State of Oregon
Department of Environmental Quality Memorandum

Date: 1/24/2014

To: File/George Davis
From: Mike Eisele

Subject: Source Test Review Report
Esco-Plant 3
Permit Number: 26-2068-TV-01

Test Date: August 19-22, 2013
Date Report Received: October 21, 2013
Source Testers: Horizon Engineering
DEQ Observed: Yes

I) Source Description: Steel parts manufacturer.

II) Process (es)/Emissions Unit(s) Tested: The three processes tested were the pouring cooling shakeout (PCS), the mold/core making, and the pug mill/sand coater.

III) Test Purpose: To determine the emissions of phenol and formaldehyde from the exhaust of the PCS, the mold/core making, and the pug mill/sand coater.

IV) Testing Location(s):

Pouring Cooling Shakeout Exhaust:

Diameter:	72"
Distance A (Method 1):	360" (5 Diameter)
Distance B (Method 1):	300" (4.2 Diameters)
Number traverse points utilized:	16

Mold and Core Exhaust:

Diameter:	59.3"
Distance A (Method 1):	35" (0.6 Diameter)
Distance B (Method 1):	123" (2.1 Diameters)
Number traverse points utilized:	16

Pug Mill / Sand Coater Exhaust:

Diameter:	46.8"
Distance A (Method 1):	32" (0.7 Diameter)
Distance B (Method 1):	100" (2.1 Diameters)
Number traverse points utilized:	16

V) Testing Methodology: The following testing methods were utilized during the testing program:

Flow Rate and Moisture Content: EPA Methods 1 & 2 and ODEQ Method 4
Phenol and Formaldehyde: NCASI Method A105.01

VI) Summary of Results: The testing parameters, test results, emission factors and operating parameters are summarized in Tables 1, 2, and 3:

TABLE 1: Pouring Cooling Shakeout Exhaust

TESTING PARAMETERS (Phenol and Formaldehyde)	Run 1	Run 2	Run 3	Average
Test Date	8/19/2013	8/19/2013	8/20/2013	
Test Time	0800-1028	1108-1018	0757-1015	
Exhaust Gas Temperature (°F)	110	118	101	110
Exhaust Gas Moisture (%)	1.8	1.8	1.6	1.7
Exhaust Gas Flow Rate (dscfm)	61900	59500	64500	62000
Mass of Phenol Collected (ug)	142	103	177	141
Mass of Formaldehyde Collected (ug)	4.2	2.7	4.7	3.9
Phenol Emissions:				
• ppm	0.54	0.43	0.70	0.56
• lb/hr	0.49	0.37	0.66	0.51
• lb/ton of metal poured	0.091	0.064	0.110	0.087
Formaldehyde Emissions:	[a]	[a]	[a]	
• ppm	0.050	0.035	0.058	0.047
• lb/hr	0.014	0.010	0.017	0.014
• lb/ton of metal poured	0.0027	0.0017	0.0028	0.0024
Metal Poured (tons/hr)	5.41	5.81	6.14	5.79

[a] The results were between the method detection limit and the limit of quantification.

TABLE 2: Mold and Core Making Exhaust

TESTING PARAMETERS (Phenol and Formaldehyde)	Run 1	Run 2	Run 3	Average
Test Date	8/21/2013	8/21/2013	8/22/2013	
Test Time	0834-1016	1100-1245	0629-0823	
Exhaust Gas Temperature (°F)	88	92	88	89
Exhaust Gas Moisture (%)	1.7	1.8	1.7	1.7
Exhaust Gas Flow Rate (dscfm)	73500	74300	74900	74200
Mass of Phenol Collected (ug)	16.2	17.6	16.7	16.8
Mass of Formaldehyde Collected (ug)	15.6	16.2	17.3	16.4
Phenol Emissions:	[a]	[a]	[a]	
• ppm	0.060	0.067	0.059	0.062
• lb/hr	0.065	0.073	0.065	0.068
• lb/ton of sand	0.027	0.027	0.022	0.025
• lb/ton of resin	0.67	0.69	0.55	0.64
Formaldehyde Emissions:	[a]			
• ppm	0.18	0.19	0.19	0.19
• lb/hr	0.063	0.067	0.068	0.066
• lb/ton of sand	0.026	0.025	0.023	0.024
• lb/ton of resin	0.65	0.64	0.57	0.62
Sand Usage (tons/hr)	2.44	2.67	3.01	2.70
Resin Usage (tons/hr)	0.10	0.11	0.12	0.11

[a] The results were between the method detection limit and the limit of quantification.

TABLE 3: Pug Mill / Sand Coater Exhaust

TESTING PARAMETERS (Phenol and Formaldehyde)	Run 1	Run 2	Run 3	Average
Test Date	8/22/2013	8/22/2013	8/22/2013	
Test Time	0719-0921	0946-1155	1219-1406	
Exhaust Gas Temperature (°F)	118	116	119	118
Exhaust Gas Moisture (%)	9	10	10	10
Exhaust Gas Flow Rate (dscfm)	560	710	740	670
Mass of Phenol Collected (ug)	8674	9775	11183	9877
Mass of Formaldehyde Collected (ug)	2019	2430	2500	2316
Phenol Emissions:				
• ppm	51	58	72	60
• lb/hr	0.41	0.61	0.78	0.60
• lb/ton of sand	0.11	0.16	0.20	0.16
• lb/ton of resin	3.2	3.9	5.0	4.0
Formaldehyde Emissions:				
• ppm	37	45	51	44
• lb/hr	0.10	0.05	0.17	0.14
• lb/ton of sand	0.025	0.039	0.045	0.036
• lb/ton of resin	0.74	0.97	1.12	0.94
Sand Usage (tons/hr)	3.8	3.9	3.9	3.9
Resin Usage (tons/hr)	0.13	0.16	0.16	0.15

VII) Concerns & Comments:

1) Horizon Engineering sent updates to report pages 1, 9, 12, 41, and 124. They also sent additional calibration information to show the Shortridge instrument was accurate at very low levels. These can be found in Attachment A.

VIII) Overall Evaluation: The test methods conducted and the data provided were sufficient to evaluate the emission units tested.

Encl: Attachment A

cc: Travis Quarles
Esco Corporation
PO Box 10123
Portland, OR 97296

David Bagwell
Horizon Engineering
13585 NE Whitaker Way
Portland, OR 97230

Attachment A

HORIZON ENGINEERING LLC

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Phone (503)255-5050 • Fax (503)255-0505
www.horizonengineering.com

Project No. 4767 Permit No. 26-2068-TV-01

SOURCE EVALUATION REPORT

ESCO Corporation
Portland Oregon
Plant 3

Pouring/Cooling/Shakeout Operations (3U-2 PCS)

Pug Mill/Sand Coater (3U-7 Mold/Core)

Mold and Core Making Vent (3U-7 Mold/Core)

Formaldehyde & Phenol

Test Dates: August 19-22, 2013

Test Site:
ESCO Corp.
Plant 3
2141 NW 25th Avenue
Portland, Oregon 97210-2578

Report ID: HORIZON ENGINEERING 13-4767
Revision 1 January 2014

Air Pollution Emission Testing

4. SUMMARY OF RESULTS

4.1 Tables of Results:

Table 1

PCS, Pug Mill/Sand Coater, Mold and Core Making Vent

Formaldehyde and Phenol Results Summary - Three-Run Averages

Test Dates: August 19-22, 2013

	Units	PCS	Pug Mill	Mold & Core
Sampling Results				
Phenol				
Concentration	ppmv	0.55	60.3	0.062
Rate	lb/hr	0.51	0.60	0.068
Metal Poured	lb/TMP	0.087	--	--
Sand Usage Basis (SU)	lb/tonSU	--	0.16	0.025
Resin Usage Basis (RU)	lb/tonRU	--	4.03	0.64
Formaldehyde				
Concentration	ppmv	0.047	44.3	0.19
Rate	lb/hr	0.014	0.14	0.066
Metal Poured	lb/TMP	0.0024	--	--
Sand Usage Basis (SU)	lb/tonSU	--	0.036	0.024
Resin Usage Basis (RU)	lb/tonRU	--	0.94	0.62

Table 3

Pug Mill/Sand Coater (3-309109)

Formaldehyde and Phenol Test Results

Test Date: August 22, 2013	**Units**	**Run 1**	**Run 2**	**Run 3**	**Average**
Start Time		07:19	09:46	12:19	
End Time		09:21	11:55	14:06	
Sample Time	minutes	70.0	64.4	60.7	65.0
Sampling Results [4]					
Formaldehyde					
Concentration	ppmv	36.9	45.3	50.5	44.3
Rate	lb/hr	0.096	0.15	0.17	0.14
Sand Usage Basis (SU)	lb/tonSU	0.025	0.039	0.045	0.036
Resin Usage Basis (RU)	lb/tonRU	0.74	0.97	1.12	0.94
Phenol					
Concentration	ppmv	50.6	58.2	72.1	60.3
Rate	lb/hr	0.41	0.61	0.78	0.60
Sand Usage Basis (SU)	lb/tonSU	0.11	0.16	0.20	0.16
Resin Usage Basis (RU)	lb/tonRU	3.16	3.90	5.02	4.03
Flow Rate (Actual)	acf/min	676	866	901	814
Flow Rate (Standard) [5]	dscf/min	559	711	737	669
Temperature	°F	118	116	119	118
Moisture	%	8.6	9.9	9.9	9.5
Process/Production Data					
Total Sand Usage	tons	4.176	4.176	3.944	4.099
Sand Usage Rate	tons/hr	3.80	3.89	3.90	3.86
Total Resin Usage	tons	0.144	0.167	0.157	0.156
Resin Usage Rate	tons/hr	0.13	0.16	0.16	0.15

[4] All formaldehyde and phenol results for the Pug Mill/Sand Coater were above the detection limit (ADL).

[5] The average flow rate, from four or five velocity traverses per run, was used in calculations. The traverses for Runs 1 and 2 showed some negative velocity pressures and these data were used in the calculations as measured.

Summary of HAPs Results

ESCO 8/22/13
Pug Mill Sand Coater Ventilation Stack mew
PORTLAND OR

RESULTS CONCENTRATION		FORMALDEHYDE 30.05	PHENOL 94.11
Run 1 (ppmvd)		**36.9**	**50.6**
Run 2 (ppmvd)		**45.3**	**58.2**
Run 3 (ppmvd)		**50.5**	**72.1**
Average		**44.3**	**60.3**

RESULTS MASS EMISSIONS	Avg. Flow Rate dscf/min	FORMALDEHYDE 30.05	PHENOL 94.11
Run 1 (lbm/hr)	558.7	**0.096**	**0.414**
Run 2 (lbm/hr)	711.4	**0.151**	**0.607**
Run 3 (lbm/hr)	737.1	**0.174**	**0.779**
Average	669.1	**0.141**	**0.600**

RESULTS MASS EMISSIONS	Total Sand Usage (ton/hr)	FORMALDEHYDE 30.05	PHENOL 94.11
Run 1 (lbm/ton)	3.799	**0.025**	**0.109**
Run 2 (lbm/ton)	3.890	**0.039**	**0.156**
Run 3 (lbm/ton)	3.897	**0.045**	**0.200**
Average	3.862	**0.036**	**0.155**

RESULTS MASS EMISSIONS	Total Resin Usage (ton/hr)	FORMALDEHYDE 30.05	PHENOL 94.11
Run 1 (lbm/ton)	0.131	**0.736**	**3.162**
Run 2 (lbm/ton)	0.156	**0.970**	**3.901**
Run 3 (lbm/ton)	0.155	**1.123**	**5.022**
Average	0.147	**0.943**	**4.028**

All results were above the detection limit

Flow Rate Results

Client	ESCO																	
Source	Pug Mill Sand Coater Ventilation Stack																	
Location	PORTLAND OR																8/22/13	Date
	EPA 1-2, NCASI 105.01																	Operator
Definitions	Symbol	Units	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	MEW	Analyst/QA
Date			8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13	8/22/13		
NCASI A105.01 Sampling Time, Starting			7:19				9:46					12:19						
NCASI A105.01 Sampling Time, Ending			9:21				11:55					14:06						
Flow Traverse Time			7:30	7:52		9:02	9:57	10:18	11:09	11:30	11:35	12:19	12:46	12:51	13:36	13:46		
Temperature, Stack gas	Ts	°F	104.8	125.2	125.4	117.1	114.6	114.4	116.3	116.9	119.9	117.5	119.6	118.9	120.0	120.3	117.9	
Run Average	Ts	°F	118.1				116.4					119.3						
Temperature, Stack Dry Bulb	Tdb	°F	121.0	94.0	130.0	124.0	130.0	131.0	131.0	137.0	130.0	136.0	133.0	134.0	138.0	126.0	128.2	
Temperature, Stack Wet Bulb	Twb	°F	120.0	85.0	117.0	112.0	116.0	119.0	117.0	115.0	114.0	116.0	115.0	115.0	124.0	112.0	114.1	
Average square root velocity pressure	dp^½	in H2O^½	0.012	0.015	0.028	0.010	0.014	0.023	0.021	0.023	0.022	0.022	0.023	0.023	0.019	0.020		
Pitot tube coefficient	Cp		0.8221	0.8221	0.8221	0.8221	0.8221	0.8221	0.8221	0.8221	0.8221	0.8221	0.8221	0.8221	0.8221	0.8221		
Pressure, Barometric	Pbar	in Hg	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80		
Pressure, Static Stack	Pg	in H2O	-0.0035	-0.0016	-0.0039	-0.0062	-0.0065	-0.0031	-0.0039	-0.0027	-0.0036	-0.0036	-0.0016	-0.0022	-0.0044	-0.0024	-0.0035	
Time, Total sample	Ø	min	60	60	60	60	60	60	60	60	60	60	60	60	60	60		
Stack Area	As	in²	1,717	1,717	1,717	1,717	1,717	1,717	1,717	1,717	1,717	1,717	1,717	1,717	1,717	1,717		
Oxygen		% O2	20.95	20.95	20.95	20.95	20.95	20.95	20.95	20.95	20.95	20.95	20.95	20.95	20.95	20.95	20.9	
Carbon Dioxide		% CO2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.0	
Molecular weight, Dry Stack	Md	lbm / lbmole	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96	29.0	
Pressure, Absolute Stack	Ps	in Hg	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.8	
Moisture, % Stack (EPA 4)	Bws(1)	%	na	na	na	na	na	na	na	na	na	na	na	na	na	na		
Moisture, % Stack (Psychrometry-Sat)	Bws(2)	%	7.47	13.34	13.40	10.67	9.94	9.89	10.43	10.61	11.52	10.78	11.44	11.23	11.56	11.64	11.00	
Moisture, % Stack (Theoretical)	Bws(3)	%	na	na	na	na	na	na	na	na	na	na	na	na	na	na		
Moisture, % Stack (Psychrometry)	Bws(4)	%	11.53	3.75	10.19	8.82	9.86	10.84	10.16	9.30	9.22	9.66	9.44	9.40	12.45	8.75	9.53	
Run Average			8.6				9.9					9.9						
Moisture, % Stack (Predicted)	Bws(5)	%	na	na	na	na	na	na	na	na	na	na	na	na	na	na		
Mole Fraction dry Gas	mfg		88.5%	96.2%	89.8%	91.2%	90.1%	89.2%	89.8%	90.7%	90.8%	90.3%	90.6%	90.6%	87.6%	91.3%	90.5%	
Molecular weight, Wet Stack	Ms	lbm / lbmole	27.70	28.55	27.85	28.00	27.88	27.78	27.85	27.95	27.95	27.91	27.93	27.93	27.60	28.01	27.92	
Velocity, Stack gas	vs	fpm	41.57	52.64	98.96	33.56	50.53	81.28	73.42	81.39	76.44	78.41	80.03	81.02	68.65	69.87	69.13	
Volumetric Flowrate, Actual	Qa	acf/min	495.6	627.5	1,179.7	400.0	602.4	968.9	875.2	970.2	911.3	934.7	954.0	965.8	818.4	832.9	824.0	
Run Average	Qa	acf/min	675.7				865.6					901.1					814.1	
Volumetric Flowrate, Dry Standard	Qsd	dscf/min	408.2	542.7	951.6	332.3	496.8	790.8	717.4	802.0	750.1	768.8	783.8	794.7	649.6	688.7	677.0	
Run Average	Qsd	dscf/min	558.7				711.4					737.1					669.1	

All six traverse runs had measured negative velocity pressures. The negative values were used in the calculations.
The average flow rate for fouror five velocity traverses per run was used for calculations.

Horizon Engineering
Shortridge Micromanometer Revised Calibrations
Technicians: Patrick Todd, Michael Wallace
January 16, 2014

The calibration procedure for the Shortridge has been revised to obtain the lowest possible pressure drops, as well as a better range at the lower end.

Equipment:
The following equipment was used for the wind tunnel. The items are listed in serial order: (See sketch attached)
Fan from the high volume sampler (for ODEQ Method 8)
A calibrated orifice from the high volume sampler, and Fluke temperature indicator; acts as the standard
Pipe, starts at 1.5 inch diameter pipe from the high volume sampler, ends at 4 inch diameter pipe
Shortridge micromanometer and p-type pitot to measure pressure drop at two ports located on the wind tunnel.

Description of procedure:
The high volume sampler was operated at five different speeds to produce five different pressure drops: 0.05, 0.1, 0.25, 0.5, and 1.0 inches water column, as measured on the high volume orifice setup.
At each speed, readings from the high volume orifice and the Shortridge Micromanometer were recorded. The readings were used to calculate flow rates, acfm, for comparison.

Calculations on attached spreadsheet:

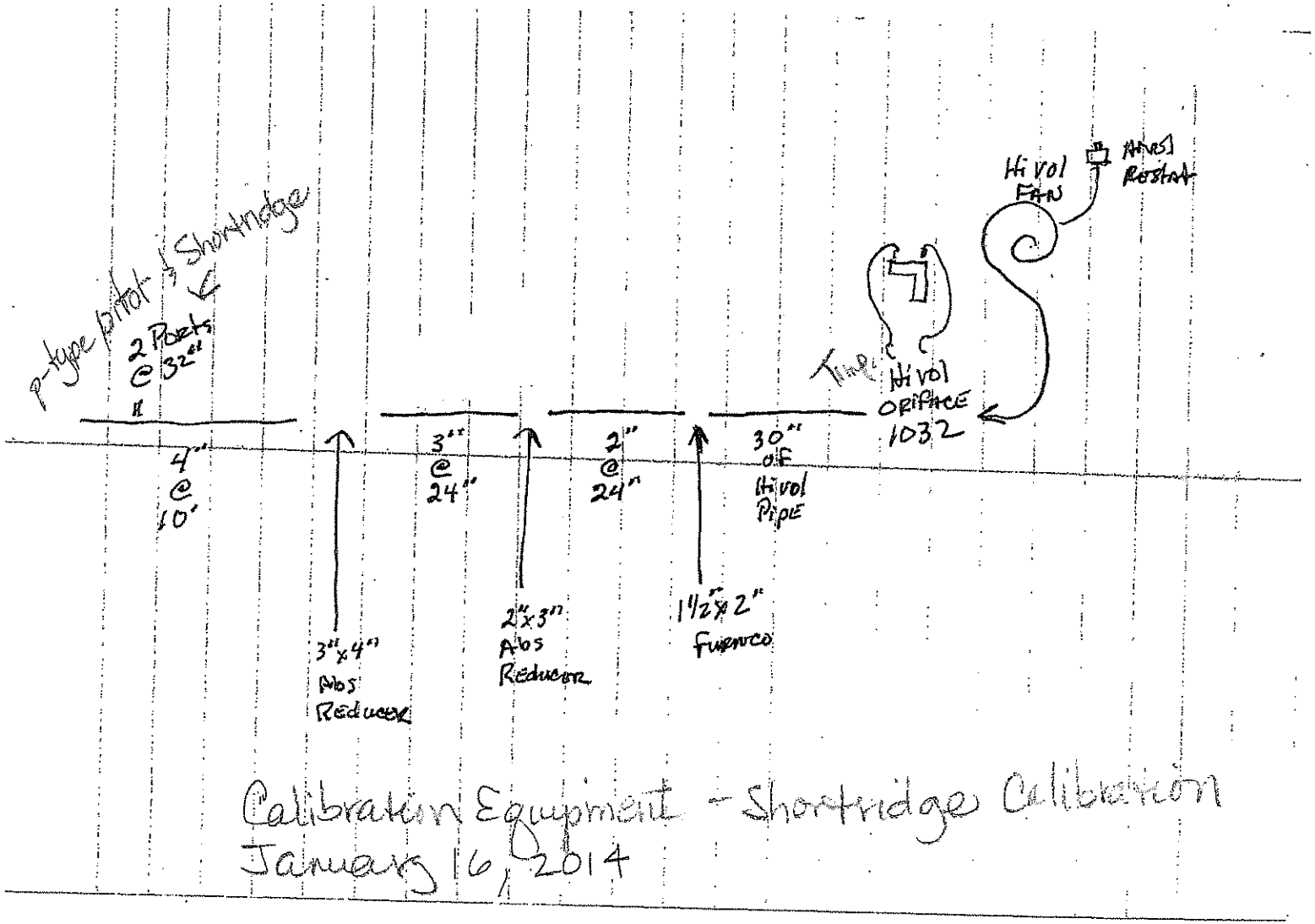
1. First nine columns from the left are data entry and calculation of high volume orifice flow, (Qa, acf/m). These are the same calculations as used for the high volume sampler semi-annual calibrations. Calculations include barometric pressure, coefficients from semi-annual high volume calibration curve (A and B), static pressure, orifice temperature, molecular weight of gas and system pressure.
2. The next three columns are calculations of flow (Qa, acf/m) from measurements recorded from the Shortridge (Qa, acf/m). The Shortridge flow is calculated from the recorded pressure drop, system temperature and pressure.
3. The difference between the High Volume orifice and the Shortridge micromanometer is in the 13th column from left (SR/OR %). The Shortridge acf/m is divided by the high volume orifice acf/m to get percent difference.
4. A vane anemometer measuring velocity, fpm was compared to the Shortridge velocity, fpm calculation. This was added as another check on the system.

high vol, acfm $= A \times \Delta p^{B} \times 21.849 \times \frac{T_o\ ^\circ R}{60 \times P_s \times M_s}$

[these refer to spreadsheet variables]

SR, acfm $= V_S \times A_S / 144$

where $V_S = 5129.4 \times cp.99 \times \sqrt{\Delta p} \times \sqrt{\frac{T_o\ ^\circ R}{P_s}}$



Calibration Equipment - Shortridge Calibration
January 16, 2014

TEST CONDITIONS

weather conditions from pdx weather underground

Barometric Pres.	30.48	Pb
Ambient Temp.	36	Tdb
	35.674	Twb
Moisture	0.67	
Moisture @ Sat	0.69	
Calibration gas Molwt (Mc)	28.89	ms

ORIFICE CALIBRATION CONDITONS 1032

Barometric Pres.	30.2	Pb	in Hg	A=	214.4713
Ambient Temp.	60	Tdb	F	B=	0.4901
	57	Twb	F		
Moisture	1.44		%		
Moisture @ Sat	1.73		%		
Calibration gas Molwt (Mc)	28.81	ms	lbm/lbmol		

16-Jan-14 mew

jy.pt

DUCT	
As	12.30
Ds	3.958
cp	0.99

SHORT RIDGE ID# 7.0

PACER VANE ANANOMETER

STANDARD P-TYPE PITOT

	Pressure Drop Across Orifice in H2O dHo	Pressure Meter in H2O Pstat	ORIFICE Outlet System Temperature To	Average System Temperature Ts	inHg Ps	lb/lbmol Ms	Orifice Flow M lbm/hr	Orifice Flow @Ts acf/min Qa acfm	Orifice Flow Calc dP inH2O	SHORT RIDGE RESPONSE dP inH2O	vs fpm	Qa acfm	SR/OR %	AVG %	SR AVG VEL fpm	VANE ANANOMETER (Spot Check) fpm	SR/VA %
1	0.0500	-0.0004	58.8	58.8	30.48	28.89	49.40	10.59	0.0010	0.0012	134.98	11.53	108.9%	104.7%	129.82	140.0	92.7%
2	0.0500	-0.0004	58.8	58.8	30.48	28.89	49.40	10.59	0.0010	0.0011	129.23	11.04	104.3%				
3	0.0500	-0.0004	58.8	58.8	30.48	28.89	49.40	10.59	0.0010	0.0010	123.22	10.53	99.4%				
4	0.0500	-0.0004	58.8	58.8	30.48	28.89	49.40	10.59	0.0010	0.0011	129.23	11.04	104.3%				
5	0.0500	-0.0004	58.8	58.8	30.48	28.89	49.40	10.59	0.0010	0.0010	123.22	10.53	99.4%				
6	0.0500	-0.0004	58.8	58.8	30.48	28.89	49.40	10.59	0.0010	0.0013	140.49	12.00	113.3%				
7	0.0500	-0.0004	58.8	58.8	30.48	28.89	49.40	10.59	0.0010	0.0012	134.98	11.53	108.9%				
8	0.0500	-0.0004	58.8	58.8	30.48	28.89	49.40	10.59	0.0010	0.0010	123.22	10.53	99.4%				
1	0.1000	-0.001	58.8	58.8	30.48	28.89	69.38	14.88	0.0020	0.0026	198.68	16.98	114.1%	113.9%	198.30	215.0	92.2%
2	0.1000	-0.001	58.8	58.8	30.48	28.89	69.38	14.88	0.0020	0.0029	209.83	17.93	120.5%				
3	0.1000	-0.001	58.8	58.8	30.48	28.89	69.38	14.88	0.0020	0.0029	209.83	17.93	120.5%				
4	0.1000	-0.001	58.8	58.8	30.48	28.89	69.38	14.88	0.0020	0.0023	186.87	15.97	107.3%				
5	0.1000	-0.001	58.8	58.8	30.48	28.89	69.38	14.88	0.0020	0.0020	174.26	14.89	100.1%				
6	0.1000	-0.001	58.8	58.8	30.48	28.89	69.38	14.88	0.0020	0.0028	206.18	17.62	118.4%				
7	0.1000	-0.001	58.8	58.8	30.48	28.89	69.38	14.88	0.0020	0.0029	209.83	17.93	120.5%				
8	0.1000	-0.001	58.8	58.8	30.48	28.89	69.38	14.88	0.0020	0.0024	190.89	16.31	109.6%				
1	0.5000	-0.0042	58.8	58.8	30.48	28.89	152.70	32.74	0.0097	0.0115	417.85	35.70	109.1%	111.0%	425.47	425.0	100.1%
2	0.5000	-0.0042	58.8	58.8	30.48	28.89	152.70	32.74	0.0097	0.0124	433.90	37.07	113.2%				
3	0.5000	-0.0042	58.8	58.8	30.48	28.89	152.70	32.74	0.0097	0.0120	426.84	36.47	111.4%				
4	0.5000	-0.0042	58.8	58.8	30.48	28.89	152.70	32.74	0.0097	0.0115	417.85	35.70	109.1%				
5	0.5000	-0.0042	58.8	58.8	30.48	28.89	152.70	32.74	0.0097	0.0120	426.84	36.47	111.4%				
6	0.5000	-0.0042	58.8	58.8	30.48	28.89	152.70	32.74	0.0097	0.0122	430.38	36.77	112.3%				
7	0.5000	-0.0042	58.8	58.8	30.48	28.89	152.70	32.74	0.0097	0.0120	426.84	36.47	111.4%				
8	0.5000	-0.0042	58.8	58.8	30.48	28.89	152.70	32.74	0.0097	0.0118	423.27	36.17	110.5%				
1	0.2500	-0.0023	58.8	58.8	30.48	28.89	108.71	23.31	0.0049	0.0060	301.82	25.79	110.6%	113.2%	308.94	305.0	101.3%
2	0.2500	-0.0023	58.8	58.8	30.48	28.89	108.71	23.31	0.0049	0.0064	311.72	26.63	114.3%				
3	0.2500	-0.0023	58.8	58.8	30.48	28.89	108.71	23.31	0.0049	0.0066	316.55	27.05	116.0%				
4	0.2500	-0.0023	58.8	58.8	30.48	28.89	108.71	23.31	0.0049	0.0062	306.81	26.21	112.5%				
5	0.2500	-0.0023	58.8	58.8	30.48	28.89	108.71	23.31	0.0049	0.0063	309.28	26.43	113.4%				
6	0.2500	-0.0023	58.8	58.8	30.48	28.89	108.71	23.31	0.0049	0.0062	306.81	26.21	112.5%				
7	0.2500	-0.0023	58.8	58.8	30.48	28.89	108.71	23.31	0.0049	0.0064	311.72	26.63	114.3%				
8	0.2500	-0.0023	58.8	58.8	30.48	28.89	108.71	23.31	0.0049	0.0062	306.81	26.21	112.5%				
1	1.0000	-0.0084	58.8	58.8	30.48	28.89	214.47	45.98	0.0191	0.0230	590.94	50.49	109.8%	110.9%	596.67	626.0	95.3%
2	1.0000	-0.0084	58.8	58.8	30.48	28.89	214.47	45.98	0.0191	0.0236	598.60	51.15	111.2%				
3	1.0000	-0.0084	58.8	58.8	30.48	28.89	214.47	45.98	0.0191	0.0242	606.16	51.79	112.6%				
4	1.0000	-0.0084	58.8	58.8	30.48	28.89	214.47	45.98	0.0191	0.0234	596.05	50.93	110.8%				
5	1.0000	-0.0084	58.8	58.8	30.48	28.89	214.47	45.98	0.0191	0.0228	588.36	50.27	109.3%				
6	1.0000	-0.0084	58.8	58.8	30.48	28.89	214.47	45.98	0.0191	0.0236	598.60	51.15	111.2%				
7	1.0000	-0.0084	58.8	58.8	30.48	28.89	214.47	45.98	0.0191	0.0236	598.60	51.15	111.2%				
8	1.0000	-0.0084	58.8	58.8	30.48	28.89	214.47	45.98	0.0191	0.0234	596.05	50.93	110.8%				

** Prior to lower flow testing, the Short Ridge was tested agains the wind tunnel at higher flows.

WT dP inH2O	SR dP inH2O
0.26000	0.26230
0.62250	0.62022
0.99500	0.99667

High Volume Orifice Calibration Data

Data Input MEW	#1032 A=	214.4713 < Intercept
QA MEW	4/10/2013 B=	0.4901 < Slope

ALL DATA POINTS

General Form Of Solution: $M=A*(dHo)^B$

1] $\ln(M)=\ln(A)+B*\ln(dHo)$
2] $Z=\ln(M)$, $W=\ln(dHo)$, $K1=\ln(A)$, $K2=B$
3] $Z=K1+K2(W)$

Point	dHo (in H2O)	M lbm/hr	M lbm/hr Calculated	2.0% Difference % ABS	Difference %
1	1.000	221.31	214.47	3.1%	-3.1%
2	1.000	221.01	214.47	3.0%	-3.0%
3	1.000	222.68	214.47	3.7%	-3.7%
4	2.500	342.18	336.05	1.8%	1.8%
5	2.500	341.98	336.05	1.7%	1.7%
6	2.500	341.92	336.05	1.7%	1.7%
7	4.000	426.92	423.11	0.9%	0.9%
8	4.000	427.08	423.11	0.9%	0.9%
9	4.000	426.51	423.11	0.8%	0.8%
10	0.100	70.96	69.38	2.2%	2.2%
11	0.100	71.46	69.38	2.9%	2.9%
12	0.100	71.47	69.38	2.9%	2.9%
13	0.200	98.52	97.45	1.1%	1.1%
14	0.200	97.11	97.45	0.4%	0.4%
15	0.200	96.43	97.45	1.1%	1.1%
16	0.400	135.89	136.88	0.7%	0.7%
17	0.400	135.89	136.88	0.7%	0.7%
18	0.400	135.89	136.88	0.7%	0.7%
19	0.500	149.88	152.70	1.9%	1.9%
20	0.500	149.88	152.70	1.9%	1.9%
21	0.500	149.85	152.70	1.9%	1.9%
22	0.700	174.56	180.07	3.2%	3.2%
23	0.700	175.67	180.07	2.5%	2.5%
24	0.700	175.77	180.07	2.4%	2.4%
25	0.900	197.08	203.68	3.3%	3.3%
26	0.900	197.08	203.68	3.3%	3.3%
27	0.900	197.08	203.68	3.3%	3.3%

Average No#	W	W²	Z	WZ
1	0.000	0.000	5.400	0.000
2	0.000	0.000	5.398	0.000
3	0.000	0.000	5.406	0.000
4	0.916	0.840	5.835	5.347
5	0.916	0.840	5.835	5.346
6	0.916	0.840	5.835	5.346
7	1.386	1.922	6.057	8.396
8	1.386	1.922	6.057	8.397
9	1.386	1.922	6.056	8.395
10	-2.303	5.302	4.262	-9.814
11	-2.303	5.302	4.269	-9.830
12	-2.303	5.302	4.269	-9.830
13	-1.609	2.590	4.590	-7.388
14	-1.609	2.590	4.576	-7.365
15	-1.609	2.590	4.569	-7.353
16	-0.916	0.840	4.912	-4.501
17	-0.916	0.840	4.912	-4.501
18	-0.916	0.840	4.912	-4.501
19	-0.693	0.480	5.010	-3.473
20	-0.693	0.480	5.010	-3.473
21	-0.693	0.480	5.010	-3.472
22	-0.357	0.127	5.162	-1.841
23	-0.357	0.127	5.169	-1.844
24	-0.357	0.127	5.169	-1.844
25	-0.105	0.011	5.284	-0.557
26	-0.105	0.011	5.284	-0.557
27	-0.105	0.011	5.284	-0.557

No#	W	W²	Z	WZ
27	-11.043	36.336	139.529	-41.470

27	-11.043	K1	139.529	
-11.043	36.336	K2	-41.470	
1	-0.409	K1	5.168	K1= 5.3682
0	31.819	K2	15.595	K2= 0.4901
1	-0.409	K1	5.168	A= 214.4713
0	1.000	K2	0.490	B= 0.4901
1	0.000	K1	5.368	
0	1.000	K2	0.490	

Data Input MEW	#1032 A=	214.4713 < Intercept
QA MEW	4/10/2013 B=	0.4901 < Slope

DATA POINTS (BEST OF)

General Form Of Solution: $M=A*(dHo)^B$

1] $\ln(M)=\ln(A)+B*\ln(dHo)$
2] $Z=\ln(M)$, $W=\ln(dHo)$, $K1=\ln(A)$, $K2=B$
3] $Z=K1+K2(W)$

Point	dHo (in H2O)	M lbm/hr	M lbm/hr Calculated	Difference % ABS	Difference %
1	1.000	221.31	214.47	3.09%	-3.09%
2	1.000	221.01	214.47	2.96%	-2.96%
3	1.000	222.68	214.47	3.69%	-3.69%
4	2.500	342.18	336.05	1.79%	-1.79%
5	2.500	341.98	336.05	1.73%	-1.73%
6	2.500	341.92	336.05	1.72%	-1.72%
7	4.000	426.92	423.11	0.89%	-0.89%
8	4.000	427.08	423.11	0.93%	-0.93%
9	4.000	426.51	423.11	0.80%	-0.80%
10	0.100	70.96	69.38	2.22%	-2.22%
11	0.100	71.46	69.38	2.90%	-2.90%
12	0.100	71.47	69.38	2.92%	-2.92%
13	0.200	98.52	97.45	1.08%	-1.08%
14	0.200	97.11	97.45	0.35%	0.35%
15	0.200	96.43	97.45	1.06%	1.06%
16	0.400	135.89	136.88	0.73%	0.73%
17	0.400	135.89	136.88	0.73%	0.73%
18	0.400	135.89	136.88	0.73%	0.73%
19	0.500	149.88	152.70	1.88%	1.88%
20	0.500	149.88	152.70	1.88%	1.88%
21	0.500	149.85	152.70	1.90%	1.90%
22	0.700	174.56	180.07	3.16%	3.16%
23	0.700	175.67	180.07	2.51%	2.51%
24	0.700	175.77	180.07	2.45%	2.45%
25	0.900	197.08	203.68	3.35%	3.35%
26	0.900	197.08	203.68	3.35%	3.35%
27	0.900	197.08	203.68	3.35%	3.35%

Average No#	W	W²	Z	WZ
1	0.000	0.000	5.400	0.000
2	0.000	0.000	5.398	0.000
3	0.000	0.000	5.406	0.000
4	0.916	0.840	5.835	5.347
5	0.916	0.840	5.835	5.346
6	0.916	0.840	5.835	5.346
7	1.386	1.922	6.057	8.396
8	1.386	1.922	6.057	8.397
9	1.386	1.922	6.056	8.395
10	-2.303	5.302	4.262	-9.814
11	-2.303	5.302	4.269	-9.830
12	-2.303	5.302	4.269	-9.830
13	-1.609	2.590	4.590	-7.388
14	-1.609	2.590	4.576	-7.365
15	-1.609	2.590	4.569	-7.353
16	-0.916	0.840	4.912	-4.501
17	-0.916	0.840	4.912	-4.501
18	-0.916	0.840	4.912	-4.501
19	-0.693	0.480	5.010	-3.473
20	-0.693	0.480	5.010	-3.473
21	-0.693	0.480	5.010	-3.472
22	-0.357	0.127	5.162	-1.841
23	-0.357	0.127	5.169	-1.844
24	-0.357	0.127	5.169	-1.844
25	-0.105	0.011	5.284	-0.557
26	-0.105	0.011	5.284	-0.557
27	-0.105	0.011	5.284	-0.557

No#	W	W²	Z	WZ
27	-11.043	36.336	139.529	-41.470

27	-11.043	K1	139.529	
-11.043	36.336	K2	-41.470	
1	-0.409	K1	5.168	K1= 5.3682
0	31.819	K2	15.595	K2= 0.4901
1	-0.409	K1	5.168	A= 214.4713
0	1.000	K2	0.490	B= 0.4901
1	0.000	K1	5.368	
0	1.000	K2	0.490	