

## Flare Metering with Optics

### From Blue-Sky Technology to the Real World

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#### Abstract

During a presentation at the 2006 North Sea Flow Measurement Workshop on new and current flare metering technologies, infrared and other optical methods of gas flow measurement were referred to as “blue-sky” technology. The inference was that these technologies, whilst they might have merit, probably would not be available for some time, if ever. In reality, this is far from true, as at least one vendor of such devices has developed its technology to the point that laboratory and field testing have been carried out, and more than twenty-five units have been sold and installed into operational plants.

The purpose of this paper is to review the development, testing and deployment of the Photon Control Optical Flow Meter. In particular, the following topics will be addressed:

1. Overview of the technology, its various embodiments, its advantages and shortcomings, with a synopsis of a Canadian JIP under which development was carried out.
2. Presentation of results:
  - Flow Laboratory testing for installation effects
  - A variety of general Canadian onshore retrofit installations
  - Specific examples from the eight ConocoPhillips Canada “Real World” installations
  - An example using optical flare metering technology in Statoil
3. Detailed conclusions on the JIP, the gradual implementation of the new technology into the industry, with feedback from both users and regulators on being able to manage flare gas discharges.

## 1. STATE OF OPTICAL FLOW METERING: A REVIEW

Historically, optics are less well known in the realm of gas flow measurement whereas analytical instrumentation – LIDAR<sup>\*</sup>, gas analyzers, etc., use the inherent features of light such as specific absorption, fluorescence or scattering which cannot be realized by any other techniques.

Optical methods for measuring gas flow, or optical flow meters (OFM), use optical velocimetry, the measurement of gas flow velocity from which the volumetric flow rate can be derived. These methods can be subdivided into laser Doppler velocimeters (LDV) and optical transit time

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\* LIDAR (*Light Detection and Ranging*) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. Like the similar radar technology, which uses radio waves instead of light, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.

velocimeters. The latter can be divided into laser-two-focus (L2F), scintillation-based and absorption-based transit time velocimeters.

## **1.1 Product History**

Spectron Development Laboratories conducted a study for the Gas Research Institute to determine the possibility of developing a volumetric gas flow meter based on the L2F technique in 1989.<sup>3</sup> Although this study never resulted in a commercial device, it caught the attention of Nova Husky Research where optical methods were in use for particle sizing and monitoring the quality of filters. A project on the L2F volumetric flow meter was conducted for several years at Nova, and later at TransCanada Pipelines Ltd. (TCPL). The effort was continued in 1999 - 2000 as a joint development project with a major flow meter manufacturer.<sup>4,5</sup> The work focused on developing a high-accuracy Optical Flow Meter (OFM) which would be suitable for gas custody transfer measurement, and in particular for the replacement of orifice meters.

In 2002 Photon Control Inc., licensed this optical flow metering technology from TCPL for the purpose of its further development and commercialization in a variety of gas flow metering applications.

During 2003 Photon Controls proposed to the Canadian oil and gas industry a Joint Industry Project venture in order to mitigate the meter development costs and to gain access to 'real world' facilities. Unfortunately the take up on this venture was poor, and it was not until somewhat later at the 2004 Canadian School of Hydrocarbon Measurement in Calgary, Alberta, that ConocoPhillips Canada (COPC) became aware of what looked like an attractive option for flare metering. At this time COPC and Photon Control began to collaborate with the development of the meter systems for flare and vent gas applications.

COPC recognised that there was a 'hole' in the management of their plants and resources, and saw that local regulations would soon require them to report flare and vent quantities to a level which had been unachievable in the past. COPC were uncomfortable with their existing estimates of stack losses and wanted more accurate information in order to reduce or eliminate background gas to the flare systems. It was seen that flare/vent metering was the only way forward, and that the existing flare and vent meters at that time did not meet the Business Units' needs as either being fit for purpose or especially cost efficient. The collaboration process continued through 2006.

## **1.2 Laser Doppler Velocimetry**

LDV is the oldest form of optical velocimeter, and was proposed soon after appearance of the first commercial lasers. However, LDV has found little industrial or commercial application because of its high cost and the need to particle-seed the flows due the very low signal-to noise ratio. In laboratories, LDV offers impressive accuracy and the ability to measure very high velocities. This, combined with the ability to measure complex 3D gas flows makes LDV an important tool in turbomachinery and avionics applications.

## **1.3 Optical Transit Time Velocimeters**

### **1.3.1 Laser-Two-Focus (L2F) Meters**

Thompson first described the possible implementation of the L2F method for flow measurement in 1968.<sup>1</sup> Schodl contributed significantly to the practical aspects of the L2F technique, but the method never went beyond flow laboratory implementation other than a few commercial L2F meters built by Polytec in the early 1980s.<sup>2</sup>

### 1.3.1.1. Principle Of Operation

The operational principle of the optical gas flow meter based on L2F velocimetry is explained in Figure 1. Small particles which accompany natural and industrial gases pass through two laser beams focused in a pipe by illuminating optics. Laser light is scattered when a particle crosses the first beam. The detecting optics collects scattered light on a photodetector P1, which then generates a pulse signal. If the same particle crosses the second beam, the detecting optics collect scattered light on a second photodetector P2, which converts the incoming light into a second electrical pulse. By measuring the time interval between these pulses,  $\tau$ , the gas velocity is calculated as

$$V=S/\tau \quad (1)$$

where  $S$  is the distance between the laser beams.

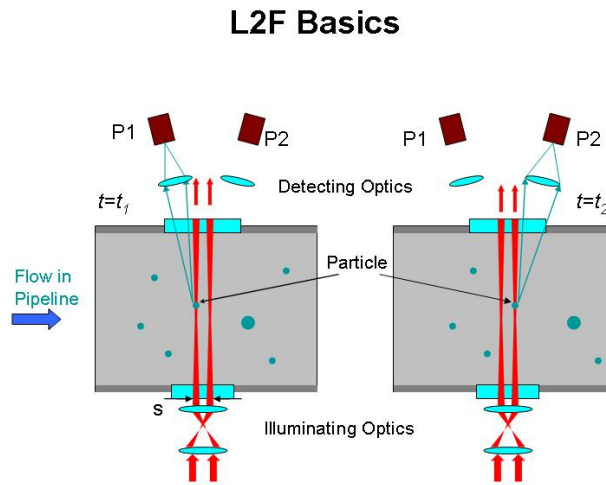


Figure 1. Operating principle of the L2F velocimetry

### 1.3.1.2. Accuracy Of The L2F Method

The linear gas velocity can be measured with high accuracy using the L2F method independent of pressure, temperature and gas composition. Using (1) above, the velocity uncertainty  $\sigma_v$  can be estimated as

$$\sigma_v = \sqrt{(\sigma_d^2 + \sigma_t^2)} \quad (2)$$

where  $\sigma_d$  and  $\sigma_t$  are the standard deviations in velocity due to errors in optical spacing and lapse time, respectively.

The uncertainty of the optical spacing is defined by the accuracy at which the beam spacing can be measured. For typical beam spacing  $d=1\text{mm}$  and positioning uncertainty of  $\Delta_d=1\ \mu\text{m}$ , the typical optical uncertainty would be around 0.1%. The lapse time uncertainty could be even smaller, as it is defined by the sampling frequency  $f_s$ . Smart, for example, reported a velocity uncertainty of less than 0.02% while using analog-to-digital conversion at a sample frequency of 100MHz.<sup>6</sup> The number of particles effectively crossing the two laser beams,  $N$ , contributes to

the velocity uncertainty as approximately  $1/\sqrt{N}$ . Conversion of the linear velocity measured at a single point to an average velocity, however, leads to a larger uncertainty due to the flow profile variations and turbulence. According to Schodl, the total error of the L2F velocimeter could be as low as 0.5% in a predictable profile, if the turbulence does not exceed 4%.<sup>7</sup>

The value  $N$  is determined by the following factors:

- a) the meter itself which includes: the efficiency of the delivery and collecting optical systems, the detectability of the photodetectors, the laser power and the wavelength;
- b) the purity of the gas moving in the pipe;
- c) the gas velocity profile and turbulence level.

In contrast to LDV devices, L2F velocimeters usually do not require seeding because of their inherently high signal-to-noise ratio, SNR. High SNR in L2F velocimeters results from the concentration of laser light into two focal sheets. LDV signals, however, consist of multiple fringes occurring after the interference of two convergent laser beams. Photodetectors such as the avalanche photodiodes used in L2F gas velocimeters, register individual photons, which allows them to use relatively low power lasers. These mass-produced semiconductor lasers transmit from 1 to 5 milliwatts through single-mode fibers, and can be focused into narrow sheets measuring between 20 and 30  $\mu\text{m}$  wide in a 2- to 6-inch pipe. The collecting optics must be designed to collect the scattered light within as large a solid angle as possible while blocking all direct light coming from the sheet. For 2-inch and 4-inch meters, the dark-field collecting optics must block the straight light from 0 to 2.5 degrees. Light scattering efficiency is determined by the size of the particles and the laser wavelength. L2F velocimeters operated at near-IR (850nm) can measure the velocity of air with a minimum particle diameter of approximately 0.3 $\mu\text{m}$ .<sup>6</sup> Shortening the laser wavelength reduces this minimum detectable particle size to less than 0.1  $\mu\text{m}$ . During the early development of the L2F gas flow meter, particles found in a typical gas pipeline were shown to range from 1 to 10  $\mu\text{m}$ .<sup>3</sup>

Lowering the gas velocity reduces the number of detectable particles. At a certain minimum velocity,  $V_{\min}$ , the OFM cannot distinguish the organized flow from the stochastic movement of particles in the pipe due to 'thermal stratification and other external factors'. The value of  $V_{\min}$  establishes the minimum measured flow rate, and thus the rangeability of the meter.

### 1.3.1.3. Turn-Down Ratio

The turn-down ratio, or rangeability, is probably the most important parameter of any flare gas meter that is proven to be repeatable. Some manufacturers of ultrasonic flare meters claim values of  $V_{\min}$  of 0.03 m/s and  $V_{\max}$  of 80 m/s, yielding a turn-down ratio in excess of 2500:1. The turn-down ratio of 100:1 recently claimed for a 12-inch flare meter from Instromet should perhaps be considered realistic for the class of ultrasonic flare meters.

In contrast to ultrasonic meters, L2F flare meters have virtually no limits for  $V_{\max}$ . An extreme maximum velocity, up to  $V_{\max}=720$  m/s, was reported during the testing of the L2F velocimeter in a recent supersonic aircraft<sup>8</sup> test.

The minimum velocity for Photon Control's OFM is defined by presence of particles - the dirtier the gas, the lower  $V_{\min}$  is possible. It has been shown that flow through the OFM can be measured down to  $V_{\min}=0.1$  m/s, as confirmed by testing in the flow loop at CEESI described below. Testing for a high  $V_{\max}$  is limited in larger pipes by the limitations imposed by the

available flow testing facilities. L2F OFM have been tested up to  $V_{\max}=100 \text{ m/s}$ <sup>9</sup>, which is used to define the L2F turn-down ratio as 1000:1.

### **1.3.2 Other Optical Meter Types**

There are a number of other optical meter types using different principles, and these are listed briefly for completeness.

#### **1.3.2.1 Optical Scintillation Meters**

Ting-I Wang<sup>14</sup> described an OFM whose operational principle is based on a scintillation technique, or registration of variations in refraction of the light beam caused by local fluctuations of the refractive index produced by turbulence and heat exchange in the gas. The scintillation OFM is the only gas flow meter whose performance improves with turbulence.

An improved version of the scintillation OFM called the "Laser-Two-Beam", or L2B meter is offered by Photon Control for larger nominal bore pipes.

#### **1.3.2.2 Optical Absorption-Based Meters**

Liquid hydrocarbons and water absorb energy more than gases in the IR region. This effect was the basic operating principle of an absorption-based OFM originally proposed for non-gaseous flow applications, such as asphalt and cement production.<sup>12</sup>

The technique was attempted recently for flare gas measurement, although laboratory testing using simulation media of air and water droplets was able to reach only  $V_{\min} = 0.4 \text{ m/s}$ .<sup>13</sup>

The principle of the IR-absorption meter is illustrated in Figure 3. Two collimated beams from IR LEDs or IR lasers cross the pipe perpendicular to the gas flow. The presence of hydrocarbons or water droplets in the flow causes changes in the optical transmission, which is detected in each channel. A cross-correlation technique is used for calculation of transit time.

An absorption-based meter requires the presence of large water droplets that discretely cross the beams amid turbulent hydrocarbons. Uniformly distributed water vapour and/or methane lead to static changes of the absorption, which can make transit time measurement very difficult.

A fundamental drawback of the absorption method is that it actually does not provide averaging across the pipe. It is probably this effect which is responsible for an average of 15% error being recorded during the lab testing of the IR absorption meter reported by NEL<sup>13</sup> at the NSFMW in 2006.

#### **1.3.2.3 OFM Based On Sagnac Effect**

Similarly to ultrasound, light passing along and against the gas flow will have different phase velocities which are related to the gas flow velocity. This difference can be detected using the Sagnac effect; the method was first described and demonstrated by Blake.<sup>14</sup>

Although encouraging laboratory data has been demonstrated<sup>15</sup>, the Sagnac OFM has never been fully investigated. The meter will be sensitive to vibration of the pipe and flow turbulence; also, one can expect significant beam deviation at a long optical distances due to the temperature gradient in the pipe.

## 2. FLARE METERING BY LASER TWO-FOCUS (L2F) METERS

L2F meters are at present the most intensively studied method of optical gas flow measurement. L2F meters were publicly introduced for flare measurement at the NEL Flare Gas Metering Seminar in 2005.<sup>16</sup>

### 2.1. Laser Two-Focus Design

The L2F consists of an optical head and a signal processing unit, which are connected by a fiber optic cable.

#### 2.1.1. Optical Head.

The basic OFM head developed by Photon Control is designed to fit into a standard ANSI flange and is shown in Figure 5.

An insertion-style optical head as shown in Figure 6 was designed for use in larger pipes, from 6 to 32 inches nominal bore. The optical system is incorporated in a  $\frac{3}{4}$ in stainless steel sleeve, which is installed in the pipe in a similar manner as thermal dispersion mass flow meters. The stainless steel optical head incorporates the delivery and collecting optical system assemblies, which are positioned perpendicular to the flange bore and are insulated from the gas by optical windows.

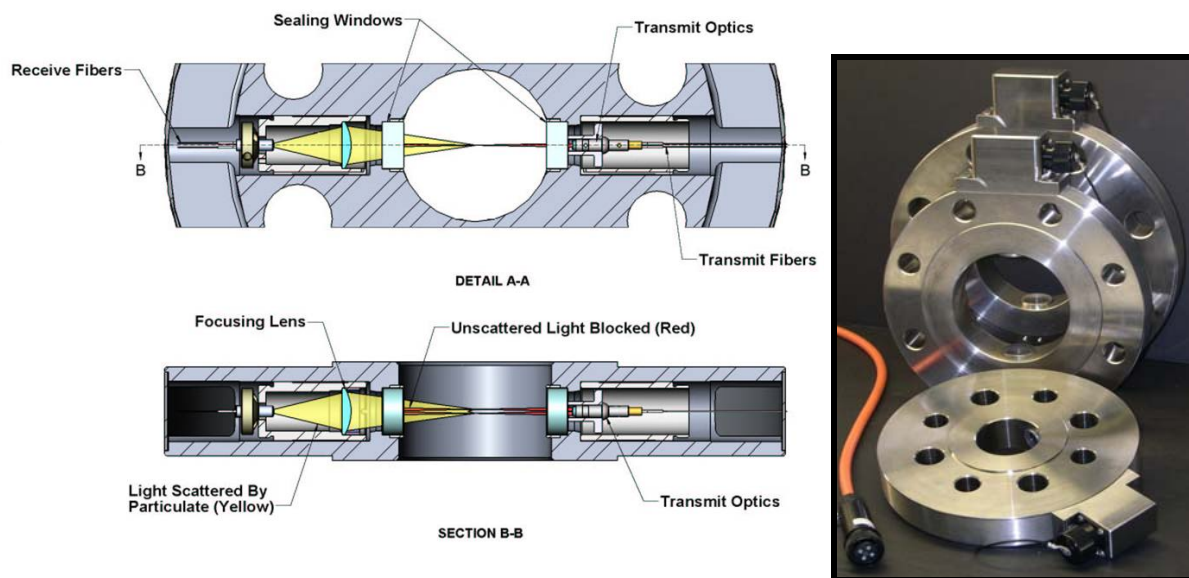
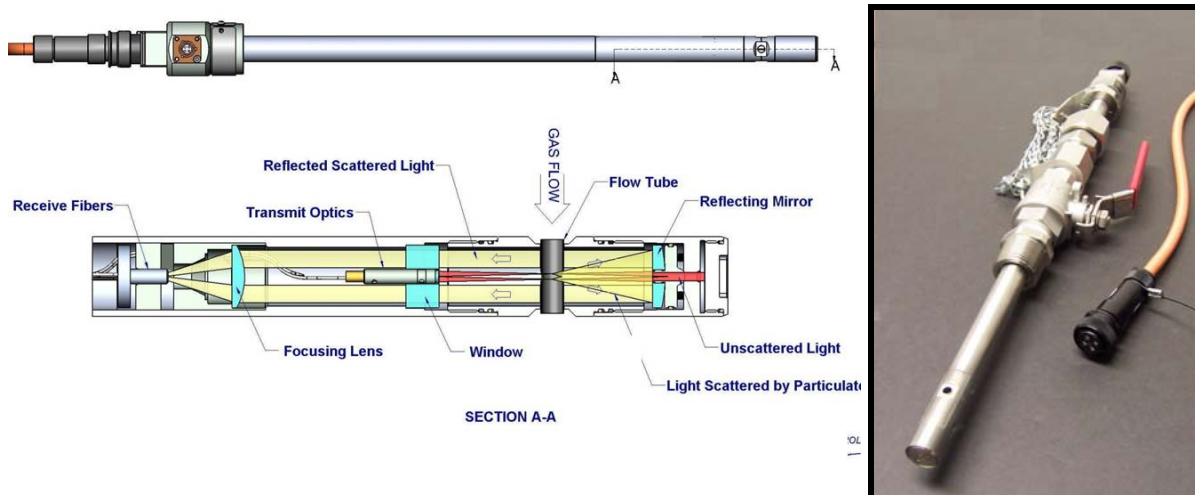


Figure 5. Flange 2-in and 4-in optical heads

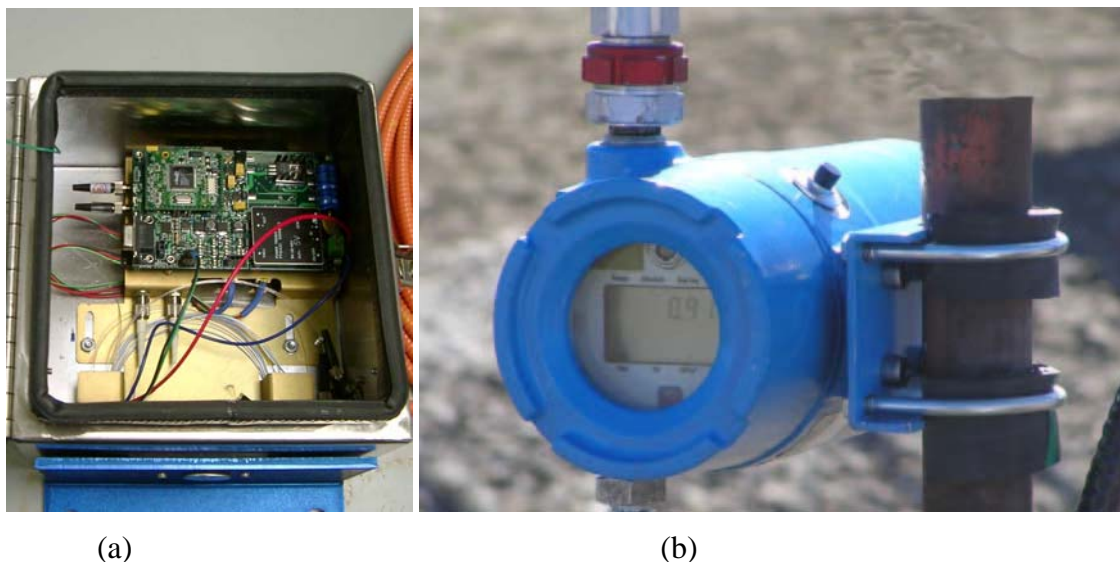


**Figure 6. 3/4-in insertion optical head with a ball valve**

The optical head is typically designed for single-point measurement which is located in the center of the pipe or at a quarter-radius from the pipe wall.

### 2.1.2. Signal Processing Unit.

The signal processing unit (or opto-electronic converter) is designed on one electronic board which fits into a normal NEMA or an explosion proof enclosure. These are shown in Figure 7.

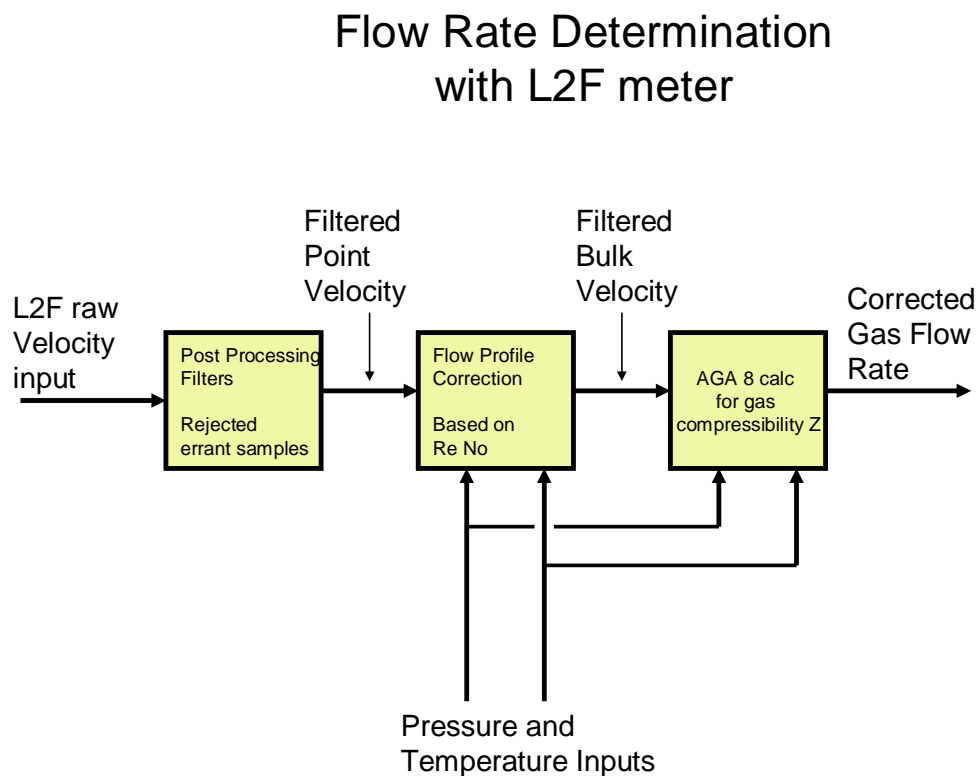


**Figure 7. Signal Processing Unit: (a) NEMA 4X and (b) explosion-proof**

The board incorporates a digital signal processing (DSP) chip with internal analog-to-digital conversion at sample rates up to 12MHz. It has inputs for pressure and temperature transmitters,

so that various flow calculations can be performed. The unit provides typical flow meter outputs: 4-20 mA, frequency and pulse, and RS232 or RS485 digital. The board is powered from 24VDC, the average power consumption is 3 watts.

Signal pulses are collected over a fixed sampling interval, which is determined from the flow rate and number of particles in the gas. The raw flow velocity is calculated using a fast correlation technique (correlogram), the raw velocity data is then input to a post-processing calculation. The flow calculation is accomplished in three stages as is described by Figure 8. The post processing filters average the output and remove spurious readings based on previously calculated data. The flow profile correction is used to calculate the average flow velocity (bulk velocity) from the point velocity reading using a programmable look-up table specific to the piping and meter configuration. The standard volumetric flow rate is determined using AGA8-determined compressibility and the local pressure and temperature.



**Figure 8. Flow calculation block diagram**

### **2.1.3. Fiber Optic Cable.**

The fiber optic cable accommodates a group of single-mode and multi-mode fibers protected by a flexible metal conduit and waterproof indoor/outdoor PVC jacket. The standard length of the cable is 20 meters, but the power budget of the system allows extension of the cable length far beyond 100m.

## **2.2. Testing the L2F meters**

L2F meters have been extensively tested over a 36 month period at several facilities, including:

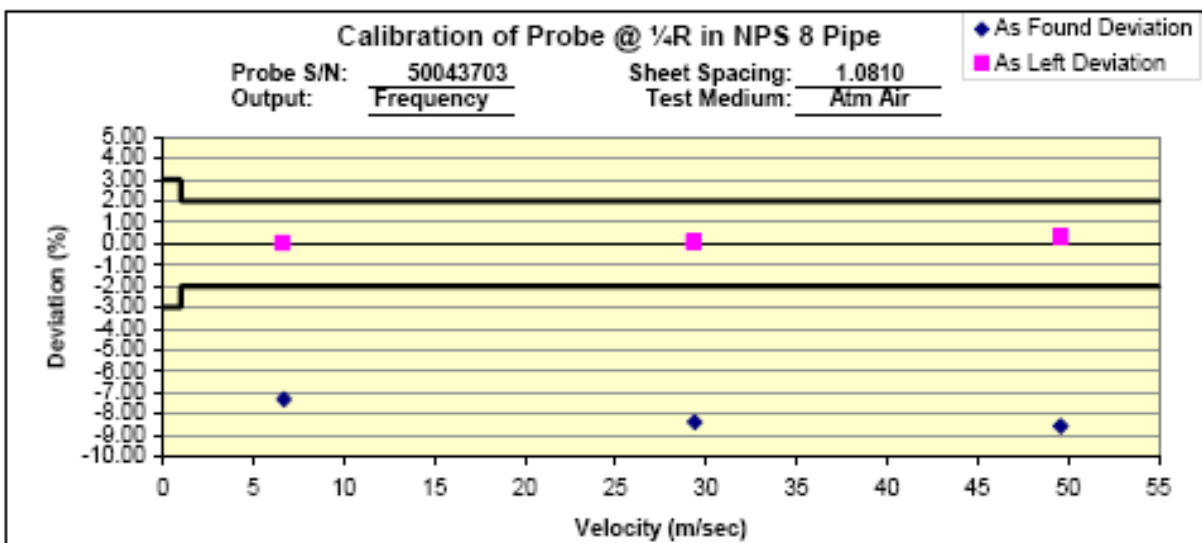


- Coanda Research, Burnaby, BC – testing to determine installation effects, particle size, and flow conditioning requirements;
- Didsbury TCPL Test Loop, Alberta – testing flanged OFMs in natural gas at high pressure;
- Southwest Research Institute, San Antonio, TX - testing in natural gas at low and high pressures;
- Colorado Engineering Experiment Station Inc (CEESI), Nunn, CO – final testing of the insertion OFM for accuracy and installation effects;
- Terasen Calibration Facility, Penticton, BC – testing and calibration against ultrasonic 4-path meter in air flows at low pressure.

### 2.2.1. Velocity Accuracy and Calibration

A set of  $N$  pulses from many scattering events are averaged to produce each data point. This reduces the variation in localized velocity measurement caused by flow turbulence by a factor of  $\sqrt{N}$ .

For example, the standard deviation of the fluid velocity in fully turbulent flow in the center of the pipe is typically 5% of reading. The number of correlated particles is usually within the range of 10 to 100 per sampling interval, therefore, the standard deviation of the velocity measurement is reduced to 0.5% to 1.5%.



**Figure 9. Example of a calibration result for the insertion L2F meter in an 8-inch pipe**

An example of a calibration report is shown in Figure 9. The velocity uncertainty from unknown beam spacing can ordinarily be neglected since the beam spacing is controlled with an accuracy better than 1  $\mu\text{m}$  and the base distance between the laser sheets is set at 1.0 mm. This feature underlines another important advantage of the L2F meter – once it is calibrated, there should be no need to recalibrate the unit in the field. In the same way that ultrasonic meter readings depend only on transducer spacing and difference in time-of-flight, the L2F depends on the fixed beam spacing and measured particle travel time. Absent changes in these two parameters, there should be no drift in the meter.

### 2.2.2. Flow Measurement Range and Accuracy

Detailed testing of the insertion OFM at CEESI was conducted in the summer of 2005.<sup>17</sup> In those tests, the Focus Probe OFM matched the reference within  $\pm 2.5\%$  over the 1.0 to 100 m/s operating range, and within  $\pm 7\%$  over the 0.1 to 1.0m/s operating range. Increased flow instability was observed by the Focus Probe meter in the 0.1 to 1.0m/s range. This is shown in Figure 10.

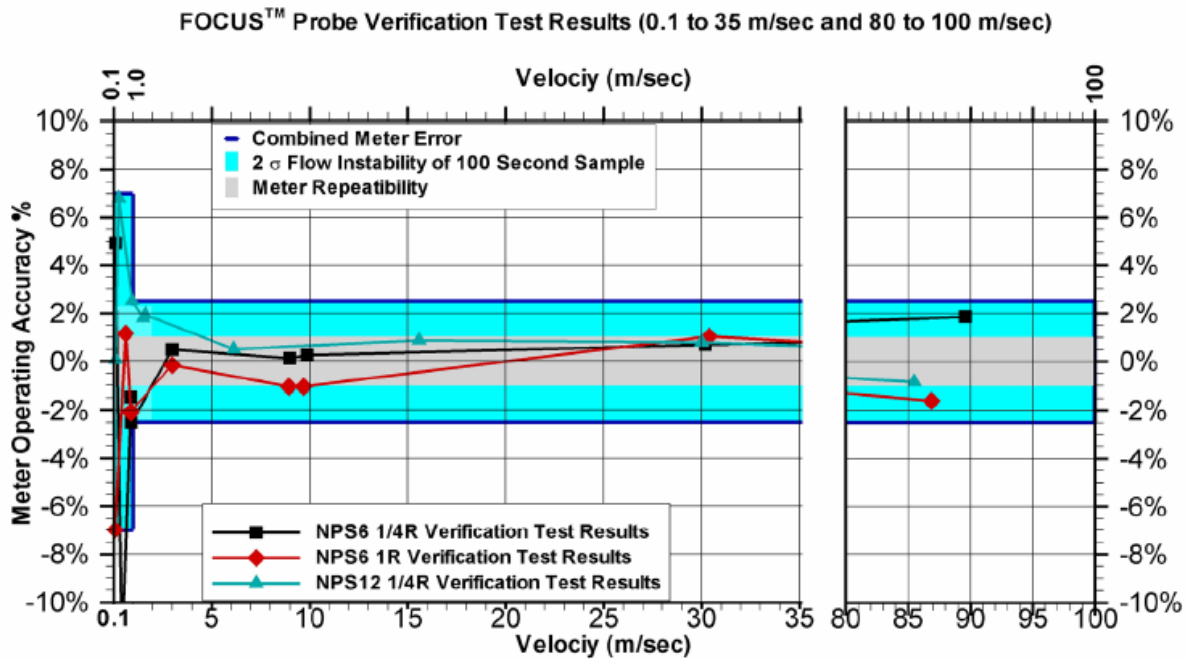


Figure 10. Verification results from testing the Insertion Focus™ Probe Meter in 6-inch and 12-inch pipes at CEESI, Nunn, CO.

### 2.2.3. Flow Meter Installation Effects

Practically all flow meters exhibit installation effects. Some of the flow testing earlier referred to concerned installation effect testing, which were recognized as an important factor when metering with a L2F flow meter.

Testing at CEESI in Colorado, included:

- 45 degree header installation
- 90 degree header
- Two elbows out of plane

for several line pipe sizes

The graphs shown below in figures 11A-C illustrate the installation bias effects recorded for some of the header configurations, sizes and gas velocities tested at CEESI. Further details are provided in Reference 17.

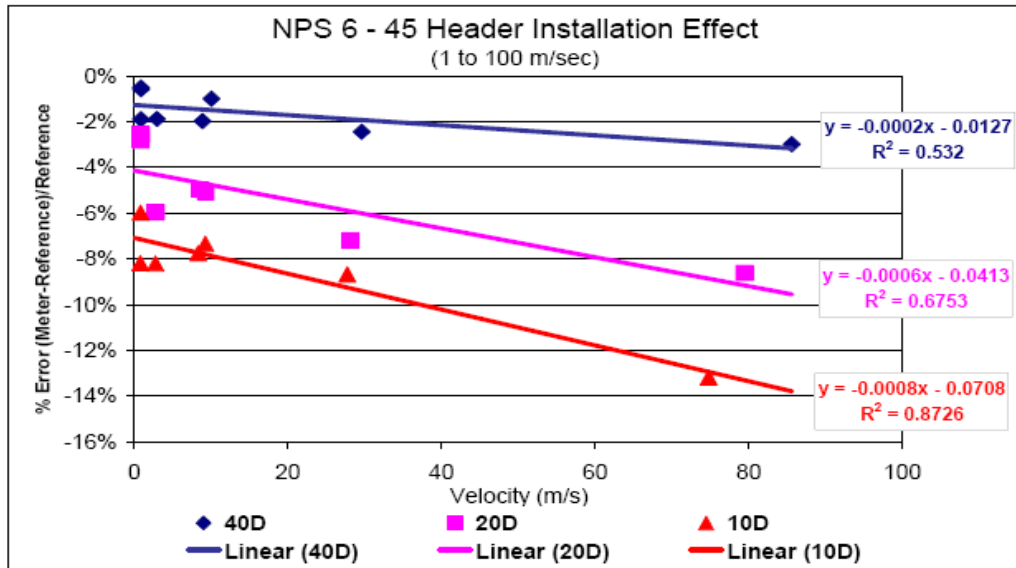


Figure 11A. 6-inch NB – 45 degree Header Installation Effect from CEESI

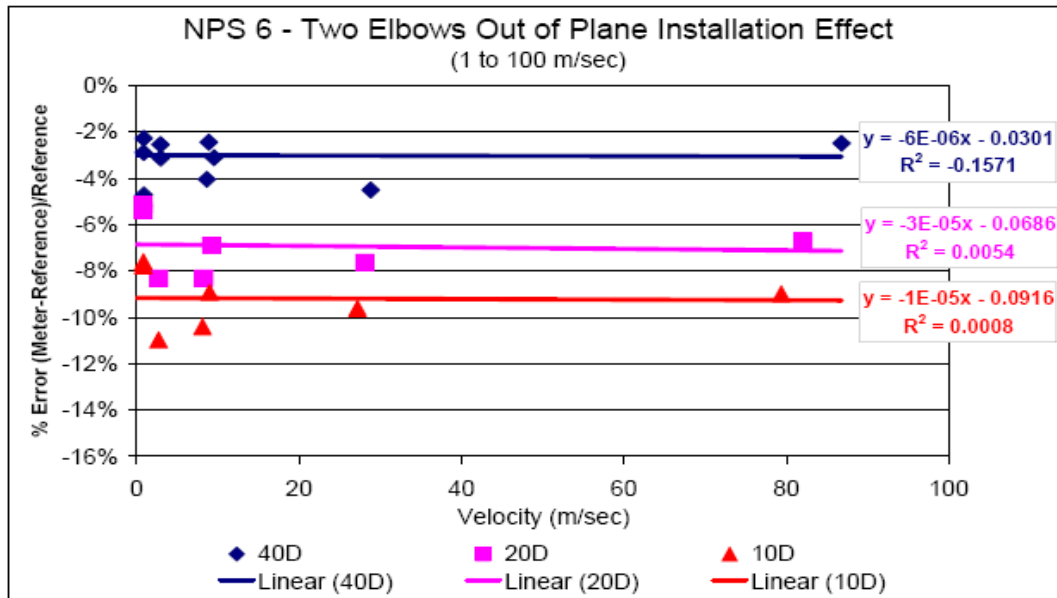


Figure 11B. 6-inch NB Two Elbows out of Plane Installation Effect from CEESI

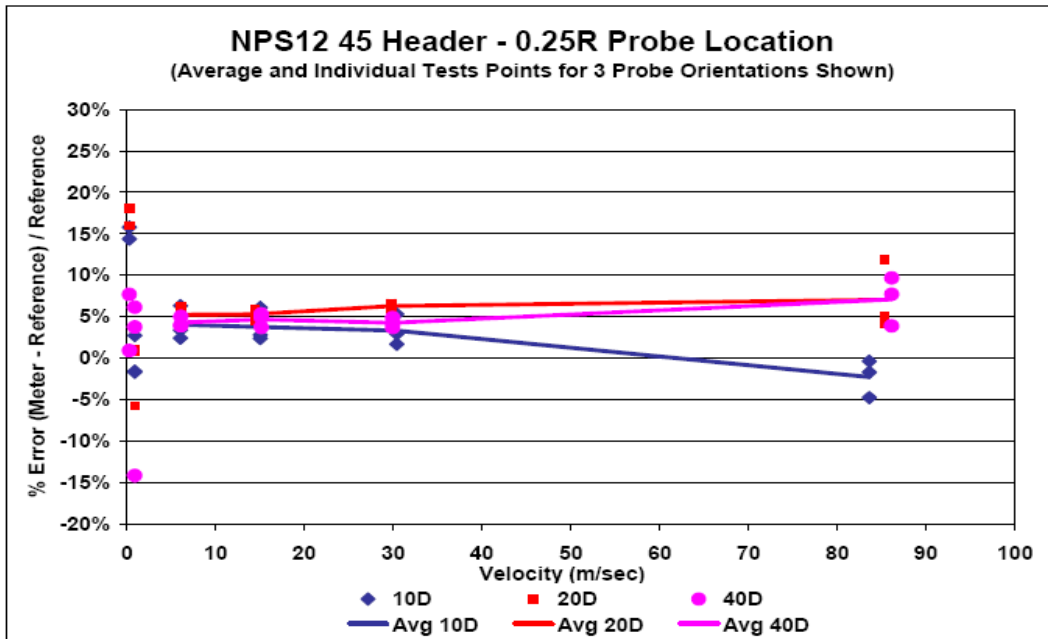


Figure 11C. 12-inch NB – 45 degree Header Installation Effect from CEESI

### 2.3. Practical Implementation of the L2F Meters

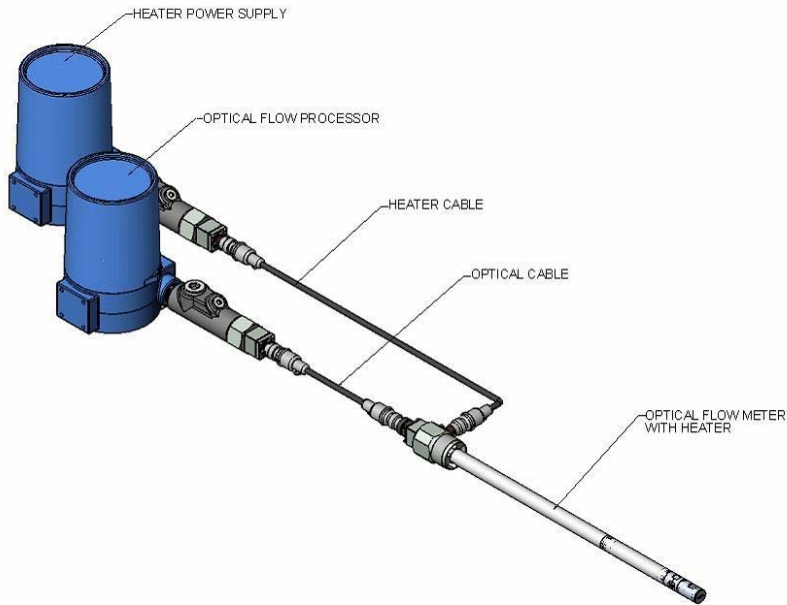
With any new technology, there are often numerous practical issues that a user may encounter in a Real-World installation. These will be addressed in the following sections.

#### 2.3.1. Mitigation Of Fouling Effects

Contamination of optical components is an inevitable concern when contemplating a flow measurement system using optics in a flare gas environment. This is especially so with flare gas, which generally have a variable composition and liquid content. Photon Control addressed this issue at the beginning of its Focus Probe development by implementing a shroud design.<sup>17</sup> This solution dramatically improved the resistance of the device to concurrent liquid hydrocarbons, which are known to cause problems for other types of flare meters.

Another improvement aimed at liquids dropping out of the gas was the application of heated windows. In early commercial installations it was discovered that many flare and biogas facilities deal with wet gas. Keeping the windows warmer than the ambient gas prevents laser light from scattering due to foggy or wet window surfaces. Currently this is a standard feature for all L2F OFMs produced by Photon Control.

In Figure 12 the Focus Probe Meter is shown with heated window kit installed.



**Figure 12. Insertion Focus™ Probe with heated windows to prevent condensation.**

### **2.3.2. Installations In The Field**

Over 25 laser-two-focus OFMs have been supplied and installed in the field since commercialization began in late 2005. Table 1 give the details of some of these installations. Applications include flare gas and associated gas flow measurement in pipe sizes from 2 inches to 24 inches, fuel gas measurement in natural gas pipelines, and biogas flow metering.

There have been a number of enquiries for larger wafer-type OFMs for separator offgas. However these will require substantial engineering, and proving.

A larger 42-inch NB pipe flare system has also been supplied for the Statoil operated Tjeldbergodden Methanol Plant, Norway. .

UPDATE 18-Sep-07

DATE	COMPANY	PLANT	PROV/STATE	QTY	METER	PIPE DIA	PLANT/	INSTALL	DAYS
			COUNTRY		TYPE	Inch	APPL.	DATE	IN SER
24-Mar-06	Blackrock Ventures now Shell Canada	Peace River 1-26-83-15w5	Alberta Canada	1	Probe	8	Oil Battery	9-Aug-05	777
24-Mar-06	Canetic Energy	Nottingham 2-34-5-2 W2	Saskatchewan Canada	1	Wafer	2	Oil Battery	17-Nov-05	677
3-May-06	ConocoPhillips	Vulcan	Alberta, Canada	1 1	Probe Probe	10 24	Flare Stack Flare Stack	28-Feb-05 28-Feb-05	939 939
30-Nov-05	ConocoPhillips	Ghostpine	Alberta, Canada	1 1	Probe Wafer	16 2	Flare Stack Fuel Gas	27-Sep-05 13-Jun-05	728 834
23-Dec-05	ConocoPhillips	Marengo	Saskatchewan	1	Probe	6	Oil Battery	1-Aug-05	785
16-Aug-05	EOG Resources	Grand Prairie	Grande Prairie, Canada	1	Wafer	4		18-Aug-05	768
7-Apr-06	ConocoPhillips	Wembley	Alberta, Canada	1	Probe-XL	16	Flare Stack	10-May-06	92
11-Aug-06	ConocoPhillips	Valhalla 16-14-75-9 W6M	Alberta Canada	1	Wafer	2	Separator Off Gas	10-Aug-06	411
25-Jul-06	ConocoPhillips	Valhalla - 7-22-75-9-W6M	Alberta Canada	1	Wafer	2	Fuel Gas	12-Sep-06	378
26-Oct-06	PetroCanada	Hanlan Robb	Alberta, Canada	1	Probe	12	Flare Stack	7-Nov-06	322
26-Oct-06	PetroCanada	Hanlon-Robb	Alberta, Canada	1	Wafer	2	Flare Stack	18-Oct-06	342
26-Oct-06	DPH/ ConocoPhillips	Cessford	Alberta, Canada	1	Probe	14	Flare Stack	11-Oct-06	349
8-Aug-07	Plains Marketing	High Prairie (780) 523-4690	Alberta Canada	1 1	Probe- HTR Wafer	10 4	Flare Stack Purge gas	20-Feb-07 4-Jul-07	217 83
18-Jun-06	GVRD	Richmond	B C, Canada	1	Probe- HTR	8	Biogas	28-Sep-06	362
15-Feb-07	Evergreen Packing	Pine Bluff	Arizona, USA	2	Probe- HTR		Fuel Gas	TBD	TBD
12-Jul-07	ConocoPhillips	Saddle Hills	Alberta, Canada	1	Probe	6	Flare Stack	8-Sep-07	17
10-May-07	Innotech		Russia	1	Probe	6	Associate d Gas	10-Jun-07	
15-Sep-07	GVRD	Lion's Gate	B C, Canada	1	Probe - HTR	4	Flare Stack	TBD	TBD

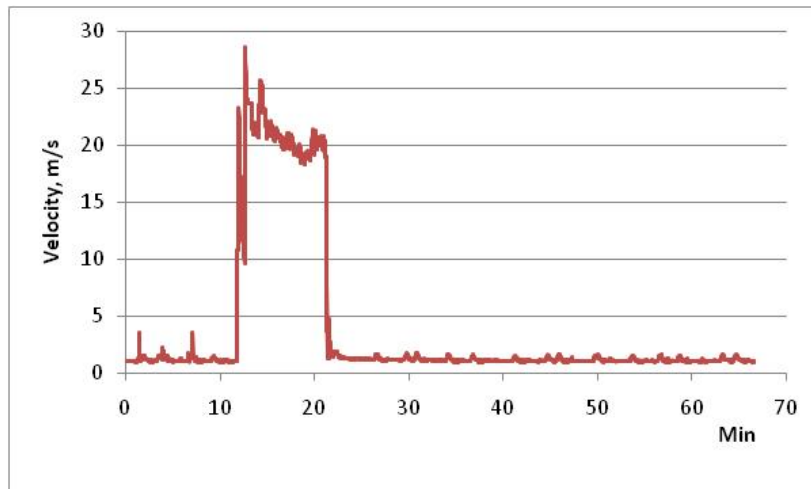
**Table 1 – Photon Controls OFM commercial installations**

Figure13 shows a typical installation of the insertion OFM in a flare line. It has been found that horizontal orientation of the probe is preferable in order to avoid trapping liquids in the space around the shroud.



**Figure 13. Insertion Focus™ Probe installed in a 12-inch pipe, gas processing plant, Alberta, Canada**

Figure14 shows a flare event metered with a Focus™ Probe flowmeter. The device was measuring a base line of 1.1 m/sec when the velocity rapidly increased to about 28 m/sec, decreasing to and holding at 20 m/sec during the plant incident.



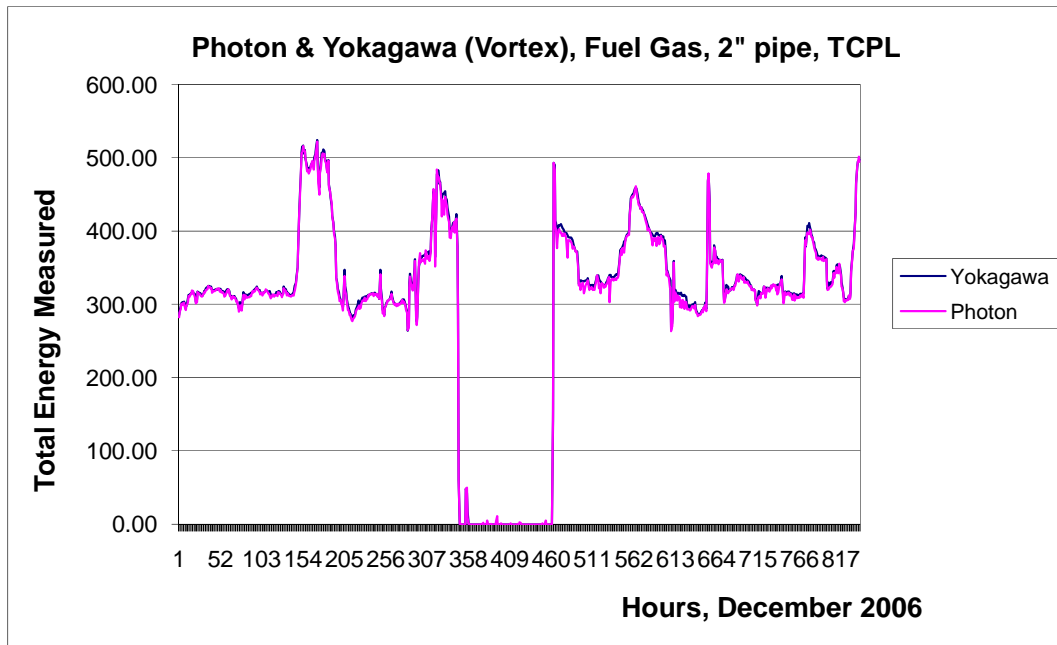
**Figure 14. Flare event recorded by Focus™ Probe meter, base line 1.1m/sec**

### 2.3.3. Performance Of The Flanged OFM

The flanged OFM (Figure 5) can operate at high pressures and temperatures, and creates no additional pressure drop in the pipe. Initially designed for pipeline gas measurement, the flanged OFM works perfectly well for fuel gas measurement and well monitoring.

Figure 15 shows an example of total energy recorded by a 2-inch OFM when compared with a vortex flow meter installed in the same fuel supply line at the Crowsnest TCPL facility gas compressor station. The total energy was calculated based on gas volume metered and the gas

energy derived from the gas composition measured by a local gas chromatograph. The data show that the OFM agrees with the Vortex meter previously approved by Measurement Canada. In general the discrepancy between the two meters is within  $\pm 1\%$ .



**Figure 15. Comparison of a flanged L2F and a 2-inch Yokogawa vortex flow meter in a fuel gas line.**

#### **2.3.4. Wet Gas Flare Measurement**

The majority of commercial OFM installations occur without the benefit of a comparison with other meters. OFMs are supplied calibrated from the Photon Control production facility.

A rare case of being able to compare the results between an OFM and a conventional meter is shown in Figure 16. Here, the flow data from an OFM and that from a thermal mass meter are presented, both measuring low pressure biogas at the Lulu Island waste treatment plant in Richmond, British Columbia.

The reason for installing the OFM was that the user had expressed concern about significant apparent over-readings by the thermal mass meter, especially in warm weather. Direct comparison with the OFM demonstrated a discrepancy between the two devices.

Whilst the OFM averaged about 1 m/sec almost continuously, the reading from the thermal mass meter steadily rose to as much as 65 m/sec after several days. The readings from the OFM matched the calculated flow rates based on the total amount of energy provided to the generator.



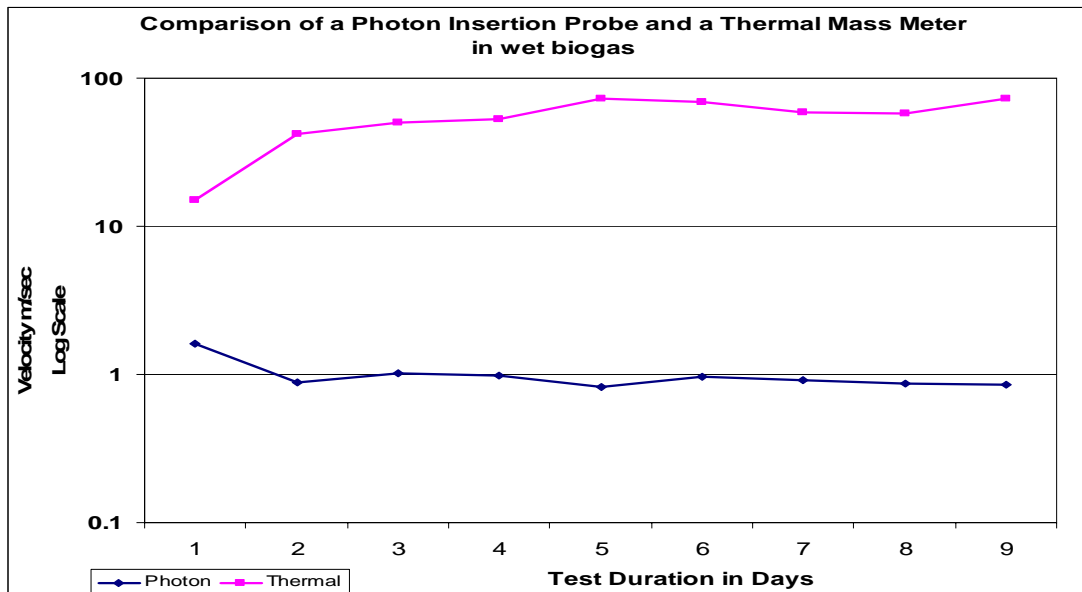


Figure 16. Insertion OFM against thermal mass meter in a 16-inch pipe, biogas plant

### 3. CONCLUSIONS

A recent editorial in The Wall Street Journal, it was reported that a World Bank-financed study valued the amount of flared gas in 2006 as being about \$40 billion, and due to a variety of reasons this value had risen by 14% from 2004. It also noted that flaring had dropped significantly in two countries, Norway and Canada, due to implementation of measurement controls and a stiff ‘carbon tax’. It is interesting that in both these countries home-based flare metering initiatives have been developed and continue to be enhanced.

The product related in this paper is a direct result of vision and partnership between an Optical sensor manufacturer with R&D capability and an Oil and Gas Operator.

Through many years of flare metering, the authors have come to the conclusion that there is no silver bullet when it comes to flare metering. The authors have direct experience with many applications and installations, both onshore and offshore, none of which have been 100% satisfactory.

These issues include:

- Limited accuracy in the low end of the meter range ( $\pm 15\%$  or more inaccuracy), where probably 95% of all flare and vent flows occur.
- High cost of installation and maintenance
- Limited rangeability, meaning for some regulators, there is a need for multiple meters to cover the full flow range of the flare
- Composition dependency
- Flow restrictions

By thinking “outside the box”, and based on preliminary discussions and a full understanding of both COPC and the local regulatory requirements, COPC began to work with Photon Control to test their Optical meter at a sour gas facility. As with any new product there were issues to overcome. The testing revealed that the meter needed:

- (1) more robust electronics,
- (2) a protective shroud,
- (3) a way of retrieving the probe without shutdown (retractable device), and
- (4) a calibration curve to move to within an acceptable accuracy of +/- 5%.

The parties worked through these issues together, and COPC now have seven flare metering installations. These installations have now accumulated about 11 man-years of operation time and are functioning correctly.

These installations are now able to maintain a closer plant balance, which gives the impression that the meters are more accurate and dependable than any previous flare metering devices. The COPC Operations and Engineering personnel are comfortable making facility decisions based on the meter information.

The advantages of accurate flare metering include:

- meeting Regulatory and environmental requirements,
- understanding your facility process, and
- making decisions based on good data.

The return on capital employed to install these meters was minimal compared to the benefits, and it has, it is felt, been adequately repaid based on a reduction in the loss of background gas. In many facilities a large quantity of background gas goes up the stack unnoticed. Flare reduction is not just an environmental responsibility, it affects the facility's bottom line. Wasted gas is lost profit, and more importantly an unnecessary environmental load.

COPC are now in a position where there is trust in the flare measurements, following close to 11 man-years of operation, and using the axiom that you "cannot optimize what you have not measured", are now in a position to optimize and manage an area of the facility operations which heretofore had been unmanageable.

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