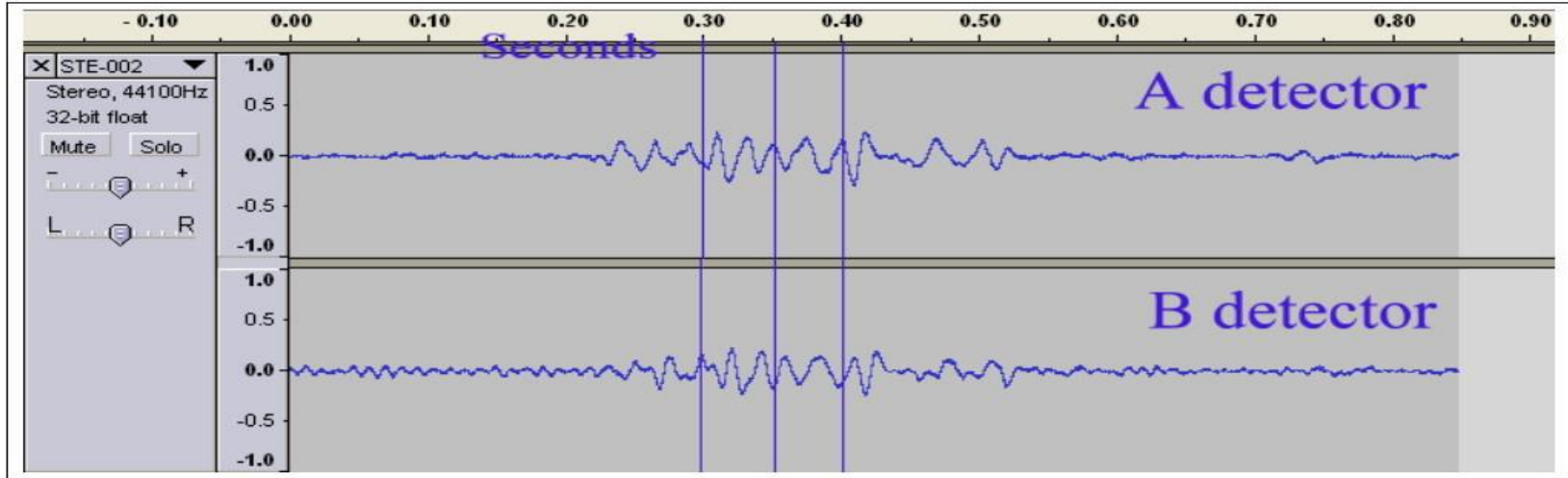
Plant and Personnel Safety

OFS vs Ultrasonic Placement Comparison



OFS Raw data signals

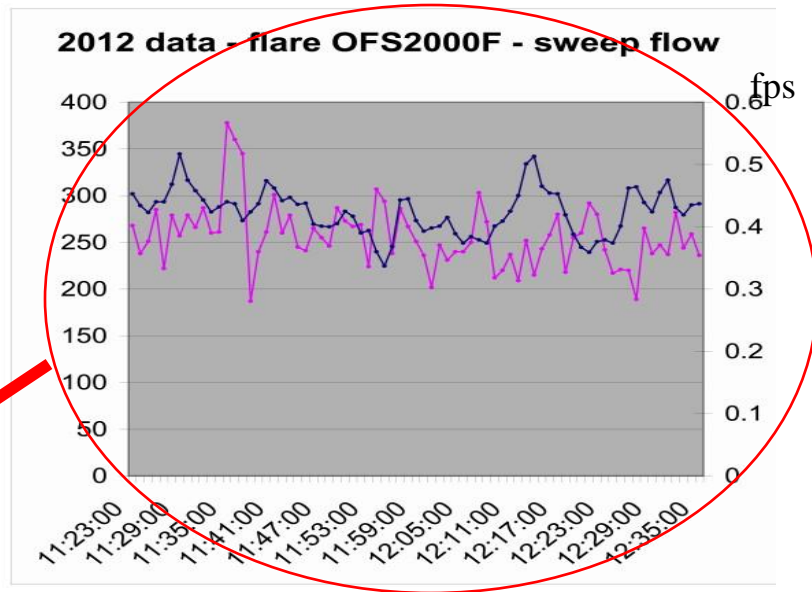
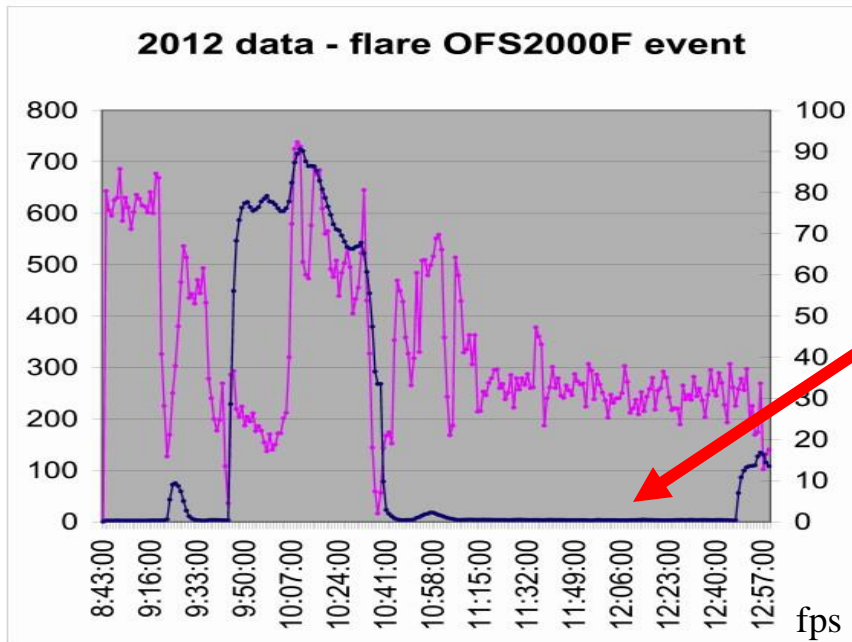
Example: Audio waveform of a single gust of air in a duct before the damper was opened...



...typical flow signatures are much more varied / higher scintillation in the time domain - looks like white noise.

OFS Very Wide Dynamic Range Capability

24" Flare Line



Baseline Zoom

Air Assist Flare Case Study

- Refinery in Northern U.S.
- Using a single air-assist blower with variable freq. drive (VFD)
- Manufacturer provided fan curve was very different from actual (not unusual)
- OFS-2000 flow sensor installed on air inlet
- Allowed for much more precise control of optimal mixture
- Measurement of flare and air flows yields much better results than estimates and flow modeling.
- API MPMS 14.10

Title 40 Subchapter C Part 63.670 (MACT)

OFS Recent Enhancements

Addition of MODBUS RTU over serial

- can update existing sensors in the field!

Optional Temperature / Pressure Enhancement option

- Adds two 4-20 mA current loop inputs to OFS, one for smart temp probe, one for smart pressure probe

AGC (Automatic Gain Control) adjusts the light intensity based on the media opacity

- Available on OFS-2000R (steam lines) & OFS-2000W (wet scrubbers)

Continuous improvements

Flow Measurement Technology Comparison

- Most traditional flow measurement technologies have serious limitations at extreme flow rates (high and low)
- Ultrasonic technologies are based on the speed of sound
 - At high flow rates, non-linear shock-wave effects will severely affect measurement accuracy
 - At very low flow rates, measurement accuracy is reduced as the flow rate becomes a tiny fraction of the speed of sound
- Pitot tubes are limited by noise and electronics resolution
 - Low flow rates produce very small pressure differences that are difficult to measure accurately
- Any kind of insertion probe can be plagued by clogging and environment extremes
 - At best, they are still a single point measurement - not representative
- **OFS technology is not limited by basic physics as are most others!**

Actual Velocity vs Standardized Measurements

- OFS can be thought of as a tachometer for shadows going by.
- It measures instantaneous average velocity along a straight line which stretches across the stack or pipe.
- It works by clocking the speed of shadows pass thru that line.
- It measures the ACTUAL velocity in feet per second (AFS).
- Multiply AFS by the cross sectional area of the pipe to get actual volume in cubic feet per second (ACFS).
- To obtain STANDARDIZED volume, separately measure the temperature and pressure in the pipe and normalize the ACFS reading to standard temperature and pressure to get standard cubic feet per second (SCFS)

OFS-2000F specifications

Flow Performance	
Measurement Technique	Optical Scintillation (OSi Patented)
Dynamic Range	0.03 to 100 m/sec, bidirectional
Accuracy (absolute)	+/- 0.01 m/sec basic -or- +/- 2% of reading, whichever is greater
Repeatability (relative)	+/- 0.01 m/sec basic -or- +/- 1% of reading, whichever is greater
Long Term Drift	Less than 1% per year
Response Time	Response 0.3 sec., Update: 3 sec., Averaging (selectable): 3-600 sec.
Automatic Calibration	2 or 3 point; user selectable interval -or- on external command
Sensor Health Monitoring	Continuous self-test of voltages, performance, optics, etc.
Media / Environmental	
Stack / Duct / Pipe Diameter	0.3 to 10 m, standard -- consult factory for other ranges
Media Temperature / Pressure / Humidity	No effect on measurement
Media Transparency	Up to 95% opacity (OFS-2000-FW recommended for high opacity)
Ambient Temperature / Humidity	-40 to 60 C (-40 to 140 F) / 0 - 100% condensing
Physical Specifications	
Light Source	Eye-safe 670 nm visible red LED, 5 deg. divergence angle
Sensor Heads (w/ 4" sch.40 flange extender)	9 x 9 x 13 inches, 13 lbs. -- NEMA4 weather resistant
Control Unit: Rack Mount Version (standard) NEMA4 Wall Mount (optional)	5 x 17 x 20 inches, 13 lbs. (for indoor use) -or- 12 x 16 x 10 inches, 15 lbs. (for outdoor / factory floor use)
Electrical Specification	
User Interface	RS-232 serial I/O and / or 4-20 mA optically isolated current loop; Also two sets of relay contacts for fault and calibration indication.
Power for Transmit Head	Universal 100-240 VAC, 50/60 Hz, 12 VA (fused & surge protection)
Power for Control Unit	Universal 100-240 VAC, 50/60 Hz, 40 VA (fused & surge protection)
Cable between Control Unit & Receive Head	15 foot standard; to 300 foot optional (shielded, 10 cond., 22 AWG)

[Specifications are subject to change without notice.]

Who Is Using OFS? (Over 1000 sensors fielded over past 20 yrs)

- MarkWest – Cadiz, OH
- Markwest - Seneca, OH
- Andeavor – Kenai, AK
- Chevron – El Segundo, CA
- ALCAN – Alma, QC, Canada
- Marathon – Robinson, IL
- ALCOA – Wenatchee, WA
- US EPA – Research Triangle Park, NC
- COMALCO – Boyne Island, Australia
- Sunbury Energy – Shamokin, PA
- Lumberton Power – Lumberton, NC
- Kaiser – Spokane, WA
- Bowater – Bowater, TN
- SCAQMD – S. California
- Exxon Mobil – Joliet, IL
- ALCOA – Rockdale, TX
- ALCOA – Massena, NY
- Hydro – Ovre Ardal, Norway
- Watson CoGen – Carson, CA
- China Petroleum – Taiwan
- BP – Carson, CA
- Shell Chemical – Deer Park, TX
- Valero (Multiple Locations)
- Citgo – LeMont, IL
- Alliant Energy – Madison, WI
- Andeavor – Gallup, NM
- Reynolds, Longview, WA
- Xcel Energy – Minneapolis, MN
- Flint Hill Resources – MN
- ALCOA – Baie Comeau, QC
- Great River Energy – Fargo, ND
- Dow Chemical -- SC
- Air Liquide – Bayport, TX
- Ametek – Calgary, CAN
- Marathon = Detroit, MI
- Westinghouse SRC – Aiken, SC
- Hua Bo Technology – Taiwan
- Linde Gas N.A., LaPorte, TX
- Shell, Deer Park, Houston, TX
- Shell Pipeline, Houston, TX
- Kindermorgan – Snyder, TX
- Conoco Phillips, Wilmington, CA
- Shell Pipeline – LA
- Chevron – Pascagoula, MS

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