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MAXIMUS™ OVERFILL DIAGNOSTIC SYSTEM FOR LP GAS TANKS

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Abstract

This paper presents a specific non-invasive technology developed by Adept Science & Technologies, LLC (ASCENT) for use on LP Gas tanks. The technology can satisfy a revision to the Railroad Commission of Texas "Liquefied Petroleum Gas Safety Rules", which calls for LP Gas vehicle owners to periodically verify the performance of overfill prevention/protection devices (OPDs). This paper will also discuss how the same technology will provide a stop-fill signal to bobtail operators while filling stationary residential and small commercial sized LP Gas tanks.

Introduction

The industry is now limited to invasive methods to determine when to stop filling LP Gas tanks. The use of outage gauges (AKA fixed liquid level gauges or “spitter valves”) is the commonly accepted method to decide when the max fill level has been reached. Leaving these gauges open during refilling (a common practice) brings about safety risks, loss of product, and liability concerns. When looking at an individual fill, the loss of product is not significant. However, on a national scale, with thousands of fills per day, it is estimated these losses add up to ~2 trillion BTUs/yr (LP Gas + anhydrous ammonia).

The intended use of the Maximus overfill diagnostic instrument is to diagnose if an OPD is working properly. A fixed liquid level gauge does not perform this function. In the case where the fixed liquid level gauge emits liquid before the OPD engages, it does not necessarily mean that the OPD has failed. The OPD may still perform within its operating tolerances (+/- 6%), except no one would know one way or the other because most refueling technicians stop the dispensing pump when liquid is seen coming from the fixed liquid level gauge.

The Maximus instrument will allow the industry to eliminate the practice of opening the fixed liquid level gauge while refueling tanks equipped with OPDs. The refueling technician will have the confidence that the tank was not overfilled. For instance, on a vehicle, in the event a tank is overfilled because of a failed OPD, the refueler will receive immediate indication from the device and the vehicle can be tagged to have the tank's OPD replaced.

The Maximus™ device uses a non-invasive technology to detect liquid levels in LP Gas and anhydrous ammonia tanks. The LP Gas industry can use the Maximus™ technology when the tank is equipped with an OPD (e.g. motor fuel tanks) or when it is not (e.g. residential tanks). The overfill diagnostic instrument is initially to be used on fleet vehicles, although handheld instruments can be used by inspectors or maintenance personnel to spot check OPD functionality of non-fleet vehicles. The instrument can be used in two ways to verify OPD functionality for LP Gas fleet vehicles: (1) permanently installed sensor assembly using the dual channel Maximus™ technology (two point level detecting sensors are installed above and below the prescribed OPD shut-off line); and (2) removable handheld sensor assembly using the single channel Maximus™ technology (single sensor is moved on the outside surface of the tank like a stud-finder to find the liquid level after the fill). Another application is that of a stop-fill mechanism for residential and small commercial tanks when being refilled by a bobtail. Both approaches avoid overfilling tanks, wasting fuel, and polluting.

The Maximus™ instrument utilizes a proprietary acoustic method to non-invasively detect the presence of either liquid or gas inside an LP Gas tank. When the sensor is activated, it indicates if there is liquid or gas inside the tank at the point where it is positioned. Thus, after a fill, the Maximus™ can tell the refilling technician if the OPD worked properly. Alternatively, as the liquid level rises during the filling process, an acoustic signal change indicates the presence of liquid on

the other side of the tank wall. When the liquid reaches a predetermined max fill level, a visual signal (e.g. a light) indicates it is time to stop filling.

For the stop-fill residential system, the Maximus™ instrument has German and Australian competitors. However, both products are invasive and require tank evacuation to install. In addition, every tank would have to be retrofitted to use these devices. The Maximus™ device requires no retrofitting or any tank alteration.

Body

Technology Description

The Maximus™ instrument draws from a patent licensed from a Los Alamos National Laboratory scientist. This core technology, complemented by additional ASCENT intellectual property (in new science as well as in proprietary hardware and software), constitutes the Maximus™ instrument know-how. The instrument has two sub-systems: (1) an electronics assembly; and (2) a sensor assembly. The electronics generate sound waves and process the received signals. The sensor assembly is attached to the outside of the tank. Within each sensor assembly, there are two transducer elements (one transmits the sound wave; the other receives the signal).

The electronics generate an inaudible sound which, through the transducers, resonates in the tank wall. The tank wall responses are monitored as the tank is filled. There is a distinct difference in the received signal between when there is liquid or vapor phase LP Gas (inside the tank) at the point where the sensor is placed.

The dual channel Maximus™ instrument uses two points of level detection (Fig. 1). When used for OPD verification, the transducer subassemblies are labeled “TOP Sensor” and “BOTTOM Sensor.” The sensors are positioned to straddle the level at which the OPD is supposed to shut-off the flow (e.g. 80% full). The desired distances above and below the OPD shut-off level must be confirmed by the tank manufacturer or the OPD installer (OPD is often installed by the tank manufacturer).

Two LEDs on the instrument are used to indicate OPD functionality. Both LEDs will glow green if two conditions are satisfied: (1) top sensor is above the liquid level; and (2) bottom sensor is below the liquid level. If the tank is overfilled, the top sensor LED will be red because it detected liquid at that point. Similarly, if the tank is underfilled, the bottom sensor LED will glow red because no liquid is detected at that point.

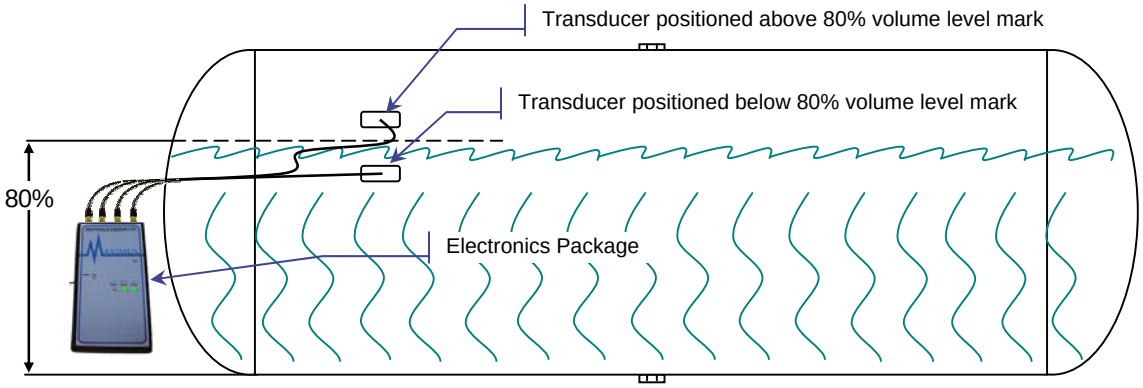

Fig. 1. LP Gas Tank Schematic with Maximus™ Dual Channel Technology

The single channel Maximus™ is used for single point level detection (Fig. 2).

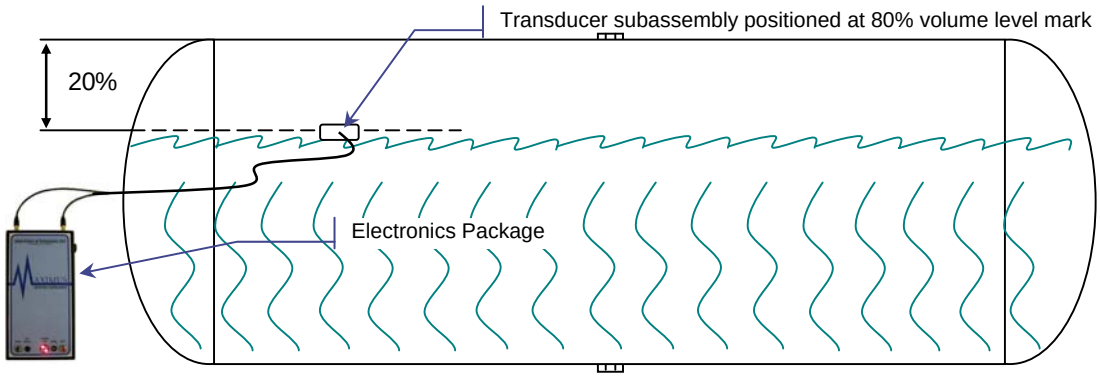

Fig. 2. LP Gas Tank Schematic with Maximus™ Single Channel Technology

Regulatory Issues

The Maximus™ instrument responds to a revised Texas Railroad Commission ruling that requires: (1) LP Gas fleet operators to keep outage gauges shut while refilling tanks equipped with OPDs; (2) documented periodic verification of the OPDs; and (3) OPD replacement every two years.[1]

In the interest of the project and to ensure on-going VIA Metropolitan Transit (VIA) cooperation, ASCENT met with the Texas Railroad Commission (RRC) in early April 2006. ASCENT submitted to the RRC that as long as LP Gas fleets were using the Maximus™ Overfill Diagnostic System on a regular basis, they should not be required to change their OPDs every two years. The RRC preliminarily indicated that the fleet may receive an exception to the every two year OPD replacement requirement as long as they had satisfactory data documenting the regular use of the Maximus™ instrument and paperwork showing that failed OPD's were replaced.

In August 2006, ASCENT engineers met with a RRC inspector to demonstrate the fully installed Maximus™ overfill diagnostic system. An important clarification was made to the RRC just prior to this visit. There was concern that the Maximus™ instrument was attempting to replace the function of an OPD. Such an undertaking was not part of this initial work. This would require satisfying the equivalency requirements in NFPA 58.[2]

ASCENT asserts that the Maximus™ overfill diagnostic instrument is not meant to be used as a fill monitoring device in lieu of the fixed liquid level gauge or the OPD (i.e. the instrument is a point sensor that is used post-fill, not used continuously during the fill). It is a diagnostic instrument only. There are no perceived equivalency issues involved that would restrict its use.

ASCENT submitted the Maximus™ single channel electronics for certification to UL 913 listing [Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 for Hazardous (Classified) Locations] in May 2006. In August 2006, ASCENT received notification of approval and is now authorized to apply the certification mark on the Maximus™ Overfill Diagnostic Instrument.

ASCENT now plans to apply for a project amendment request with the nationally certified testing laboratory to include the small changes and certify the Maximus™ dual channel electronics under UL 913. Such certification approval is anticipated in November 2006.

Data Collection – March 2006

To support the claim that OPDs do not need to be replaced if a Maximus™ instrument is periodically used, a specific data collection effort was conducted in March 2006. Tests were conducted at VIA to:

- Confirm the final Maximus™ system design;
- Finalize logistics for the 20-bus installation; and
- Determine where the OPDs typically stop the filling process.

The Maximus™ dual channel system tests were successful. VIA's bus #729 was set aside for extensive testing. All modes of instrument operation were tested by moving the two transducers subassemblies above and below the liquid level. The Maximus™ instrument functionality was verified by infrared camera photos showing that the ASCENT transducers were straddling the liquid level (Fig. 3 and 4). To create a temperature differential for the infrared camera to work, a small amount of LP Gas was vented to cool the liquid portion of the tank.

Fig. 3. Setting up Infrared Camera at VIA

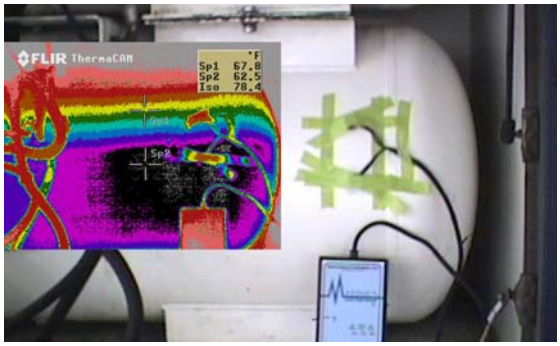

Fig. 4. Infrared Camera Picture Overlaid with Actual Photo of Maximus™ Instrument Temporary Installation

Fig. 5. Measuring the Maximus™ Detected Liquid Level after Refueling

Subsequently, data was collected from six buses during VIA's nightly fast-fill operation (Table 1). The tanks were tested with the Maximus™ instrument when the OPD stopped the flow during refueling. The arc length was measured (using a tailor's measuring tape) from the top weld of the tank to the point on the side of the tank where the Maximus™ instrument detected the LP Gas liquid level (Fig. 5). A single channel Maximus™ unit was used to non-invasively detect the liquid level by moving the magnetized sensor head assembly up and down the surface of the tank shell along the vertical axis.

Table 1. Data Collected March 2006 at VIA

Measurements of Arc Length from Top Weld on Tank to Line Where the Liquid Level was Detected by Maximus™ Point Sensor			
Bus #	Side Tank	Lower Rear Tank	Upper Rear Tank
665	Did not fill tank	11.5"	OPD did not stop filling process
683*	9.5" (95% full)*	11.25" (0% full)*	11.75" (80% full)*
708	9.5" **	11.5"	OPD did not stop filling process
712	10.375"	11.5"	11.5"
725	10.0"	11.25"	11.25"
729	10.5"	OPD did not stop filling process	11.75"

Sleegers Engineering Inc. (Sleegers) advised that the OPD's in their tanks (VIA's tanks are made by Sleegers) are positioned to operate at the 78% full level to allow for an extra safety margin. Sleegers provided tank drawings for their 18" and 20" tanks that showed the 78% arc lengths (Fig. 6). Reportedly, the OPD's are accurate within ±6%. The data collected to date has shown that permanently mounted transducers at the 70% and 85% full lines is how to proceed (Table 2).

Table 2. Arc Lengths for Specific Volume Percents on VIA's LP Gas Bus Tanks

Tank Diameter	70%	78% Level	85%
18" (Side Tank)	11.3"	10.0"	8.6"
20" (Rear Tank)	12.5"	11.2"	9.5"

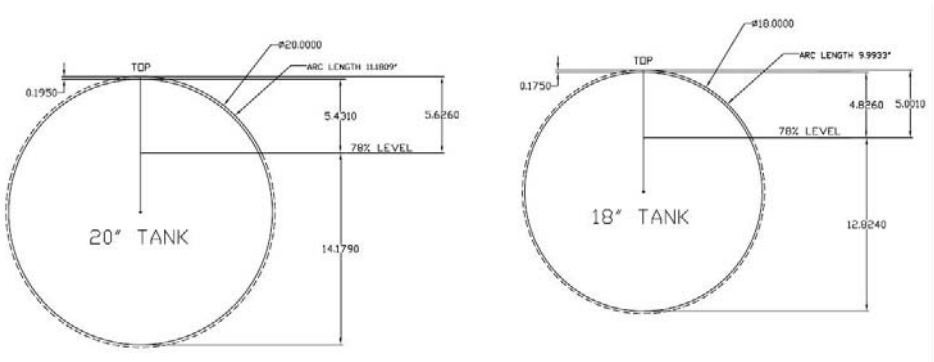

Fig. 6. Sleegers' LP Gas Tank Cross Sectional Views Showing Arc Lengths for 78% Full Volume

3 out of 17 refuelings on the tested bus tanks were not stopped by the OPDs. The refueler turned off the pump after noticing a mostly liquid cloud of LP Gas streaming from the tank's outage gauge. Then, when the outage gauge indicated that liquid has reached its bottom opening, the refueler added up to five more gallons to see if the OPD would trigger. If it did not trigger, then it was concluded that the OPD required further investigation to make sure it works properly.

Possible causes for such undesirable occurrences include:

- defective OPD;
- OPD is positioned inside the tank higher than it should be;
- outage gauge is positioned lower than it should be; or
- combinations of the above.

Data Collection – June 2006

In the same manner as in March 2006, 81 tanks were investigated in June 2006. The collected data (Table 3) confirmed the suspicions on two of the three suspect tanks found in the March 2006 tests. Six of the 69 tanks investigated (~9%) were flagged for OPD replacement after these tests. Unlike the March 2006 tests, the arc length was measured for every tank, regardless of whether or not the OPD stopped before the outage gauge indicated liquid. This was to determine if the margin of error exceeded the shut-off valve tolerance of the OPD (i.e. whether or not the OPD failed).

Table 3. Data Collected June 2006 at VIA (part 1 of 1)

Data Collection Log: June 12-13 Monitoring of LP Gas Bus Refilling							
		Before Outage Gauge	After Outage Gauge		Maximus™ Reading		
Bus #	Tank	OPD Shut-off	OPD Shut-off	Volume before Stop-fill (gal)	Arc Length* to Liquid (in)	Variance from 78%** full (in)	Comments
114	Side	Yes	N/A		11.25	-	Trolley - Sleegers 18x30
114	Rear	Full	N/A		10.75	-	Trolley - Sleegers 18x30
663	Side	Yes	N/A		10.50	0.51	Outage gauge not working
663	Lower	Yes	N/A		11.00	-0.18	
663	Upper	Yes	N/A		11.25	0.07	
665	Side	Full	N/A		10.25	0.26	
665	Lower	Full	N/A		11.00	-0.18	
665	Upper	No	?	?	11.00	-0.18	
669	Side	Yes	N/A		9.50	-0.49	
669	Lower	No	No	>10	7.50	-3.68	Operator shut-off required
669	Upper	No	Yes	?	9.00	-2.18	
680	Side	Yes	N/A		9.25	-0.74	Outage gauge not working
680	Lower	Yes	N/A		11.25	0.07	
680	Upper	No	No	>8	7.75	-3.43	Operator shut-off required
683	Side	Yes	N/A		10.25	0.26	
683	Lower	No	Yes	2	10.75	-0.43	
683	Upper	No	Yes	?	12.00	0.82	Shut-off, then restarted and allowed to fill until OPD triggered - Outage gauge not working
684	Side	Yes	N/A		10.75	0.76	
684	Lower	Yes	N/A		11.00	-0.18	
684	Upper	Yes	N/A		11.25	0.07	
686	Side	Yes	N/A		10.50	0.51	
686	Lower	No	Yes	2	10.75	-0.43	
686	Upper	Yes	N/A		11.00	-0.18	
690	Side	Yes	N/A		10.00	0.01	
690	Lower	Yes	N/A		11.25	0.07	
690	Upper	Yes	N/A		12.25	1.07	
692	Side	Yes	N/A		10.50	0.51	
692	Lower	Yes	N/A		11.25	0.07	
692	Upper	Yes	N/A		11.50	0.32	
693	Side	Yes	N/A		10.75	0.76	
693	Lower	Yes	N/A		10.50	-0.68	
693	Upper	Yes	N/A		10.50	-0.68	
696	Side	Yes	N/A		11.00	1.01	
696	Lower	Yes	N/A		11.00	-0.18	
696	Upper	Yes	N/A		11.50	0.32	
699	Side	Yes	N/A		10.00	0.01	
699	Lower	No	Yes	0.5	11.50	0.32	
699	Upper	Yes	N/A		12.00	0.82	
700	Side	Yes	N/A		10.25	0.26	
700	Lower	Yes	N/A		12.00	0.82	
700	Upper	Yes	N/A		11.50	0.32	
701	Side	Full	N/A		11.00	1.01	
701	Lower	Full	N/A		11.00	-0.18	
701	Upper	Full	N/A		11.50	0.32	
708	Side	Yes	N/A		10.25	0.26	
708	Lower	Full	N/A		11.50	0.32	
708	Upper	Full	N/A		12.25	1.07	
711	Side	Yes	N/A		9.50	-0.49	
711	Lower	No	Yes	2	10.75	-0.43	
711	Upper	Yes	N/A		11.25	0.07	
713	Side	Yes	N/A		?	-	Questionable data
713	Lower	Yes	N/A		11.50	0.32	
713	Upper	Yes	N/A		?	-	Questionable data
715	Side	Full	N/A		10.25	0.26	

Table 4. Data Collected June 2006 at VIA (part 2 of 2)

		Before Outage Gauge	After Outage Gauge		Maximus™ Reading		
Bus #	Tank	OPD Shut-off	OPD Shut-off	Volume before Stop-fill (gal)	Arc Length* to Liquid (in)	Variance from 78%** full (in)	Comments
715	Lower	Full	N/A		11.25	0.07	
715	Upper	Yes	N/A		11.25	0.07	
716	Side	Yes	N/A		9.50	-0.49	
716	Lower	Yes	N/A		11.25	0.07	
716	Upper	Yes	N/A		11.50	0.32	
719	Side	Yes	N/A		10.00	0.01	
719	Lower	Full	N/A		12.50		
719	Upper	Full	N/A		11.75		
720	Side	Yes	N/A		10.25	0.26	
720	Lower	Full	N/A		11.25	0.07	
720	Upper	No	Yes	?	11.25	0.07	
721	Side	Yes	N/A		10.25	0.26	
721	Lower	Yes	N/A		11.50	0.32	
721	Upper	Yes	N/A		11.25	0.07	
724	Side	Yes	N/A		9.75	-0.24	
724	Lower	Yes	N/A		11.25	0.07	
724	Upper	Yes	N/A		10.25	-0.93	
726	Side	Yes	N/A		10.00	0.01	
726	Lower	No	No	>4	10.50	-0.68	Fill rate slowed towards end of fill. Stopped manually.
726	Upper	Yes	N/A		11.25	0.07	
727	Side	Yes	N/A		10.25	0.26	
727	Lower	Full	N/A		11.00	-0.18	
727	Upper	Yes	N/A		11.50	0.32	
729	Side	No	No	>5	9.00	-0.99	Operator shut-off required
729	Lower	No	No	>5	9.00	-2.18	Operator shut-off required
729	Upper	Yes	N/A		12.00	0.82	
947	Side	Yes	N/A		10.50	0.51	
947	Lower	No	Yes	0.5	10.25	-0.93	
947	Upper	Yes	N/A		10.50	-0.68	

Test Summary	
# of Buses	28
# of Tanks Measured	81
# of Tanks Filled	69
% Total OPD Failures	9%
% OPD Function post Outage	12%

Legend	
Cell Color	Description
	Tank not filled - bus had ~0 hours
	Filling process stopped by OPD
	Issues during filling
	OPD did not stop filling process

*Arc length was measured from tank's top weld to where the Maximus™ Sonic Point Sensor detected liquid level on the shell of the tank.
**Sleegers Engineering Inc.'s arc lengths for 78% liquid level on 20" (rear) and 18" (side) diameter tanks are 11.18" and 9.99" respectively.

These tests reaffirmed the previous conclusion that the transducers should be permanently installed at the 70% and 85% full lines to consistently straddle the level where the OPD is designed to operate.

Work Progress

In August 2006, ASCENT engineers permanently attached sonic sensors to the outside of the tanks at 70% and 85% full (straddling above and below the 80% fill level) on 20 buses. To install the transducers on 20 buses, ASCENT manufactured 120 sensors with wires (20 buses x 3 tanks/bus x 1 wire pair/tank = 60 wire pairs). The sensors were paired up and the wires were pre-cut at lengths prescribed by VIA's maintenance foreman. The wires were routed to a junction box on the side of the

bus. The color-coded wires were stripped and soldered to a 24-pin connector that plugs into the circuit board in the junction box. The junction box consists of a connector receptacle (where the quick-release connector on the Maximus™ instrument plugs in) and a 3-position switch. The switch allows the refueling technician to switch between tanks.

Six Maximus™ instruments were built for VIA (the instrument can be handheld or hung from the filling station ceiling).

In August 2006, ASCENT trained an electronic technician on the Maximus™ system installation. Subsequent to this visit, the user guides and installation manuals for the Maximus™ Overfill Diagnostic Instruments were drafted and sent to VIA for review and comment.

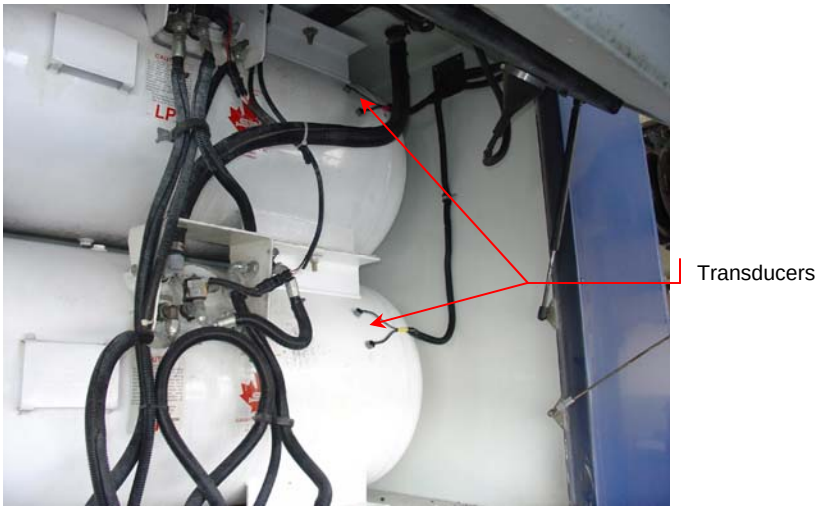

Fig. 7. Permanently Installed Transducer on Two Rear LP Gas Bus Tanks

Fig. 8. Technician Using the Maximus™ Instrument after Refueling the LP Gas Bus Tanks

Conclusion

The dual channel Maximus™ instrument is an effective low cost means to verify OPD functionality.

Acknowledgments

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References

1. Railroad Commission of Texas, "Liquefied Petroleum Gas Safety Rules," http://www.propane.tx.gov/publications/lpg_safetyrules.pdf (accessed May 15, 2006).

2. National Fire Protection Association, "NFPA 58 Liquefied Petroleum Gas Code, 2004 Edition," http://www.nfpa.org (accessed September 5, 2006).