Vent Line and Fugitive Emissions Study

National Gasoline Dispensing Facility

ARID Technologies, Inc.

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30 December 2009

Overview

A study was undertaken at a National Gasoline Dispensing Facility located in Federal Way, Washington. The primary purpose of this study was to quantify gasoline storage tank evaporative emissions. These emissions are comprised of both vent emissions escaping through a pressure/vacuum (p/v) valve and fugitive emissions, which may be emitted anywhere within the storage tank hardware, fuel dispensers, nozzles and vapor piping system. Two secondary goals of this study were to compare the total measured evaporative losses with the hydrocarbon losses estimated by ARID's proprietary Evaporative Loss Model (ELM), and to assess the impact of elevated storage tank pressures on fugitive emissions for a site passing the standard leak decay test.

Approach

ARID supplied an American Meter AC-250 dry gas flow meter equipped with a pulse counter for recording direct measurements of vent line emissions (Please refer to Appendix 1 for technical specifications and other details on the meter). ARID also supplied our sensors and remote data acquisition gear (ARIDAS – ARID Data Acquisition System. Please refer to Appendix 2). This equipment includes an ambient temperature sensor, an atmospheric pressure sensor, and a tank pressure sensor. In addition, a modem is included which allows remote data acquisition for monitoring data in real-time and for downloading batches of data at various time intervals.

The AC-250 dry gas meter and ARIDAS sensors were mounted on the vapor vent line as seen in Figure 1. The modem and power supply for the ARIDAS equipment were mounted inside the kiosk at the site.

Total Evaporative losses are equal to the measured vent emissions plus the fugitive emissions. The fugitive emissions, in-turn are a function of the average storage tank pressure. Therefore, ARID applied a CARB correlation for estimating the fugitive component of the total emissions based on the average pressure data collected by our equipment. (For a station passing a standard 2 inch pressure decay test, there are still allowed leakages).

To check the accuracy of the fugitive correlation, we wanted to make a more direct measurement of the fugitive emissions. One straightforward means to accomplish this is to simply reduce the backpressure on the storage tank system. Since the storage tank pressure will be reduced, the flow through various fugitive leak sources will in-turn be reduced, and the fugitive emissions will then be preferentially directed through the meter and be readily measured.

If one assumes that the Total Evaporative Loss rate is relatively constant (with variables such as temperature, RVP, A/L ratio, ORVR penetration, and throughput being held approximately the same), the measured vent emissions will increase and the fugitive emissions will decrease. By reducing the back pressure on the storage tank system, we did not add any incremental emissions to the environment; we simply re-directed a larger proportion of the "fugitive losses" through our meter for direct measurement.

This is pioneering work, and by making direct measurements, we have very accurately quantified the total evaporative losses at this site. Previous attempts at such emissions studies have relied upon sophisticated air dilution schemes to indirectly process a portion of vent emissions through a complicated sampling train of sensors and flow meters, with questionable results.

Results

The equipment was installed and operational at the Federal Way site on 9 October 2009, and the test equipment was removed from the site on 18 December 2009. The pulse counter on the AC-250 meter yields one pulse for each cubic foot per minute of vapor flow. We stored one minute averages on the pulse counter, and during our 70 day test interval, we accumulated 100,600 pulse count data points. On the tank pressure, ambient temperature and atmospheric pressure data logger, we recorded data every 4 seconds and stored 2 minute averages; thus, ARID accumulated 50,300 data points for each sensor.

The National Gasoline Dispensing Facility is a Stage II vacuum-assisted site with 16 refueling points (Eight Dispensers). From 9 October through 20 November, we collected data with a standard p/v valve on the outlet of the AC-250 meter. This configuration resulted in a relatively high average storage tank pressure of 3.343 inches water column – Case 1. On 20 November, we installed a ball valve between the standard p/v valve and the flow meter outlet. Between 20 November and 18 December 2009, the average storage tank pressure measured 0.592 inches water column – Case 2. The average ambient temperatures were 51 degrees Fahrenheit and 40 degrees Fahrenheit for Case 1 and Case 2 intervals, respectively.

The storage tank pressure profiles are presented below in Figures 2 & 4 for each case. The storage tank pressure data were used as inputs into the CARB correlation for fugitive emissions; these charts are presented in Figures 3 & 5. The concept is to generate a pressure interval chart, where times at certain pressure intervals are quantified and then used as inputs into the CARB correlation matrix.

The fugitive emissions for each case using the pressure data and CARB correlation were:

Case 1: 0.270 cfm (cubic feet per minute of vapor flow)

Case 2: 0.111 cfm

(Please refer to footnote 1.)

The measured vent emissions from the pulse count data were as follows:

Case 1: 0.5038 cfm

Case 2: 0.6983 cfm

(The raw pulse count data is available in spreadsheet format – about 10 MB.)

Thus, the total evaporative emissions for each Case are equal to the sum of vent and fugitive emissions:

Case 1: Total Evaporative Emissions = 0.5038 + 0.270 = 0.7738 cfm

Case 2: Total Evaporative Emissions = 0.6983 + 0.111 = 0.8093 cfm

Discussion of Results

The two cases yield very close agreement, within about 4.5%. Upon further study of this result, an on-going emission rate of 0.8 cfm means that 8,617 gallons of gasoline **vapor** are emitted from a site passing the standard leak decay test each day. If one assumes fugitive emissions from Case 1 (normal case with Stage II and p/v valves in use) comprise about (.27/.77) or 35% of the total emissions; then roughly (.35*8,617) or 3,016 gallons of gasoline **vapor** per day are being emitted from a "tight" site at numerous point sources. Of particular concern, a large portion of these fugitive emissions may be released below grade, eventually condensing and finding their way into groundwater. The equivalent liquid fuel volume lost from fugitive emissions for this case is equal to about 7 **gallons of liquid gasoline** per day (Total liquid fuel losses average about 20 **gallons of liquid gasoline per day**). Again, these emissions are for a "tight site", passing the standard 2 inch water column pressure decay test.

As seen in Figure 2 for Case 1, the storage tank pressure exceeds +2.51 inches H2O for 91.33% of the time. The impact of elevated pressures on fugitive emissions is significant. By reducing the backpressure with the ball valve, we have shown that the "fugitive" emissions predicted with the pressure correlation are accurately measured as "vent" emissions. <u>Furthermore, the p/v valve does not "magically stop total evaporative emissions"; it simply reduces a portion of vent emissions, while at the same time increasing fugitive emissions w/in the vapor piping of the facility.</u>

Table 1 presents summary data for Case 1 and Case 2; showing monthly fuel loss of 591 gallons and 618 gallons, respectively. With the use of a vapor processor such as ARID's PERMEATOR, the annual fuel savings are equivalent to 7,088 gallons and 7,411 gallons for Case 1 and Case 2, respectively. In addition, the reduction of emissions with a vapor processor will yield savings of 17.72 and 18.53 tons per year for each case, with an annual fuel savings of approximately $20,200 and $21,120 for Case 1 and Case 2, respectively with fuel price of $2.85/gal.

ARID's Evaporative Loss Model (ELM) is presented in Figure 6. With inputs as shown, fuel savings of 22.83 gallons per day are tabulated. This figure is within about 3 gallons or 15% of the average measured value. Key inputs into the ELM include gasoline throughput, gasoline storage tank temperature, A/L ratio of Stage II system (sometimes referred to as "V/L ratio"), fuel RVP (Reid Vapor Pressure), and altitude of the fueling station.

<u>Other Comments and Observations</u>

The raw pulse count and ARIDAS data are shown in Figure 7. It is interesting to note relatively large swings in atmospheric pressure as a high pressure weather system brought in low ambient temperatures from 2 December thru 13 December. Even with the low temperatures, the pulse count data showed high counts as seen in the last plot for 8 December on page 15. Please note that the average vent flowrate equaled 1.13 cfm for the period of 9:59 am thru 4:25 pm on this day. For many periods of time, the vent emissions were at the 2.0 cfm level. During this same time interval, the ambient temperature ranged from 34.8 deg F to 49.1 deg F, with an average of 43.8 deg F. Atmospheric pressure over this same interval averaged 408 inches water column.

Also, the CARB correlation does not consider the impact of pressures > 4.25 inches water column on fugitive emissions. For Case 1, storage tank pressures exceeded 4.25 inches H2O for 4.78% of the time.

Footnote

1 First, to correct the leak rate from 3.343 to .592 inches water; apply the square root of the differential pressures; so SQRT (3.343/.592) = *2.37*. (This ratio is from combining Bernoulli equation with Continuity equation, to yield following equation, m = A * SQRT(2 * P atm/RT* (P tank - Patm)); which calculates mass flux through hole of Cross sectional area A as a function of P atm

(atmospheric pressure), T, Temperature, and Tank Pressure, P tank). Thus, the actual ratio of fugitive leak rates is 0.27/0.111 = *2.43*. Thus, the ratio shows good agreement 2.37 vs. 2.43, within 2.5%, and therefore the data collection appears very accurate.

Figure 1: AC-250 and ARIDAS Gear Mounted on Vent Line

Figure 2: Storage Tank Pressure Profile

Case 1: High Backpressure

9 October – 20 November 2009

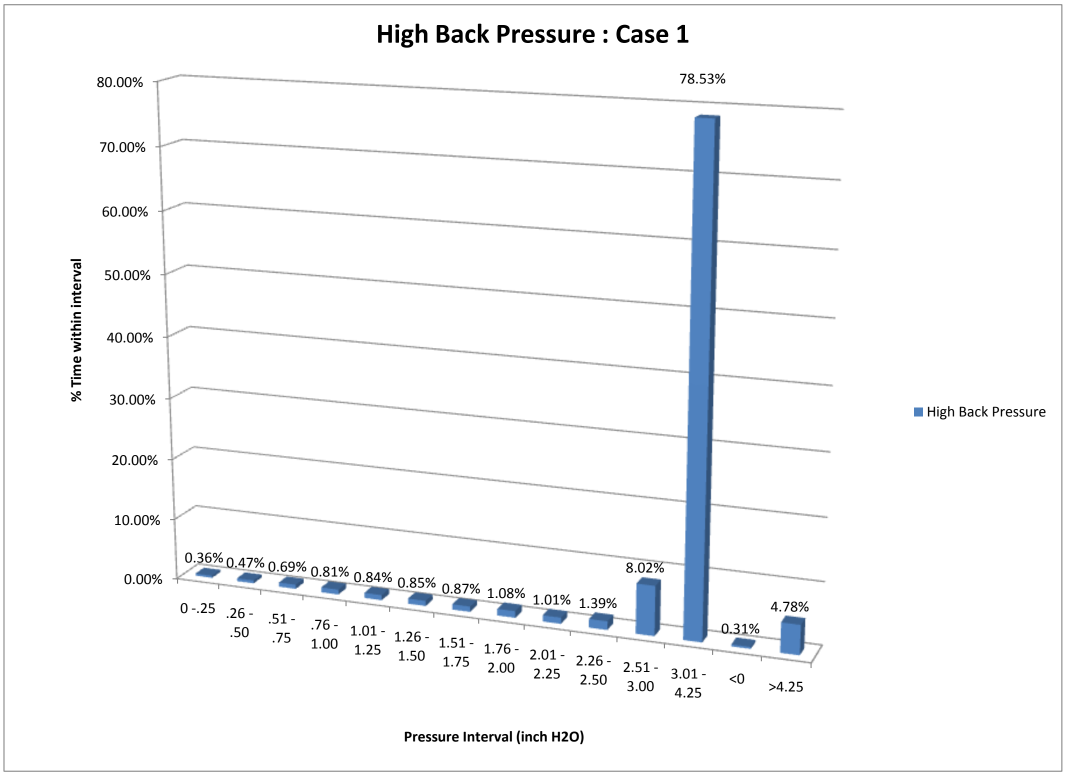

Figure 3: Case 1: High Back Pressure

CARB Correlation with Pressure Intervals

0 -.25	.26 - .50	.51 - .75	.76 - 1.00	1.01 - 1.25	1.26 - 1.50	1.51 - 1.75	1.76 - 2.00	2.01 - 2.25	2.26 - 2.50	2.51 - 3.00	3.01 - 4.25	<0	>4.25
0.36%	*0.47%*	*0.69%*	*0.81%*	*0.84%*	*0.85%*	*0.87%*	*1.08%*	*1.01%*	*1.39%*	*8.02%*	*78.53%*	*0.31%*	*4.78%*
3.599881	4.766509	6.933104	8.133064	8.433054	8.533051	8.733045	10.93297	10.133	14.03287	80.83066	791.67382	3.166562	48.16507

2. Fugitive Flowrates (Equation 9.1.1):

P range considered (in WC)	P range average value	Q (cfh)
0 -.25	0.125	3.15
.26 - .50	0.38	5.49
.51 - .75	0.63	7.06
.76 - 1.00	0.88	8.35
1.01 - 1.25	1.13	9.46
1.26 - 1.50	1.38	10.46
1.51 - 1.75	1.63	11.36
1.76 - 2.00	1.88	12.20
2.01 - 2.25	2.13	12.99
2.26 - 2.50	2.38	13.73
2.51 - 3.00	2.76	14.79
3.01 - 4.25	3.63	16.96

3A. Mass Emissions (Equation 9.2.1):

High BackPressure

Q (cfh)	Time at Pressure (hrs)	Cubic Ft
3.15	**3.60**	11.32853
5.49	**4.77**	26.15306
7.06	**6.93**	48.98107
8.35	**8.13**	67.90877
9.46	**8.43**	79.79109
10.46	**8.53**	89.22246
11.36	**8.73**	99.24069
12.20	**10.93**	133.4281
12.99	**10.13**	131.631
13.73	**14.03**	192.6927
14.79	**80.83**	1195.256
16.96	**791.67**	13425.48

Total hrs = 956.74

Total Days = 39.9

Q total = 16.202 cfh

Q total = 0.2700 cfm

Figure 4: Storage Tank Pressure Profile

Case 2: Low Backpressure

20 November – 18 December 2009

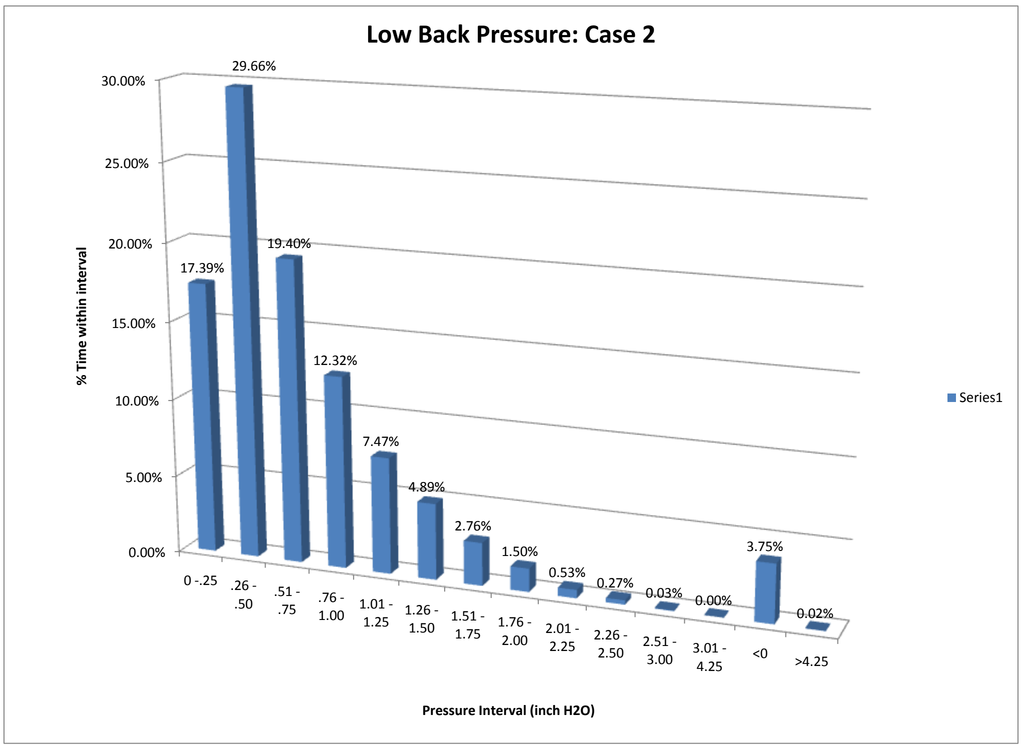

Figure 5: Case 2: Low Back Pressure

CARB Correlation with Pressure Intervals

0 -.25	.26 - .50	.51 - .75	.76 - 1.00	1.01 - 1.25	1.26 - 1.50	1.51 - 1.75	1.76 - 2.00	2.01 - 2.25	2.26 - 2.50	2.51 - 3.00	3.01 - 4.25	<0	>4.25
17.39%	*29.66%*	*19.40%*	*12.32%*	*7.47%*	*4.89%*	*2.76%*	*1.50%*	*0.53%*	*0.27%*	*0.03%*	*0.00%*	*3.75%*	*0.02%*
116.2609	198.2901	129.6935	82.36256	49.96418	32.66504	18.43241	9.999501	3.566489	1.833242	0.233322	0	25.06542	0.133327

3B. Mass Emissions (Equation 9.2.1):

Low BackPressure

Q (cfh)	Time at Pressure (hrs)	Cubic Ft
3.15	**116.26**	365.8633
5.49	**198.29**	1087.986
7.06	**129.69**	916.2603
8.35	**82.36**	687.7039
9.46	**49.96**	472.7464
10.46	**32.67**	341.549
11.36	**18.43**	209.4625
12.20	**10.00**	122.0359
12.99	**3.57**	46.32986
13.73	**1.83**	25.17321
14.79	**0.23**	3.450166
16.96	**0.00**	0

Total hrs = 643.30

Total Days = 26.8

Q total = 6.651 cfh

Q total = 0.1108 cfm

Table 1A

Emissions Reductions and Savings Summary

	Vent Emissions (cfm)	Average Tank Pressure inches H2O	Fugitive Emissions (cfm)	Total Emissions (cfm)	Average Ambient Temperature (deg F)	Average Atmospheric Pressure (inches H2O)
Case 1	0.504	3.343	0.270	**0.774**	50.737	403.648
Case 2	0.698	0.592	0.111	**0.809**	40.137	405.405

Fuel Savings & Emissions Reduction Summary

Total Emissions *(cfm)*	Hydrocarbon Concentration *(%)*	Gallons of Fuel *(per day)*	Gallons of Fuel *(per month)*	Gallons of Fuel *(per year)*	Emissions Reduced *(tons/year)*	Value of Fuel *($/yr) at $2.85/gal*
0.774	50%	19.053	590.644	7,087.73	17.719	**$ 20,200.03**
0.809	50%	19.922	617.568	7,410.82	18.527	**$ 21,120.84**

Table 1B

Gasoline Throughput Over Test Interval

9 October – 18 December 2009

(available upon request)

Figure 6: ARID Evaporative Loss Model

ARID TECHNOLOGIES - Evaporative Loss Model for Stage II Vac-Assist site

INPUTS			
Monthly Throughput (gallons)	806,404	Vapor/Liquid Ratio	0.97
Monthly Gasoline Gallons Saved Yr 2009	708	Gasoline RVP	13.00
Daily Gasoline Gallons Saved Yr 2009	22.83	Storage Tank Temperature	50.00
Gasoline Saved, Year 2009, % of throughput	0.09%	Depreciation Life (yr)	5.00
System Installed Cost	$40,000.00	Altitude (feet above sea level)	750
Discount Rate	10%	Lessee Discount Rate (After Tax)	10%
Value of Recovered Gasoline	$2.85		

BENEFIT SUMMARY		
OWNING UNIT		
After Tax IRR		52%
After Tax NPV @	10%	$81,534
Total Avoided Emissions (Tons)		271.73

ARID Technologies, Inc.

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PRODUCT SAVINGS	Coefficients	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ORVR Vehicle Population			55%	67.0%	71.0%	75.3%	78.6%	80.2%	81.8%	83.4%	85.1%	86.8%
Evaporative Emissions, V/L =xx, Tons/Yr-Station	0.97		11.22	14.09	15.06	16.08	16.88	17.26	17.64	18.03	18.43	18.84
Recovery with Membrane (Tons of Gasoline)	99.3%		11.14	14.00	14.96	15.96	16.76	17.13	17.52	17.91	18.30	18.71
Pounds of Gas Saved (1 ton =2,000 lbs)			22,286.65	27,992.28	29,913.18	31,929.17	33,522.00	34,269.72	35,032.40	35,810.33	36,603.82	37,413.18
Gallons of gas Saved (5.2 lb = 1 gallon)			4,285.89	5,383.13	5,752.53	6,140.23	6,446.54	6,590.33	6,737.00	6,886.60	7,039.20	7,194.84

CASH FLOW FOR PURCHASED UNITS	Coefficients	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Value of Liquid Gasoline Saved	$2.85		$12,214.80	$15,341.92	$16,394.72	$17,499.64	$18,372.63	$18,782.44	$19,200.45	$19,626.82	$20,061.71	$20,505.30
Bulk Tanker Loading Savings			$11,986.26	$11,986.26	$11,986.26	$11,986.26	$11,986.26	$11,986.26	$11,986.26	$11,986.26	$11,986.26	$11,986.26
Subtotal Product Savings			$24,201.06	$27,328.19	$28,380.99	$29,485.91	$30,358.90	$30,768.71	$31,186.71	$31,613.08	$32,047.97	$32,491.57
Annual Capital, Operating & Maintenance Expenses	1.50%	($40,000.00)	($600.00)	($600.00)	($600.00)	($600.00)	($600.00)	($600.00)	($600.00)	($600.00)	($600.00)	($600.00)
Depreciation: 5 year ACRS			($16,000.00)	($9,600.00)	($5,760.00)	($4,320.00)	($4,320.00)	$0.00	$0.00	$0.00	$0.00	$0.00
Incremental Operating Income			$7,601.06	$17,128.19	$22,020.99	$24,565.91	$25,438.90	$30,168.71	$30,586.71	$31,013.08	$31,447.97	$31,891.57
Incremental Tax Expense	32.00%		$2,432.34	$5,481.02	$7,046.72	$7,861.09	$8,140.45	$9,653.99	$9,787.75	$9,924.19	$10,063.35	$10,205.30
Incremental Net Income After Tax			$5,168.72	$11,647.17	$14,974.27	$16,704.82	$17,298.45	$20,514.72	$20,798.97	$21,088.89	$21,384.62	$21,686.26
Add Back Depreciation			$16,000.00	$9,600.00	$5,760.00	$4,320.00	$4,320.00	$0.00	$0.00	$0.00	$0.00	$0.00
After Tax Cash Flow		($40,000.00)	$21,168.72	$21,247.17	$20,734.27	$21,024.82	$21,618.45	$20,514.72	$20,798.97	$21,088.89	$21,384.62	$21,686.26
Cumulative Cash Flow		($40,000.00)	($18,831.28)	$2,415.89	$23,150.16	$44,174.98	$65,793.43	$86,308.15	$107,107.12	$128,196.01	$149,580.63	$171,266.90
Volume saved/month (gallons)		870.94	707.63	799.07	829.85	862.16	887.69	899.67	911.89	924.36	937.08	950.05
% Throughput Saved		0.11	0.088	0.099	0.103	0.107	0.110	0.112	0.113	0.115	0.116	0.118
gallons saved per day		28.09	22.83	25.78	26.77	27.81	28.64	29.02	29.42	29.82	30.23	30.65

Figure 6: ARID Evaporative Loss Model (cont'd.)

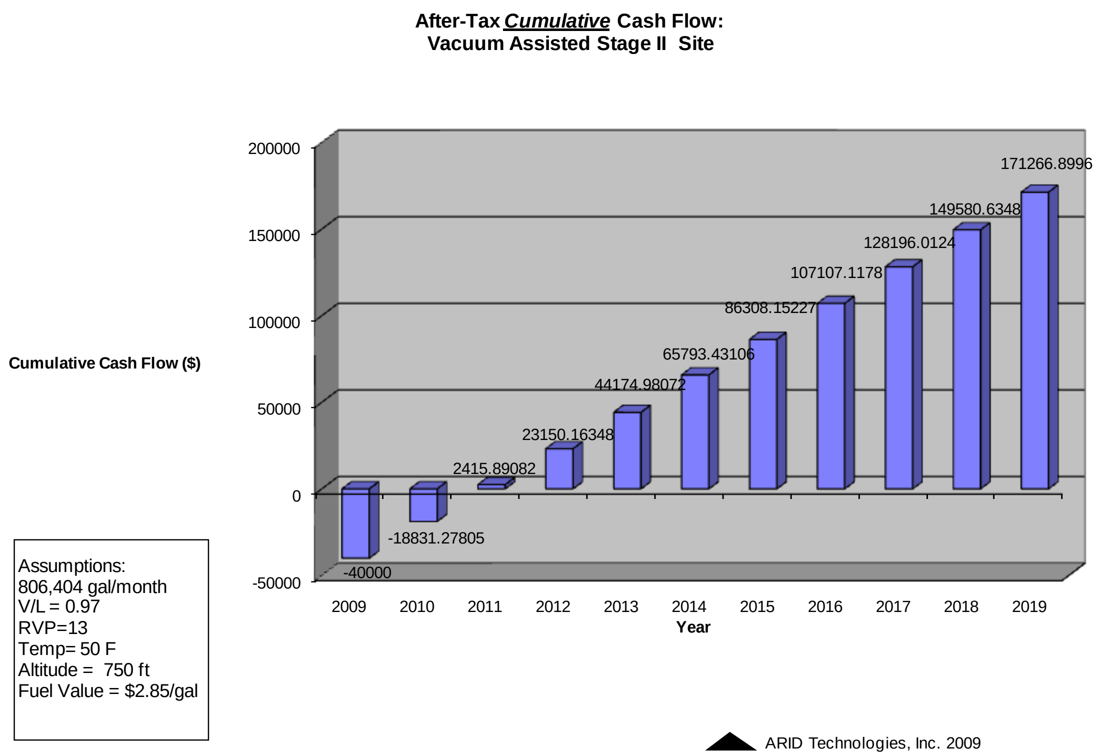


Figure 7: Pulse Count and ARIDAS Raw Data

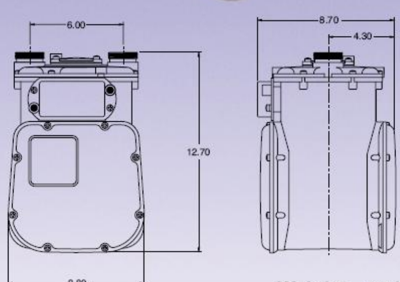
(Available upon request)

Appendix 1: American Meter AC-250

AC-250

FEATURES

- Die-cast aluminum case
- Oil-impregnated, self-lubricating bearings
- Exclusive convoluted diaphragm
- Rigid, reinforced flag rods
- Graphite-filled phenolic valves
- Long-life grommet seals
- Temperature compensation available from -30° F to 140° F
- 10 LT, 20 LT, 30 LT and #1 Sprague connection sizes
- Pointer or odometer index
- 5 PSI MAOP and 250 cfh at 1/2-inch w.c. differential
- Automatic meter reader compatibility



Weight = 12 lbs.

Reference Materials

Installation Instructions. AIM-3715
Repair Parts List RPL-3835

AMC Quality System
QMI is Accredited by:

ISO 9001 Certified
Certificate #006697

Dutch Council for Accreditation

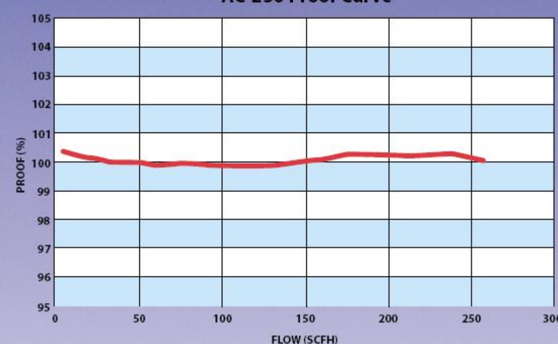
APPLICATIONS —The American class AC-250 is the industry's most cost-effective gas meter for residential applications. It is unequaled for accuracy retention and for life cycle maintenance economies.

Rated Gas Capacity For 0.60 S.G. Gas

Inlet Pressure PSIG	Inches W.C. Differential	Capacity SCFH
.25	1/2"	250[1,2]
.25	2"	565
1	2"	583
2	2"	600
5	2"	656
10	2"	742

1 - Propane - 158 cfh
2 - Butane - 138 cfh

AC-250 Proof Curve



Order Information:

Regular or Temperature Compensated:________________
U.S. or Metric: ________________
Size of Connection: ________________
Type of Index: ________________
Proof Preference: 100 +/- 1% ________________
Standard Color – ASA #49 Grey: ________________

Contact American Meter with any questions or orders at the address and phone number below.

American Meter Company has a program of continuous product development and improvement and, therefore, the information in this bulletin is subject to change or modification without notice.

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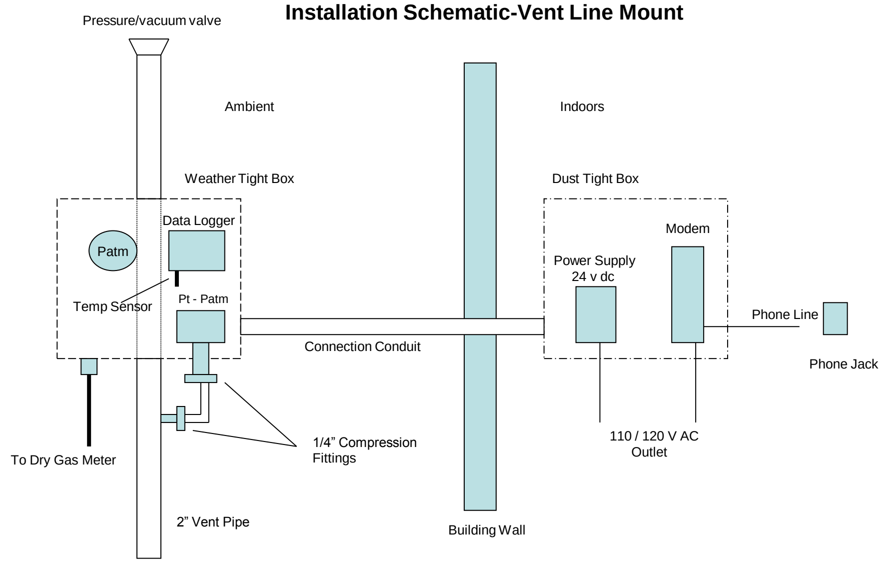
PCG/2500/12-02 FP 01-99

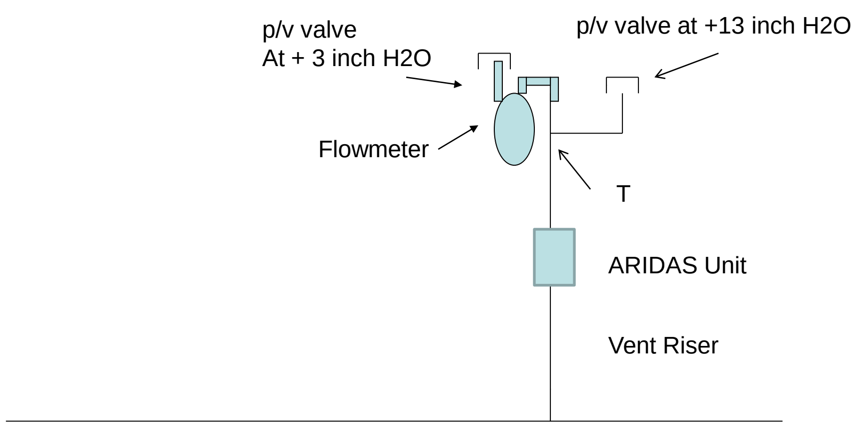
Appendix 2: ARIDAS Equipment (shown without Flowmeter)

ARIDAS 150

Installation Schematic-Vent Line Mount



Test Equipment Schematic (with Flowmeter)



Appendix 2, cont'd. – ARIDAS Equipment

Outside Box

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Inside Box

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Appendix 2, cont'd. – ARIDAS Equipment